Antonella Vastola *Editor*

The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin

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ISBN 978-3-319-16356-7 ISBN 978-3-319-16357-4 (eBook)
DOI 10.1007/978-3-319-16357-4

Library of Congress Control Number: 2015937597

Springer Cham Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer International Publishing AG Switzerland is part of Springer Science+Business Media (www.springer.com)

Preface

This book focuses on the challenges to implement sustainability in diverse contexts such as agribusiness, natural resource systems and new technologies. The project arose from the editor's experience during the International Edamus M.Sc. course on "economics of quality for sustainable development"—the School of Agricultural, Forestry, Food and Environmental Science (SAFE), University of Basilicata, is a partner of the Edamus Mundus Programme. The exchange of ideas and the experience with students from all continents led to the idea to gather in one volume the experiences of researchers at the SAFE of the University of Basilicata in Southern Italy.

Basilicata's production system is mainly based on the agricultural sector and exploitation of natural resources. However, in recent years, it has witnessed industrial development driven by the discovery of oilfields. SAFE research took up the challenge posed by market competition to create value through the sustainable use of the region's renewable and non-renewable resources. Moreover, due to its unique geographical position in the middle of the Mediterranean basin, Basilicata is an excellent field laboratory for testing sustainable solutions adaptable to other Mediterranean areas.

The book offers a broad, multidisciplinary approach to identifying and testing different solutions tailored to the economic, social and environmental characteristics of the region and the surrounding areas. The volume is a collection of multidisciplinary case studies involving SAFE researchers and their scientific partners. It is intended as a stimulating contribution to the debate on the development of sustainable techniques, methods and applications for the Mediterranean regions. Last, but not least, a global event like Expo 2015 represents a unique opportunity to present the volume.

The book consists of three parts, with agro-food systems examined in Part I, natural resource systems and the environment in Part II and new technologies in Part III.

The first part includes the case studies related to experiences in the agro-food system. The first article addresses food security in the southern Mediterranean, providing readers with an overview of important factors to achieve more inclusive, integrated and efficient food systems. Thus, after setting the scene, the next two articles deal with crop production from the twin angles of sustainability and healthy food production. The next five articles are case studies related to livestock production typical of the Mediterranean including goats, sheep but also buffaloes and Podolian cattle. The focus is on a more sustainable rearing method but also on enhancing the products obtained from the milk of these species; the last article in this group describes the innovative uses of donkey milk. This is followed by two studies dealing with sustainable agricultural practices in protecting traditional crops in southern Italy from disease: the cherry tomato and the PGI-labelled Sarconi bean. To follow, there is the experience of the Turkish Cypriot community's adoption of pomegranate farming. Last, but not least, is a contribution on the role of women in the wine industry.

The second part explores issues relevant to the sustainability of natural resource systems and the environment. The first four case studies analyse the effects of climate change and the use of non-renewable resources in relation to the region of Basilicata. Of considerable interest is the case study on the allocation of oil royalties from the presence of oilfields that have to coexist with the extensive agricultural and forestry resources of the region. The next article addresses the role of soil variability on potential groundwater pollution and recharge in a Mediterranean agricultural watershed. The last three articles discuss biodiversity from original standpoints such as the use of native grasses for turfgrass, hypogeous fungi and the role of grazing for biodiversity conservation on a Nature 2000 network site.

The third part pools experiences in the use of new technologies such as geographical information systems as a tool for landscape modelling and three-dimensional analysis; satellite technologies to apply precision farming; technologies for extending the shelf life of fresh fruit and vegetables; cost-effective and non-invasive geophysical techniques for near-surface investigation; the use of electrolysed water as the disinfecting agent in the food industry.

I wish to thank my colleagues Michele Perniola and Severino Romano, as former and current SAFE Head, who believed in and supported the idea and its execution. I would like also to thank all the authors, with special thanks going to Aysen and Fabio who joined the team despite everything. Finally, I would like to express my gratitude to Fabio Massimo and Nicolò for their unwavering encouragement and for sharing the "sunny and cloudy" moments during the realisation of this book.

Potenza, Italy Antonella Vastola
January, 2015

Introduction

Sustainability and Sustainable Development: The Background and the Current Perspectives

The roots of the concept of sustainability can be found, according to various scholars, in two contributions, both published in 1972: a book by Meadows et al., namely *The Limits to Growth*, which modelled the dynamics of the human presence on the planet, and an article by Goldsmith et al., *A Blueprint for Survival*, which forecast "*the breakdown of society and the irreversible disruption of the life-support systems on this planet*" without profound social changes. Both agreed that "*if current trends are allowed to persist*" (Goldsmith et al. ibidem) the actual growth model is bound to collapse within a century and that a consensus has to be found at the global level involving governments, the private sector and public opinion leaders. Such statements underline the fact that sustainability, defined literally as the ability to maintain or support and, more broadly, as the ability to continue a certain behaviour indefinitely, can be used as a key concept for the definition of development models to be pursued.

Since the 1980s the term *sustainability* has been applied to the human capacity to live on the planet. It was the energy crisis in the 1970s which underlined the fragility of global economic development, after which awareness of sustainability issues began to grow slowly. In 1987, the UN World Commission on Environment and Development (WCED), commonly known as the Brundtland Commission, gave in its report *Our Common Future* the first—and most widely quoted—official definition of sustainable development, which "... *is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". This broader definition emphasises the importance of people's aspirations for a better life, of global preservation and the essential relevance of future generations to the goals of current actions.

From this definition there emerged the widely accepted idea that sustainable development is based on three pillars: economic, social and environmental.

Economic sustainability concerns the capacity of an economy to support a certain level of economic production. Environmental sustainability is the ability of the environment to support a certain level of natural resource extraction rates. Finally, social sustainability is related to the ability of a social context to function at a certain level of social well-being and harmony.

At this point, a final remark has to be made to clear the field for all the following considerations that will be based, directly or indirectly, on the concept of sustainable development. Indeed, as many scholars have noted, the Brundtland Commission did not define sustainability but stated a definition of sustainable development as the "solution" to the problem of sustainability.

In 1992 in Rio de Janeiro, the UN Conference on Environment and Development defined the so-called Agenda 21, which is a broad action plan to implement sustainable development on a global, national and local level with the widest involvement of local stakeholders. Agenda 21 included 40 separate chapters, setting out actions related to the social and economic dimensions of sustainable development (e.g. poverty, health, demographics), conservation and management of natural resources (e.g. air, forest, water, chemicals), strengthening the role of major groups (e.g. women, young people, the elderly, NGOs, farmers) and means of implementation (e.g. information, training, international cooperation, finance).

In 2001, the UNESCO's Universal Declaration on Cultural Diversity added a fourth pillar: culture, as an element that shapes economic development and people's behaviour. The UNESCO initiative is twofold: one side focuses on the development of the cultural sector itself (e.g. creativity, cultural tourism, heritage), while the other deals with the proactive role that culture should have in shaping public policies—first of all, those regarding education followed by the environment, science and so forth.

In more recent years, due in particular to the financial crisis that has had global repercussions, albeit of different intensity between countries and industries, the concept of sustainable development as well as the set of tools to approach it has changed. In 2005, the UN World Summit which led to the definition of the Millennium Development Goals (MDGs) restated that development is a central goal in itself and that sustainable development calls for a convergence between the three pillars of economic development, social equity and environmental protection. The driving principles are: reducing poverty and hunger, improving health and well-being and creating sustainable production and consumption patterns.

The literature underpinning the MDGs identified a series of requirements for sustainable development: equity, poverty alleviation, a better use of non-renewable resources and integrating economic, environmental and social issues in decision making. Finally, a last but not least consideration—while the challenge of sustainable development is a shared one, countries have to adopt different strategies to advance sustainable development goals.

Given that the MDGs are only valid until 2015, in 2012 the Rio+20 Conference with the report *The Future We Want* proposed a set of sustainable development goals (SDGs) that updated MDGs to the 2015–2030 scenario.

Box 1. Sustainable Development Goals—*The Future We Want*

Goal 1. End poverty in all its forms everywhere.
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.
Goal 3. Ensure healthy lives and promote well-being for all at all ages.
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.
Goal 5. Achieve gender equality and empower all women and girls.
Goal 6. Ensure availability and sustainable management of water and sanitation for all.
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.
Goal 10. Reduce inequality within and among countries.
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
Goal 12. Ensure sustainable consumption and production patterns.
Goal 13. Take urgent action to combat climate change and its impacts.
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and halt and reverse land degradation and halt biodiversity loss.
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
Goal 17. Strengthen the means of implementation and revitalise the global partnership for sustainable development.

Recent years have witnessed a rising global alert due to the steady increase of global warming, mainly caused by increases in greenhouse gas (GHG) emissions generated by production systems as well as lifestyle models with too high an impact on the environment. Rio+20 reaffirmed that the ultimate objective under the United Nations Framework Convention on Climate Change is to stabilise GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The stable functioning of earth systems is a precondition for a decent level of global development. This means that for the SDGs to be feasible, they have to take into account the effects of increasing human pressure on the planet (the human population is expected to top nine billion by 2050), like water shortages, extreme weather, deteriorating conditions for food production, ecosystem loss, ocean acidification and sea level rise. These are real dangers that could threaten development and trigger humanitarian crises across the globe (Griggs et al. 2013).

A criticism of the system proposed by SDGs is the large number of goals, rising from six MDGs to 17 SDGs. This would not appear to simplify the framework of measures adoptable. This consideration holds especially if one thinks of the set of indicators that must be put in place. Indeed, another criticism levelled at the MDG/SDG complex is the appropriateness of indicators measuring actions and hence the assessment of their effectiveness. Managing the sustainable development process requires a much strengthened evidence base and the development and systematic use of robust sets of indicators and new ways of measuring progress. Taking into account these considerations, Griggs and colleagues (2013) proposed to set a medium-term horizon and some provisional targets (less ambitious than the SDGs) to accomplish. Results achieved with respect to these targets should be quantified in order to review them and to achieve the expected results in 2030.

It seems that the latest UN Secretary-General's synthesis report *The Road to Dignity by 2030* (2014) is going in the above-mentioned direction. In presenting the vision for the post-2015 sustainable development agenda, the 17 goals have been rearranged in a focused and concise manner that enhances the necessary global awareness and allows implementation at the country level. The report proposes a set of six essential elements underpinned by rights, with people and the planet at the centre.

Box 2. Sustainable Development Goals—*The Road to Dignity by 2030*

1. Dignity: to end poverty and fight inequality.
2. People: to ensure healthy lives, knowledge and the inclusion of women and children.
3. Prosperity: to grow a strong, inclusive and transformative economy.
4. Planet: to protect our ecosystems for all societies and our children.
5. Justice: to promote safe and peaceful societies and strong institutions.
6. Partnership: to catalyse global solidarity for sustainable development.

Given this scenario, the basic commitment is related to the capacity to act with solutions that lead to an inclusive growth for all countries and all communities. Particular attention is given to planetary needs in terms of climate stability, biodiversity loss and unsustainable land use. This means that, to implement a sustainable agenda, finance, technology, science and investments in capacities should be included, while to monitor and review implementation, the report proposes the use of new and non-traditional data sources, enhancing data capacity, availability, disaggregation, literacy and sharing.

Since the beginning of the new millennium, as evidenced by the above framework, the concept of sustainable development has been closely linked to that of well-being. In the last decade the economic crisis has affected all countries, albeit to a varying degree. This has shown that the measurement of welfare or well-being cannot be reduced to a single indicator such as Gross Domestic Product (GDP). Many scholars and international organisations have been involved in drawing up a measure that does not use only economic performance to assess the wealth and social progress of a country. Although this issue lies somewhat beyond the scope of this analysis, it is instructive to see that it is closely linked to sustainability. In its final remarks, the Commission on the Measurement of Economic Performance and Social Progress (CMEPSP)—generally referred to as the Stiglitz-Sen-Fitoussi Commission (created in 2008 on the French government's initiative)—did not identify a new indicator but, on the contrary, drafted a set of 12 recommendations (Stiglitz et al. 2009), three of which deal with sustainability: (1) GDP is "an inadequate metric to gauge well-being over time particularly in its economic, environmental and social dimensions, some aspects of which are often referred to as *sustainability*" (ibidem, p. 8); (2) environmental sustainability—including the destruction of resources and the risks of climate change—is a component of growth; (3) well-being has a multidimensional nature which involves material living standards (income, consumption and wealth) but also health, education, the quality of governance, social networks, the environment (present and future conditions) and insecurity (economic and physical aspects).

Sustainability in the Agro-Food System

Agriculture has a vital role to play as the planet's food provider, but it also uses a wealth of non-renewable resources. This makes it one of the best fields to study the application of sustainable development.

Given the current high levels of hunger and malnutrition—805 million chronically hungry people in the period 2012/2014—and increasing food demand—over nine billion people will have to be nourished in 2050—the challenge for agricultural production coincides with the goals of sustainable development. Food security is achieved "*when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life*" (FAO 1996).

The linkage between the goal of food security and the path towards a sustainable development model is evident: in order to achieve a decent level of nutrition for all people, responsible environmental stewardship is required as well as greater equity in food management. This applies to agricultural and food systems at global, national and local levels.

A recent FAO report states "*sustainable agriculture must nurture healthy ecosystems and support the sustainable management of land, water and natural resources, while ensuring world food security. To be sustainable, agriculture must meet the needs of present and future generations for its products and services, while ensuring profitability, environmental health and social and economic equity. The global transition to sustainable food and agriculture will require major improvements in the efficiency of resource use, in environmental protection and in systems resilience*" (FAO 2014). The above-mentioned report sets out five key principles that balance the social, economic and environmental dimensions of sustainability: (1) improving efficiency in the use of resources; (2) conserving, protecting and enhancing natural ecosystems; (3) protecting and improving rural livelihoods and social well-being;

(4) enhancing the resilience of people, communities and ecosystems and (5) promoting good governance of both natural and human systems.

As emphasised in the FAO reports and by several other international institutions, the different components of sustainability cannot be considered separately because they are strongly interrelated and need to be analysed using an integrated, holistic approach given the complexity of agro-food systems. This means considering the close interdependence of different aspects of food production and consumption.

A review of different reports about the sustainable path of agro-food systems suggests that, regardless of the perspective of the analysis, the main goals of a sustainable agro-food system concern: (a) sustainable production systems; (b) sustainable consumption guidelines; (c) biodiversity protection; (d) combating climate change; (e) developing local economies and small-scale production. Last but not least, each goal must be set and pursued as part of an overall strategy that takes all the other elements into account simultaneously.

Without exploring every single goal in depth, it would be useful to highlight some of their aspects. Given that the food production model concerns both industrial production as well as small and medium-scale production systems, sustainable food production is facing a challenge that can be summarised with the statement "*in order to grow, agriculture must learn to save*" (FAO 2013a). This means that, given the increasing food demand, the effects of climate change and the competition for resources such as land water and energy, farmers around the world have to look at a new paradigm: sustainable crop production intensification (SCPI) which "*produces more from the same area of land while conserving resources, reducing negative impacts on the environment and enhancing natural capital and the flow of ecosystem services*" (FAO ibidem). An example of this paradigm is conservation agriculture, which minimises tillage, protects the soil surface and sows crops in rotations that enrich the soil; moreover, it helps to reduce water needs by 30 % and energy costs by up to 60 %. With regarding to water management, the SCPI paradigm requires the use of precision technologies for irrigation and farming practices that use ecosystem approaches to conserve water. To increase crop productivity, a best practice is minimisation of chemical fertilisers, given the impact that nitrates and phosphates have in terms of GHGs.

Today more than ever the paradox of food is increasingly evident: on the one hand, there are people who are overweight or obese—2.1 billion across the world—and whose social cost is $2 trillion each year, and on the other there are one billion people suffering from hunger and another two billion suffering from micronutrient deficiencies. In all countries, especially in the developed world, and in those that are experiencing new conditions of well-being, a sustainable consumption model must be developed from the concept of sustainable diets.

Box 3. Sustainable Diets

Sustainable diets are those diets with low environmental impacts, which contribute to food and nutrition security and to healthy lives for present and

(continued)

future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy, while optimising natural and human resources (FAO 2010).

The spread of a food model that is based on sustainable diets allows the conservation of biodiversity to be enhanced through the raw materials that are used as ingredients. Moreover, it can provide nutrient recommendations to consumers and have positive effects on their awareness vis-à-vis the positive repercussions of an environmentally sustainable food chain.

The last, but not the least, effect of the above-mentioned food paradox is the increasing phenomenon of food losses and waste. Recent estimates indicate that each year approximately one-third of all food produced for human consumption in the world is lost or wasted (FAO 2013b). The phenomenon occurs in both high- and low-income countries. In the first case, the food is largely wasted at the consumption stage while in low-income countries, it is lost mostly during the early and middle stages of the food supply chain.

Food waste represents an evident inefficiency and a missed opportunity to improve global food security, but also to mitigate environmental impacts and resource use. Given that the food and agriculture sectors together generate 30 % of total GHGs, appropriate solutions have to be found. In developed countries, programmes are under way to increase consumer awareness of food waste and energy use in food products, as well as regulations mandating reductions in organic waste management. In low-income countries, options include promoting low-cost farm storage facilities as well as upgrading transport and processing facilities (FAO 2011).

The search for better food chain efficiency is another key element of the sustainable development model. The importance of logistics systems, their management and how they can improve sustainability lies at the heart of the recent concept of green logistics. The premise is that optimisation of logistic operations across the supply chain has positive results in terms of: reduction of post-harvest losses, savings in energy, reduction of the environmental footprint and more competitive market positioning. In order to remain competitive, agro-food agents need rapid access to emerging technologies and, in addition, to be profitable their activities have to meet environmental standards and regulations, as well as deal, directly or indirectly, with consumers.

To define the elements of sustainability and a framework for assessing trade-offs and synergies among all dimensions of sustainability, an international reference tool has been developed, the Sustainability Assessment of Food and Agriculture system (SAFA). SAFA is an assessment of economical, environmental, social and governance sustainability. The field of application is the entire food supply chain from the site of primary production (agriculture, fisheries, forestry) to the retail outlet. Its main purpose is to support effective sustainability management of a company or production site.

The SAFA framework identifies four dimensions of sustainability: good governance, environmental integrity, economic resilience and social well-being. For each of these four dimensions, SAFA outlines essential elements of sustainability through 21 high level themes (Fig. 1). These are applicable at any level of development, for instance at the national level, or commodity-specific. The themes are further divided into 58 sub-themes that are tailored to food and agriculture supply chains and thus are not well suited for policy development (FAO 2013c).

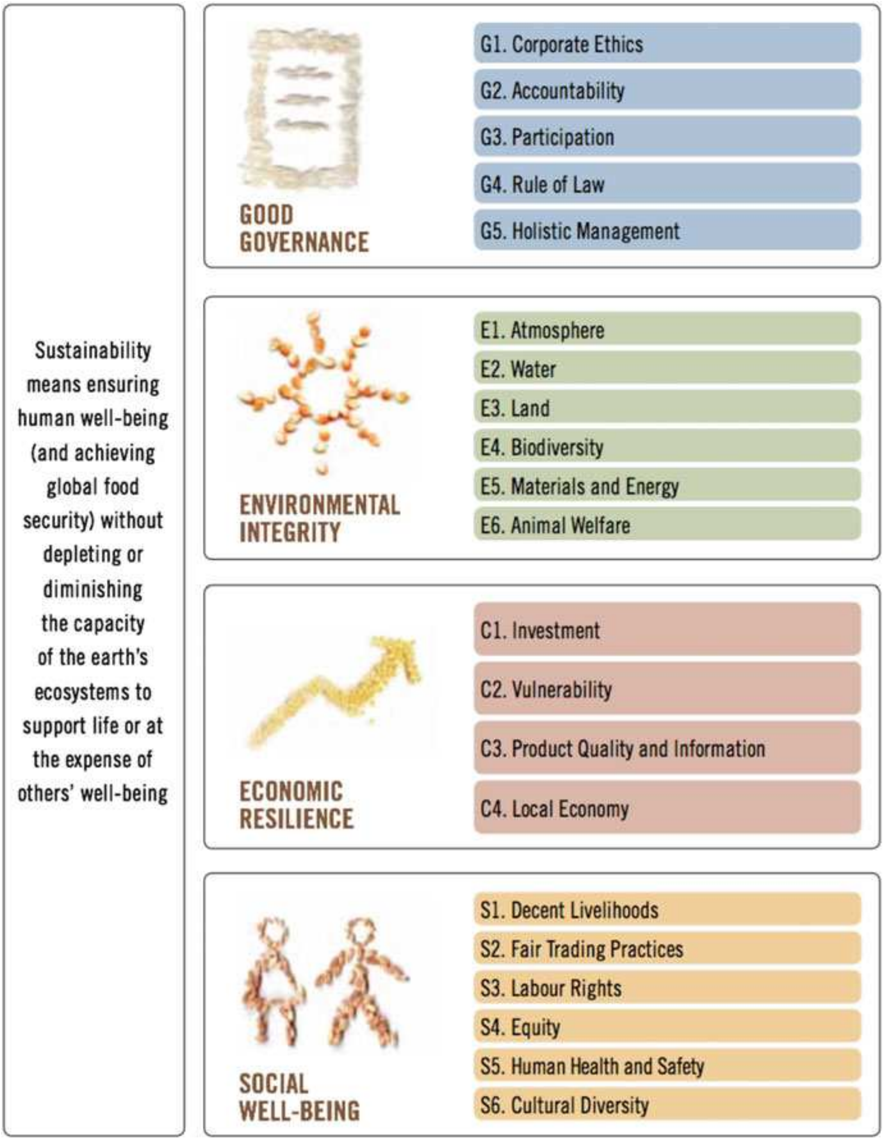

Fig. 1 SAFA sustainability pillars and themes (FAO 2013)

The different types of indicators within the SAFA system have varying weight in terms of their likelihood to fulfil the sub-theme objective. The SAFA system has a five-scale rating for the performance of indicators to which colours are attributed: red/orange/yellow/green/dark green are used, respectively, for unacceptable/limited/moderate/good/best levels of performance, corresponding to percentage scores from: 0–20/20–40/40–60/60–80/80–100. The SAFA sustainability performance ratings of a company are represented by the polygon (the thick black line) that connects theme performance following a traffic light colour code: best/good (green), needs improvement (yellow/orange) or unacceptable (red) as illustrated in Fig. 2.

The SAFA methodology is partly rooted in international metrics such as ISO 14040 (2006), the standard for Life Cycle Assessment (ISO 2009), and the ISEAL Code of Good Practice. The SAFA system provides a framework for improving the understanding of what a sustainability claim covers in practice and for comparing different production systems. It is also a useful quality assessment tool to identify performance of hotspots related to all aspects of sustainability within a company.

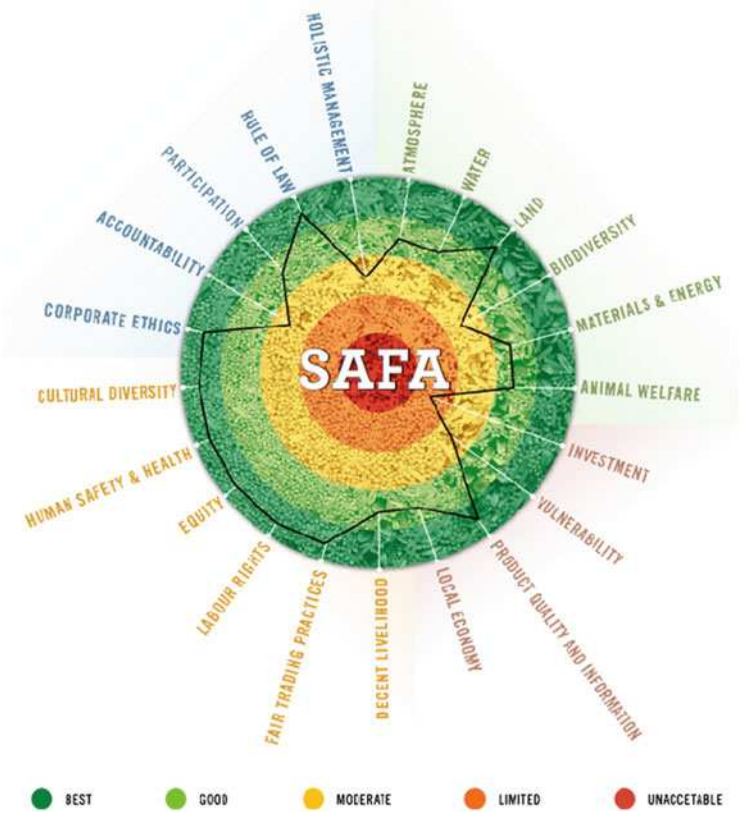

Fig. 2 SAFA sustainability polygon (FAO 2013)

Some final considerations have to be made on the cost of shifting to a more sustainable production model. As experienced in recent decades, the trade-offs between achieving a certain level of well-being, food security goal and environmental objectives often result in a negative-sum game, because of inappropriate policies and inadequate governance systems. On the production side, major costs are those including investments and operating expenses, but also opportunity costs related to income loss during the transition phase. The problem of delayed returns on investments is a significant barrier to achieving sustainability across all sectors. Risk and transaction costs are other significant elements during the transition to more sustainable systems. Transaction costs are those related to each stage of the business—e.g. transportation, communication and coordination activities. Various studies have reported that sustainable production systems require more coordination activities, for example in managing common-property natural resources, or in coordinating post-harvest, processing, storage and marketing activities. Natural market risks—e.g. volatility, the prices of raw materials, the supply of energy resources, sudden and catastrophic climate events—impact on most of the variables that affect the path towards sustainability.

The consumption system is facing a similar set of costs. The cost concerning the uncertainty of the quality of the goods purchased is of particular importance. Often the communication of sustainability features of the good is not effective and is made less efficient by the large number of claims that emphasise the "greening" of many products and which often deceive the consumer. A dietary model that considers the cradle-to-grave scenario has to be linked to the investment costs for the technology for disposal or re-use but also the cost of public action in terms of information. Finally, the effects of these behaviours are verifiable only in the medium-long run, which may cause a degree of disaffection of the consumer/citizen in continuing with equitable action.

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Part I
Agro-Food Systems

Food Security in the Southern Mediterranean/North Africa

Aysen Tanyeri-Abur

Abstract The Southern Mediterranean, comprising the five countries of North Africa, has become increasingly dependent on food imports over the past few decades. High levels of population growth, a variable and arid climate along with scarce and fragile resources are contributing factors. Volatile food prices and political changes in the past few years have exacerbated the problems related to food import dependence, threatening food security. Addressing food security will require sustainable improvement of productivity, better management of natural resources, improved allocation of private and public resources to agriculture, and actions to achieve more inclusive, integrated, and efficient food systems.

1 Introduction

Throughout history, the southern Mediterranean has been a major food producing region, and during the first and second centuries, the region is said to have provided a large portion of the food consumption in Rome (Kehoe 1988; Rickman 1980). During the sixteenth century, grains, rice, and legumes such as fava beans and chickpeas were exported from Egypt through the Nile across the Mediterranean. The Mediterranean has never been a region of abundance and glut, but it has adapted skillfully to circumvent its deficiencies in production (Braudel 1990). Over time, a combination of climatic and environmental changes, population growth and changes in the political and economic environment have transformed the region into one that is highly dependent on imports to satisfy its basic food needs, particularly in cereals.[1]

The five countries of the Southern Mediterranean[2] (hereafter SM) cover an area of 5.8 million km^2—almost 68 % of the total area of the Mediterranean basin

The views expressed in this chapter are those of the author and do not necessarily reflect the views or policies of FAO.

[1] For more on the environmental history of the region, see Davis 2007 (pp. 1–15).

[2] Algeria, Egypt, Libya, Morocco, and Tunisia.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_1

Table 1 Population (in millions) in the Mediterranean (1960–2012)

	2012		1960		Change 1960–2012 (%)	
	Total	Rural	Total	Rural	Total	Rural
Mediterranean basin (total)	486.1	164.3	249.8	130.4	49	21
Northern and eastern Mediterranean	317.4	87.9	192.6	92.8	39	−6
Southern Mediterranean (North Africa)	168.7	76.4	57.3	37.6	66	51

Source: World Development Indicators (WDI) (2014)

(which includes 23 countries[3])—and have a population of nearly 169 million (2012), a third of the total population of the Mediterranean region (see Table 1). The SM comprises three large countries, Algeria (alone almost four times the size of France), Egypt, and Libya. Egypt has the highest population followed by Algeria and Morocco, with high concentrations in urban/coastal areas (or along the Nile in the case of Egypt[4]), in higher altitudes, and in areas with favorable climate. Economic inequalities persist between the regions within countries due to past policies with a strong urban bias and historical concentration of wealth in economic centers located in coastal areas. Significant differences in economic and natural resources exist across the countries in the subregion. Algeria and Libya rely on rich oil and mineral endowments, while the other three countries are more dependent on agriculture.

The subregion is characterized by an arid climate with highly variable agricultural production. It has strong trade linkages with the Northern and Eastern Mediterranean, but investment in agriculture remains low, with lower productivity and capital intensity compared to Northern Mediterranean countries. This chapter provides a brief overview of the economic and demographic characteristics of the SM region, identifies the major challenges for food security and related problems, and proposes areas of priority action to tackle food insecurity.

2 The Southern Mediterranean/North Africa

2.1 General Characteristics

The countries of North Africa are all considered middle income countries with GDP per capita varying from about US$6,000 in Libya to US$3,000 in Morocco. The percentage of the total population living in rural areas has increased in absolute

[3] Albania, Algeria, Bosnia and Herzegovina, Croatia, Cyprus, Egypt, France, Greece, Israel, Italy, Lebanon, Libya, Malta, Monaco, Montenegro, Morocco, Portugal, Slovenia, Spain, Syria, Tunisia, Turkey, West Bank, and Gaza.

[4] 95 % of Egypt's population lives within 12 km of the Nile and half of the population lives in the Nile delta (UNDP 2009).

Table 2 Evolution of total and rural population in North African countries

	1960	1960 Rural population (% of total)	2012	2012 Rural population (% of total)
Algeria				
Total population	11.3		38.5	
Rural population	7.8	69 %	12.0	31 %
Egypt				
Total population	27.9		80.7	
Rural population	17.4	62 %	46.1	57 %
Libya				
Total population	1.4		6.2	
Rural population	1.0	71 %	1.3	21 %
Morocco				
Total population	12.4		32.5	
Rural population	8.7	70 %	13.4	41 %
Tunisia				
Total population	4.21		10.8	
Rural population	2.6	62 %	3.6	34 %
Total				
Total population	57.3		168.7	
Rural population	37.6	65.7 %	76.4	45 %

Source: FAOSTAT

Table 3 Economic and demographic indicators (2012)

	Population (total) 2012 (million)	Population (rural) 2012 (% of total)	Annual pop growth rate 2012 (%)	GDP/cap (current US$)	Agriculture value-added (% GDP)	Employment in agriculture (% of total)	% female of economically active population in agriculture
Algeria	38.5	31.1	1.9	5,272	9.9	25.7	52.6
Egypt	80.7	56.9	1.6	2,973	14.5	29.2	40.6
Libya	6.2	22.1	0.8	5,685	n/a	n/a	73.3
Morocco	32.5	41.3	1.5	3,044	14.4	39.8	48.7
Tunisia	10.8	33.7	1	4,305	9.2	16.2	32.9
Total	168.7	44.1			11.8		45.1

Source: FAOSTAT and World Development Indicators (WDI) (2014)

numbers but has decreased considerably in recent decades in terms of percentage of total population. Population living in rural areas represents nearly a third of total population on average with the exception of Egypt where more than half of the population lives in rural areas (Table 2). The majority of the rural population of North Africa is engaged in agriculture and farming involved directly or indirectly. Agriculture is an important economic and social plan in the subregion employing more than a quarter of the population in the countries of the region, with a high concentration of females (Table 3).

Table 4 Migrant remittances (receipts), US$ current (millions)

	1989–1991	1999–2001	2009–2011
Algeria	310	750	2015
Libya	–	9.5	17
Morocco	1778	2453	6591
Tunisia	509	828	1965

Source: UNCTADstat

As in many developing countries, the subregion is characterized by continuous population growth, despite a slight decline in recent years; the growth rate tends to be higher than in other regions. The proportion of youth in the population of the region is significant, ranging from 25 to 28 % (Population Reference Bureau), and their integration into the labor market is increasingly difficult. The population of the region has more than doubled in the last five decades (Table 1).

The share of agriculture in GDP has declined steadily over the years. Even in Morocco and Egypt, where agricultural activity is most important, it represents less than 20 % of GDP. Agriculture, however, still employs a significant share of the subregion's population and is the main source of employment in rural areas, particularly for women who represent between half- and nearly three-quarters of the economically active population in agriculture in most of the countries (it is only in Tunisia, where the proportion of women in the agricultural labor force is about 30 %) (Table 3).

The population of migrants from the region is numerous and accounted for about 10 % of the total population of the Maghreb[5] in 2010. Remittances from migrants have a fairly significant economic impact for the countries of the subregion. Despite the global economic environment, remittances have continued to increase in recent years. In 2011, migrant remittances accounted for 7 % of the GDP of Morocco and 4 % in and Tunisia accounted for approximately US$10.6 billion in average for the period 2009–2011 (Table 4).

2.2 Agriculture and Natural Resources

The SM region has a diverse resource base but faces constant pressure from population growth and national development activities—a situation that renders the countries very vulnerable to climate hazards. Much of the subregion is desert or semi-desert: between 75 % and 90 % of the territory of Egypt, Algeria, and Libya, the proportion of agricultural land is low (less than 10 % in Libya and less than 5 % in Egypt), while in Morocco and Tunisia, it is over 60 % (Table 5).

[5] Algeria, Libya, Morocco, Tunisia.

Table 5 Agriculture indicators (2012)

	Agricultural land (% of total)	Area equipped for irrigation (% of total agricultural area)	Arable land with permanent crops (% of total agricultural area)	Value added in agriculture (% GDP)
Algeria	17.4	1.4	20.4	6.9
Egypt	3.7	100	21.7	15.5
Libya	8.8	3.0	13.2	1.9
Morocco	67.3	4.9	30.1	15.1
Tunisia	63.0	4.5	50.4	8.8

Source: FAOSTAT

Table 6 Renewable water resources per person (cubic meters/year)

	1963–1967	1983–1987	1998–2002	2008–2011	2011 (% of 1963)
Algeria	976	528	382	331	32
Libya	369	157	115	95	23
Morocco	2,174	1,302	1,008	912	39
Tunisia	992	631	481	438	42

Source: United Nations Environment Programme (2013)

Agriculture continues to occupy a prominent place in the countries of the SM both at the level of its value-added in GDP, employment, and exports of goods (the participation of agriculture varies depending on the existence of exports of petroleum and energy products or not). Agriculture is also important in its role in rural development, environmental protection and regional balance. The agricultural sector is a refuge sector in rural areas: it provides many jobs to rural people, it is the main source of income, it contributes greatly to the preservation of the environment, and it is a catalyst for development.

Because of the arid climate, irrigation is an essential factor in productivity, but despite numerous projects the share of irrigated agricultural land does not exceed 5 %, between 1 and 3 % in Libya and Algeria (Table 5). The Maghreb countries enjoy a variable climate with higher altitudes and rainfall and rely on dryland agriculture to a large extent, while agriculture in Egypt is 100 % irrigated. Water resources are constantly and rapidly declining due to population and economic growth, and the subregion suffers from severe water stress with an estimated water supply of less than 500 m^3 per capita except for Morocco (Table 6). This lack is compounded not only by recurrent droughts that severely affect the region but also by the pressure on water resources coming from large-scale industries of agricultural and animal products. Adaptation to water scarcity include many projects but success is limited due to weak capacity of institutions and resource planning, and efforts for better management of water have produced only limited effects so far.

Along with water scarcity and desertification, there are also problems such as deforestation and rangeland degradation, especially important for the region, given

Table 7 Value of livestock production as percent of total value of agricultural production in North Africa (2011)

	Value of livestock production (as % of total value of ag. production)
Algeria	36 %
Egypt	42 %
Libya	40 %
Morocco	44 %
Tunisia	22 %

Source : FAOSTAT

the importance of the livestock sector in all these countries. The livestock sector has a diverse agricultural ecosystem and a unique geographical position, two key factors for the development of this sector. Livestock plays an important role in the Maghreb economy where it represents more than a third of the value of agricultural production and contributes the fight against poverty as a source of employment and cash incomes for rural farmers. Structural problems also arise, such as the fragmentation of farms (average farm size is around 10 ha in Tunisia and Algeria, and Morocco over 70 % has less than 5 ha). Finally, fisheries and forests provide badly or insufficiently exploited potentials (Table 7).

3 Challenges and Problems Related to Food Security

Although differences exist among the countries of the SM regarding economic and social conditions and resource endowments, they share the same challenges in ensuring food security of their populations, including (1) scarce and fragile natural resources and climatic hazards (2) high rates of growth of the population with a particularly young population (3) a decline in public investment and weak private investment in agriculture and rural development.

These challenges are at the root of the problems that the region must address to improve the performance of the agricultural sector as a step toward improving food security. Main problems to overcome are high rates of import dependency, low levels of agricultural investment, and addressing the problem of a growing young population with increasingly older population in rural areas. Low productivity and high variability of agricultural production comes largely from heavy reliance on systems based on rainfall. In addition, limited investments in agriculture have kept the limited agricultural performance with much lower yields than other regions. These problems related to production accompanied by a change in cereal demand structure in the last two decades (increased demand for grain for feeding livestock) increased the gap between supply and demand of cereals, resulting in heavy dependence on imports to meet domestic demand.

3.1 Dependence on Food Imports

Figure 1 depicts the evolution of demand for four staple crops in the SM region against production. The annual variability of production is quite pronounced, and the gap between total demand and production has continued to increase.

Cereals are staple food in North Africa. The proportion of energy intake from cereals, roots and tubers is about 55 % (FAO 2013). As incomes increase, the share of cereals is expected to decline, but continue to be important in the local diet. Increasing urbanization and changes in dietary practices will also mean an increase in demand for cereals, particularly for feed. The countries in the region are heavily dependent on imports, particularly cereals. Import dependency[6] ratios are high compared to the rest of the Mediterranean countries, ranging from 93 % in Libya to 40 % in Egypt (Table 8).

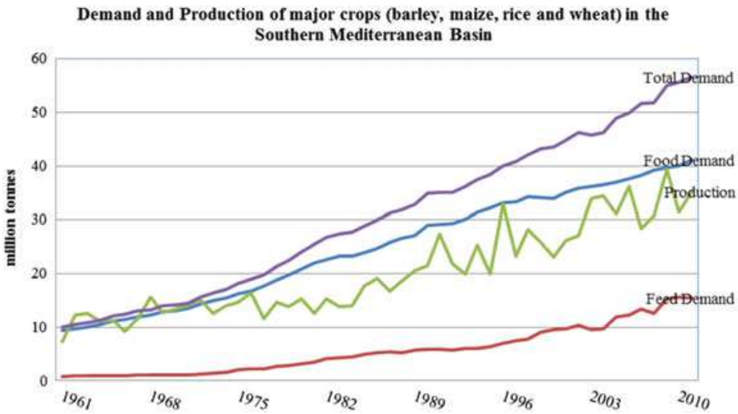

Fig. 1 Production and demand for cereals 1960–2011. Source: FAOSTAT

Table 8 Import dependency ratios, North Africa and the Mediterranean basin

	Import dependency ratio (%) 2008–2010
Algeria	66.1
Egypt	40.4
Libya	92.7
Morocco	47.4
Tunisia	54.4
Southern Mediterranean	49.6
All Mediterranean	33.1
North and eastern Mediterranean	26.1

[6] Defined as Cereal Imports/(Cereal Imports + Cereal Production) – Cereal exports.

Because of their extreme dependence on imports of food, agricultural and food trade balance of the SM countries is heavily in deficit. Libya and Algeria are most concerned, although they face less of a fiscal constraint compared to other countries. Cereal imports accounted for 32 % of all agricultural imports in the subregion in 2010. In the longer term, Morocco is the only country where grain imports are expected to decline in the next 20 years due to existence of opportunities for extension of cereal acreage under irrigation.

The North African countries are price takers and therefore exposed to substantial risks in terms of prices and quantities arising from strongly fluctuating import quantities and prices. The vulnerability is measured as a combination of exposure to risks of prices and quantities, and given that the SM countries all have high import dependency with substantial fiscal deficits, which exposes them to risks in terms of quantity and price.

The level of economic integration in the subregion is low. Intra-regional trade accounted for only 2.4 % of imports and 8.6 % of food exports in 2011, with the exception of trade between Tunisia and Libya (51 % of intra-regional food trade). This is explained by the complexity of procedures (average of 8 documents are required to import procedures and 7 for export for North African countries except Libya), the continued presence of barriers to trade the poor performance of some sectors, the relatively limited diversification of production and exports, and the lack of infrastructure and lack of complementarities between the agricultural sectors.

3.2 Insufficient Resources Allocated to Agriculture

Agricultural investment in the region in the past was driven by public investment with most of these investments in large projects. Countries in the region have made measurable progress in agricultural productivity and overall growth in the agricultural sector. However, agriculture still lags behind other regions in terms of productivity. Agricultural productivity in the countries except Libya has improved significantly, but remains well below the values of developed countries including the European Union. A sustainable improvement in agricultural productivity is possible and necessary given the untapped potential for sustainably improving agricultural production.

Data on capital stock show that in the countries of the region capital stock is mainly composed of land (51 %) and livestock (26.1 %) and less by the infrastructure, tools, machinery, and buildings (Table 9). The countries in the region have limited investment in agriculture, the mainstay of the evolution of agricultural productivity and performance. Investment in agriculture in the North Africa was down by 77 % during the period 1980–2007 and continues to represent a small portion of the value of the sector in GDP.

Ideally, most of the investment in agriculture should be from private sources and in most cases from farmers themselves. Data on private investment in agriculture is

Table 9 Capital formation in North Africa

	Capital formation (million US$ constants 2005)	Livestock (as % capital formation)	Machinery and equipment (as % of capital formation)	Structures for livestock (as % of capital formation)	Land development (as % of capital formation)
Algeria	14,545.2	28.8	15.8	1.4	42.0
Libya	7,531.4	15.4	11.1	0.5	64.6
Morocco	26,006.2	22.9	3.7	1.2	63.2
Tunisia	10,303.7	19.2	10.5	0.9	40.5

Source: FAOSTAT

rather scarce and hard to value, though many countries have revised their investment policies to enable more private investment in agriculture.

Historically, public investment has been the most important source of resource for the agricultural sector; however, in the past 10 years, private agricultural investment in relative terms has become more important. The agricultural sector in the countries receives special support, and government expenditures remain an essential element for the economic and social development. The agricultural research and extension, infrastructure and utilities, response measures against transitory shocks, programs to facilitate the adjustment of certain sectors or regions and enable innovation at risk for an environment sustainability, and food security are some of the features that continue to be applied to the public sector, more and more frequently in a decentralized manner and in partnership with the private sector and civil society (FAO 2014).

The extent of support and the instruments differ from one country to another, ranging from financial assistance (income support for farmers) or price supports to agricultural loans or granting of an investment premium. The expenses also vary from 1 year to another. The forms of taxation adopted by governments also have an impact on the level of available resources, while constituting an effective instrument for redistribution.

The share of expenditure on agriculture should reflect, at a minimum, the share of agriculture in the overall economy. While data on public spending for agriculture are scarce and not comparable, available data show that in many countries allocation of public spending does not reflect the economic or social importance of the sector. By taking data on the share of agriculture in GDP and compare it with total expenditures, it is possible to establish an agricultural orientation index indicating the extent to which public spending on agriculture match (or not) the importance of agriculture in the overall economy. To calculate this index, the share of agricultural spending in relation to total public expenditure is divided by the share of agriculture in GDP. The higher the index, the higher the share of agricultural spending is close to the share of agriculture in GDP.

For example, in Tunisia public spending on agriculture decreased over time as a percentage of total expenditures. The orientation index decreased by 0.39 in 2001 to 0.31 in 2011 (Table 10).

Table 10 Agricultural orientation index (Tunisia)[a]

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Orientation index[a]	0.39	0.34	0.40	0.43	0.40	0.41	0.38	0.33	0.35	0.32	0.31

Source: FAOSTAT
[a]Agricultural orientation index: Share of agriculture in total expenditures/share of agriculture in value-added

In most of the countries covered, historically public investment in agriculture was primarily oriented towards the mobilization of natural resources (water, soil, forests, fisheries to assist in preparing the conditions for sustained agricultural development (including through private operators) that would achieve the strategic objective of food security. Investment in research and development has been no more than 2–3 % of all agricultural investment (FAO 2014).

4 Achieving Food Security in the Long Run

Following the hike in prices of agricultural commodities (including grains and oilseeds) in 2007–2008, agriculture and food security have become important, not only the recognition of the negative impacts on the poorer urban populations facing increases in cost of food but also in fostering interest in agriculture which fueled agricultural investments. While there has been substantial increase in investments, the impacts of the food price hikes in the region have been more negative than positive. At the same time, political upheavals in the region have slowed down economic growth in Tunisia, Libya, and Egypt, severely affecting the ability to pay for increasing cost of imports. While prices are no longer on the increase, it is the volatility of prices that have the most devastating impact on the poor. The major threat to food security in the region is the vulnerability at national and household level due to price volatility of imported foods.

In developing a medium-term vision for the agriculture sector, the countries of the region themselves have revised their agriculture and rural development policies in an effort to take steps to sustainably improve agricultural productivity and farmers' income; access to these technologies, means of production, and the market; conservation, improvement and sustainable use of natural resources; adaptation to climate change and prevention of its adverse effects; and improving food security in subregional level.[7] Capacity building and improved management of natural resources and special emphasis on rural development and youth appear as clear priorities.

Opportunities should be explored, particularly in fisheries and livestock and other high value products such as olive oil. With the extent of the coastline in the

[7] Plan Maroc Vert in Morocco and Agriculture and Rural Renewal Strategy in Algeria.

Mediterranean and the Atlantic Ocean, the SM countries have an important fishing potential, both in quantity and quality, plus aquaculture resources. In Morocco, in particular, the fisheries sector accounts for a significant share of GDP and especially agricultural exports. This potential can contribute substantially to the economy of the country as well as improve food security and employment, with due consideration of the wide ranging institutional, legal, economic, and social impacts of fisheries activities.

In sectors such as olives and olive oil, dates, and other fruits and vegetables, there is much room for improvement, not only in terms of production but also in marketing and distribution.

Over the past two decades, governments in the region have also adopted agricultural market deregulation and reduction of price distortion and giving a greater role to the private sector in economic activities. These measures, although necessary, are not always sufficient to induce the investment needed to improve productivity and increase production. In order to stimulate investment in agriculture, transparent and functioning markets, access to finance and extension, and an appropriate legal and regulatory framework are needed. More generally, political stability and strengthened institutional framework are necessary to ensure adequate private investment. Strong complementarity between public and private investment is also essential to support agricultural growth, and governments need to invest in areas with significant public interest—research, extension and infrastructure (including water control, roads, storage facilities, and marketing), education, standards, and rules.

Improving food security requires efforts not only on the part of the countries themselves, but through regional and international actions.

Actions toward improving food security in the region need to focus on three key areas of action:

- National level
  - Sustainable improvements in productivity (inputs, technology, extension)
  - Promoting efficient supply chains (reduce waste, better logistics)
  - Targeted safety nets for the vulnerable populations
  - Better management of risks associated with high import dependency (food reserves, futures contacts)
  - Improving employment prospects in agriculture, particularly for the young
- Regional Level
  - Cooperation in policies affecting pricing of common resources
  - Cooperation in harmonizing trade policies
  - Strengthening infrastructure in the region
  - Improve market information systems and coordination of action to respond to world market volatility
- International Level
  - Countering market volatility through new financing mechanisms

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Sustainability in Cereal Crop Production in Mediterranean Environments

Michele Perniola, Stella Lovelli, Margherita Arcieri, and Mariana Amato

Abstract The continuous increase of the world population (a growth of about one-third is expected by 2050), together with an even larger increase in food demand (especially in emerging countries), will lead in the next 30 years to the necessity to produce 70 % more food. To keep the pace with food demand, global cereal production would need to increase by 40 % overall, or by some 900 million tons between the present and 2050. Single countries can either increase production or increase net imports or a combination of both.

This new global emergency involves researchers, farmers, politicians, the agro-food industry, and all stakeholders, and the new challenge can be summarized as follows: to produce more, but in a sustainable way. The goal of "sustainable intensification" constitutes one of the priorities for the research in agriculture and one of the cornerstones of the new Common Agricultural Policy. In this context, all the techniques designed to maximize production through the more efficient use of resources are in line with the objectives of sustaining production with minimal impact.

In Mediterranean environments, cereal crops are grown mainly in the semiarid and subhumid areas. In arid and semiarid areas dryland farming, techniques are of renewed interest in the view of sustainability. They are aimed to increase water accumulation in the soil, reduce runoff and soil evaporation losses, choose species and varieties able to make better use of rainwater, and rationalize fertilization plans, sowing dates, and weed and pest control.

Fertilization plans should be based on well-defined principles of plant nutrition, soil chemistry, and chemistry of the fertilizer elements. Starting from the calculation of nutrient crop uptake (based on the actually obtainable yield), dose calculation must be corrected by considering the relationship between the availability of the trace elements in soil and the main physical and chemical parameters of the soil (pH, organic matter content, mineralization rate, C/N, ratio of solubilization of phosphorus, active lime content, presence of antagonist ions, etc.).

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_2

The choice of traditional, minimum, or no-tillage is one of the most controversial aspects of agricultural research; much depends on soil texture, crop type (depending mainly on the characteristics of the root), rainfall regime (mainly intensity), long-period tillage plan, structural stability of the soil (in function of the organic matter content), and all other variables and their interaction. In any case, minimum tillage and sod seeding are generally less expensive and evidence points to a lower production of CO_2 with respect to traditional tillage.

Weed and pest control is also a critical point for the sustainability of cereal production: sustainability in control strategies involves minimizing the use of chemicals while safeguarding yields. To this end, priority should be given to preventive and nonchemical agronomic measures, while chemical means should be used only when the level of weeds and pests exceeds the threshold of economic damage.

Finally, precision farming is one of the most powerful tools for the sustainability of cereal crop production. This technique helps the farmers in their decisions, taking into account the local variability of physical, chemical, and biological properties of the soil, as well as the timing of input application. With this management strategy, input of resources is balanced and optimized in order to increase yields and reduce interventions and costs; the environmental impact is significantly reduced, as well as the amount of resources used for the production.

1 Introduction

The continuous increase of the population (worldwide a growth of about one-third is expected by 2050), together with an even larger increase in food demand (especially in emerging countries), will lead in the next 30 years to the necessity to produce 70 % more food to keep pace with the demand (FAO 2013).

Worldwide, cereals represent the main agricultural staple food; more than 50 % of the daily energy intake is accounted for by cereals (FAO 2014b). Overall, cereal production has followed the trend of increasing food demand in the past, and according to the High-Level Expert Forum, this trend is expected to continue in the future (Fig. 1).

To keep the pace of food demand, global cereal production would need to increase by 40 % overall, or by some 900 million tons between the present and 2050. Single countries can either increase production or net imports or a combination of both. As shown in Fig. 1, cereal production is increasing more in developing countries, to sustain their own demand; anyway it is not excluded that export of cereal commodities from developed countries will be necessary to meet the needs of developing countries. Wheat is the main food grain in Western countries; Europe, Central Asia, and the Russian Federation are the main wheat producers, with a huge yield per hectare variability as a function of environmental conditions

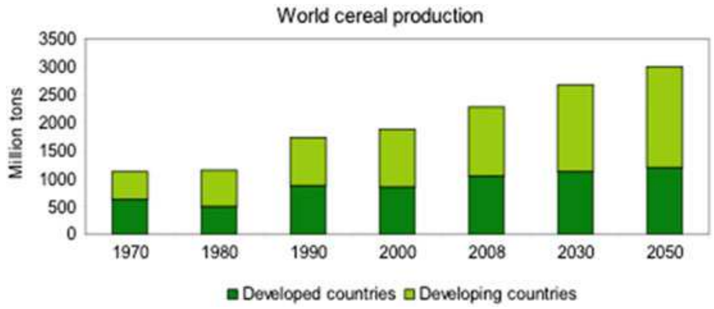

Fig. 1 Trend of world cereal production (High Level Expert Forum 2009)

and farming practices: generally yields range from 9 t/ha in the more favorable environment and intensive farming practice to less than 1 t/ha in less favorable conditions.

After a large increase from the beginning of the nineteenth century until the Green Revolution years, in recent years growth rates of cereal yields have slowed down in many countries; namely, growth rates of 6 % were calculated in 1960, but they gradually dropped to 1.5 % in 2000 (Fig. 2). While a constant increase in productivity growth rate is limited by the physiological limits of plant production, many other causes led to the above said reduction: among these the shift to less intensive farming practice due to environmental issues, a lower investments in agricultural research and development, and the adverse effects of climatic changes.

Increases in food production can be achieved by changing soil use from natural to agricultural land; this is not a viable option in general, considering the relatively low surface of natural land and its important role in the ecological equilibrium of the planet.

At the same time, agricultural land has been steadily decreasing due to over-building, desertification, erosion, salinization, change of use, and abandonment of marginal lands; in Italy in the last 3 years, 7.3 % of the arable land was lost due to a combination of these destinations (ISPRA 2014). **It is not surprising**, **then**, **that** agricultural production no longer keeps up with the food demand since 1990. The result is a significant increase in food costs (FAO 2014a).

This new global emergency involves researchers, farmers, politicians, the agro-food industry, and all stakeholders, and the new challenge can be summarized as follows: to produce more, but in a sustainable way. The goal of "sustainable intensification" constitutes one of the priorities for the research in agriculture and one of the cornerstones of the new Common Agricultural Policy.

About 26 % of worldwide agricultural land is grown under irrigation, mostly used for high-value crops such as fruits and vegetables, and produces 40 % of food needs. The yield recorded in these areas has achieved in recent years 80 % of the maximum potential yield (World Bank 2008). A relatively low margin remains then for a further increase of production in irrigation regime.

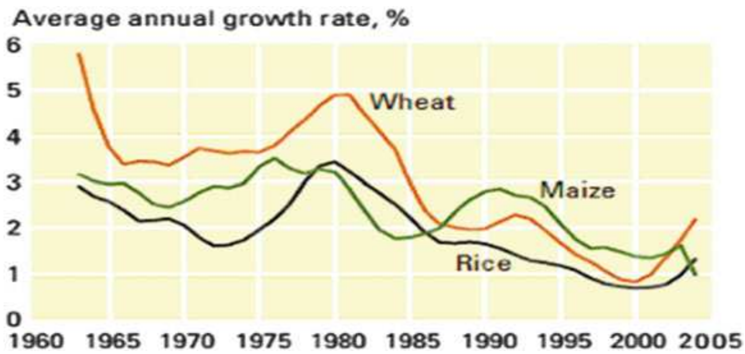

Fig. 2 Annual average growth rates of cereal yields [Source: World Bank (2008)]

The remaining 74 % of agricultural crops worldwide are grown in rainfed conditions, generally in semiarid environments, where 60 % of food and feed, such as cereal and fodder crops (Birard et al. 2009), are produced.

As opposed to what happens in the irrigated areas, the average production in dryland is well below the maximum potential yield (Passiura and Angus 2010). It is generally thought that the limiting factor in rainfed areas is the scarce water availability. Nevertheless, from the analysis of data obtained in a large body of research on wheat (reported in Fig. 3), it turns out that yields are generally lower than those potentially obtainable even at the level of water availability during the whole cropping cycle.

Indeed, besides water scarcity, other factors interact to limit crop production (Angus and van Hearwardeen 2001; Grassini et al. 2009). Some of these include planting date, weed competition, pathogen attacks, nutritional deficiencies, abnormal edaphic conditions, and high and low temperatures.

In this context, all the techniques designed to maximize production through the more efficient use of resources are in line with the objectives of "sustainable intensification." In Mediterranean environments, cereal crops are grown mainly in the semiarid and subhumid areas; in arid and semiarid areas, dryland farming is of renewed interest in the view of sustainability. It consists of a series of techniques aimed to increase the water accumulation in the soil, reduce runoff and soil evaporation losses, and choose species and varieties able to make better use of rainwater and, eventually, of supplementary irrigation.

Dryland farming has to be reconsidered also in view of the effects of climate change on cropping systems; in this context, new approaches need to be developed and evaluated on a series of issues such as the rational use of windbreaks, fertilization, irrigation scheduling in situations of "deficit irrigation," and the latest techniques for weed control, planting density, and planting dates for the newer varieties.

Within this framework the next few paragraphs will address the main aspects of cropping technique aimed at the sustainability of cereal production in Mediterranean environments.

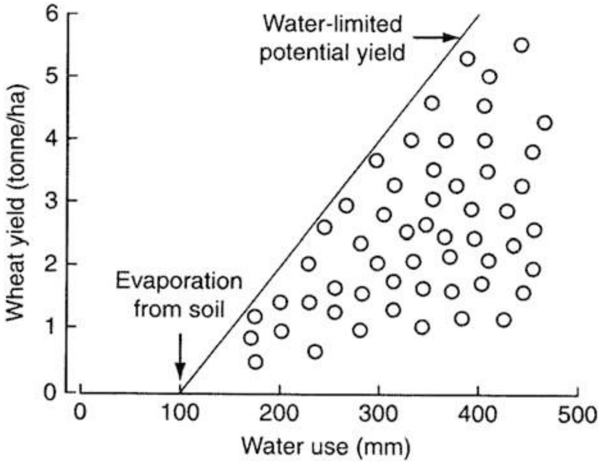

Fig. 3 Schematic representation of wheat yield in relation to seasonal water supply. The *solid line* depicts yield if water is the only limitation. The points cover the range of farmers' experience and are typically below the *solid line* because of yield limitations due to factors other than water such as weeds, diseases, poor nutrition, frost, and other problems (from Passiura and Angus 2010)

2 Soil Fertilization

Soils of the arid and semiarid environments are generally characterized by a limited content of organic matter and macronutrients such as nitrogen and phosphorus. It is well known, however, that the availability of these elements strongly affects the crop productivity and food quality. Therefore in dry farming, organic and mineral fertilization must be carefully considered, since they represent the cropping technique which allows a direct control of the quantitative and qualitative crop response. As for organic fertilization, and then the content in humified organic matter of the soil, it is just worth recalling the nutritional action resulting from the slow and gradual release of the nutritive elements, more synchronous to the rhythm of crop uptake, if compared to the more rapid and often unbalanced release operated by the organic matter mineralization process. From a biochemical point of view, humus plays an important role in the increase of the anion exchange capacity of the soil and organic matter stimulates soil microbial activity. From a physical point of view, the positive effects of soil organic matter on structure and its stability are very relevant, also due to the important consequences structure bears on the increase in water retention capacity of the soil aggregates. The source of organic fertilizer considered more appropriate in agriculture is manure. However, the gradual diversification of livestock activities from farming, as well as the difficulties in transportation and marketing, makes its use impractical and not economically convenient.

Furthermore, livestock wastes are increasingly used for biogas production. The use of commercial stabilized compost in rainfed crops is generally uneconomical. Then, crop residues are the only viable source capable of maintaining a minimum soil organic matter balance in dry farming systems. According to many authors, this remains a fundamental practice in cereal cultivation, in spite of the many drawbacks of the management of crop residues linked to soil tillage mechanization (especially in the case of abundant and coarse residues), to a depressive effect on the crop (for the removal of nitrogen by microorganisms in the case of a C/N relationship exceeding 80–100), and to the accumulation of pathogens (Zhou et al. 2009; Ward et al. 2009).

Crop residues, in addition to the benefits arising from the presence of organic matter, perform other functions which positively improve the soil water balance. They reduce soil water evaporation thanks to their mulching action (O'Leary and Connor 1997); by increasing the ground roughness, they slow down the speed of water surface runoff; also, they contrast surface compaction especially in clay soils, thus improving the water permeability. All such factors favor soil water infiltration and storage, especially in sloping surfaces (Foley and Silburn 2002). Another consequence is the reduction of soil erosion, to the advantage of soil fertility in extreme fragile environments such as the dry environment of cereal cropping areas.

The generally low levels of soil organic matter that characterize rainfed environments contribute to a reduced availability of nutrients, principally nitrogen and phosphorus. In calcareous and red soils, phosphorus availability is further reduced by fixation process.

Regarding nitrogen, it is important to stress the role it plays in the synthesis of chlorophyll and in the assimilative processes that influence root growth and as a consequence trigger a virtuous circle of improved water and nutrient uptake along the soil profile (Kirkegaard et al. 1994). Also phosphorus participates in overall plant growth and in particular in root development; it also controls flowering and fruit setting and assimilates translocation and balances the relations between vegetative and reproductive functions of the plant. The root nutrient uptake occurs through the soil solution, and this explains the strong positive interaction between water availability and mineral fertilization. In synthesis, the availability of water favors the removal of nutrients and the efficiency of their use on one side; on the other side the availability of nutrients favors plant and root growth, and this in turn improves the removal of water and its efficiency (Zhong and Shangguan 2014). Figure 4 shows the response of durum wheat production to a combination of water and fertilization regimes in an experiment conducted by Wang et al. (2010). In particular, nitrogen fertilization increases the yield response at all water regimes by improving the utilization of water resources. As also, a higher water intake improves nitrogen use efficiency at each of the five doses of nitrogen fertilizer supplied to the crop (Wang et al. 2010).

Fertilization is therefore a technique capable of improving the agronomic response to water and enhancing, and in some ways substitute, the effect of natural water resources. However the choice of the dates and rates of supply and the choice of the type of fertilizer must be particularly accurate as a function of the water availability. Indeed, any defect in the calculation of the dose or in the choice of the abovesaid factors can reduce the effectiveness and efficiency of the fertilizer use; on the other side an excessive dose may lead to lush vegetation resulting in excessive water use, such as to result in periods of water stress, and this would be particularly dangerous in times of increased sensitivity of the crop. Therefore computation of these parameters should be based on well-defined principles of

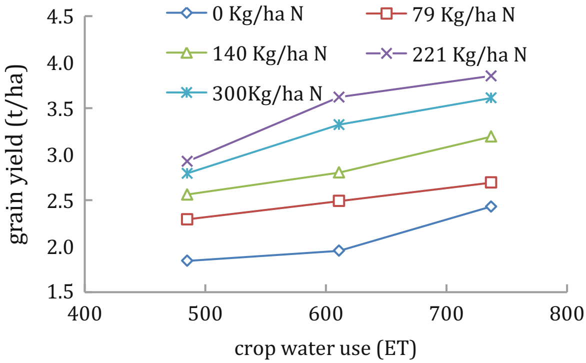

Fig. 4 Response of durum wheat grain yield to the soil water regime and nitrogen fertilization (redrawn from Wang et al. 2010)

plant nutrition, soil chemistry, and chemistry of the fertilizer elements. The dose calculation from nutrient crop uptake (based on the actually obtainable yield) must be corrected by taking two major factors into account: the availability of the element in the soil and the interaction between the fertilizer and the main physical and chemical parameters of the soil (pH, organic matter content, mineralization rate, C/N, ratio of solubilization of phosphorus, active lime content, presence of antagonist ions, etc.) (Mori and Di Mola 2012).

3 Surface Water and Sediment Control Systems and Soil Tillage

Cereal-growing areas in Mediterranean environments are generally characterized by rather low rainfall amounts, especially in the spring–summer. Furthermore, precipitation may further lose efficacy due to poor surface water systems management. Indeed, if the rain intensity exceeds the storage capacity of the soil, this will accumulate on its surface if the ground is flat generating flooding, with damage to the crop. On slopes losses for runoff will occur and reduced water storage will be associated with erosion and therefore with further reduction of soil fertility. Such losses will increase as the rainfall intensity and the slope steepness increase and as the soil permeability decreases.

For an efficient water and soil use, techniques to promote water infiltration into the soil and to reduce losses of surface runoff need to be used. The management of surface water systems through land remodeling and drainage design plays a key role in controlling water outflows, avoiding flooding and containing losses for runoff at the same time. In flat areas the basic element of the surface water management is a slightly convex shaping of fields generally obtained by tillage operations (local name in Italy is baulatura), which has the function of creating gentle slopes in order to drive excess water to ditches at the side of fields. In subhumid and arid environments, slopes should not exceed 1 % and fields may be as wide as possible (usually over 30–50 m) in order to increase the water traveling time on the soil surface and thus facilitate retention and water infiltration before it is intercepted by the ditch and removed from the field.

In sloping land water losses for runoff are generally higher, and surface water and sediment control is strategic for improving soil fertility. Although terracing is not economically viable for cereal crops, in these areas land surface shaping may be addressed though a simpler system, and runoff and erosion control is entrusted to ditches. Depending on the slope and soil texture, downstream ditches should be positioned before excess water reaches the threshold speed triggering erosion. In this way not only it contains the erosion, but it also directs water to flatter areas where it can be absorbed by the soil. This system is more effective if combined with techniques to facilitate soil water infiltration, like strip cropping. All agronomic techniques designed to increase permeability and water infiltration into the soil greatly improve cereal productivity. It is well known that the rate of water infiltration into the soil is mainly controlled by the distribution and size of the pores: it is directly proportional to the square of the average diameter of the pores, in particular macropores with diameter between 30 and 500 μm (Pagliai 1986). A balanced presence of macropores is therefore a guarantee of good permeability. As it is known, however, as a result of the action of the water and its variations during the cycles of wetting–drying, as well as the pressure of the field machinery, the soil tends to lose structure and therefore microporosity increases. Soil tillage is one of the agronomic practices which directly improves the soil structure.

Technical progress has led to the transition from traditional and energy consuming soil tillage to conservative techniques of minimum and no-tillage. The conservative techniques impact less on soils and are capable of maintaining structure without reversing the soil layers (Holland 2004). In this context several techniques have been proposed, ranging from a simple reduction of tillage depth to subsoiling (minimum tillage) to sod seeding. Minimum tillage is achieved through machinery (harrows or plows disk) which is capable of affecting the topsoil to a depth useful only for the seedbed preparation. No-tillage is a more extreme technique based on specific seed drills equipped with disk elements which break the soil (top 5 cm) and directly deposit the seed without any previous tillage (sod seeding). The energy savings can reach 70 % compared to traditional tillage. The choice of traditional, minimum, or no-tillage is one of the most controversial aspects of agricultural research; effects on crops and soil conditions depend mainly on soil type and texture, crop type (depending mainly on the characteristics of the root), rainfall regime (mainly intensity), long-period tillage strategy, structural stability of the soil (in function of the organic matter content), and all other variables interacting with them. In any case, minimum tillage and sod seeding are generally less expensive and research results suggest lower CO_2 emissions compared to traditional tillage.

Everything that contributes to improve the structural stability of soil aggregates has a positive effect on soil and crop behavior, mainly by increasing the stability of the macropore network and therefore in improving infiltration. In this context the contribution of organic matter and crop residues management is undoubtedly positive. The partial burial of residues with harrowing, rather than their removal from the field, is an advisable solution particularly in hilly areas. In this case, indeed, the partial burying of crop residues constitutes one of the few viable techniques for providing organic matter sources and promoting infiltration and water storage by increasing the soil coefficient of roughness and therefore slowing runoff. Moreover, by mulching the soil, crop residues reduce both the negative impact of raindrops on soil structure and water loss by evaporation. Infiltration is also favored, and runoff reduced by tillage, even if minimum, and by contour sowing, by increasing the soil roughness perpendicular to the lines of water flow; this slows down the water speed and thus promotes infiltration.

4 Choice of Species, Varieties, Planting Date, and Weed and Pest Control

The choice of crop is based on two main criteria: (a) the length and season of the growing cycle and (b) the ability of the species to keep good levels of productivity and resources use efficiency under conditions of environmental stress. Regarding the growing cycle, in the dry areas of Mediterranean environments, autumn–winter species are the most indicated, since their cycle occurs in correspondence with the time of highest precipitation amount. Among them, the most widespread are durum and spring wheat, barley, oats, and rye. Among these species, the choice falls on those which are capable to better tolerate low winter temperatures since they maintain a higher growth rate in a period which is not entirely favorable to plant physiological processes. In the most arid conditions, species which are able to tolerate water stress are preferred. Under this respect, barley, oat, and rye are more tolerant than durum and spring wheat.

More difficult is the choice of the variety that better suits the different environmental conditions. Conventional breeding and biotechnology have produced varieties which can adapt to different growing environments, such as drought-tolerant varieties and very high-yielding varieties in more favorable environmental conditions. In any case, the objective of breeding was to obtain the highest possible yield as a function of environmental conditions. The question is among the commercially available varieties, which are those that combine high production with water use efficiency? The relationships among yield potential, drought resistance, water use, and water use efficiency are not easy, since many physiological plant traits are involved in these relationships. Accurate studies on this topic were conducted by Hsiao (1993a, b) and Blum (2005). Both authors demonstrated that high productive cultivars maintain a high water use efficiency both in well-watered and in water-stress conditions compared to landrace varieties. According to Hsiao et al. (2007), over the last century plant breeders have inadvertently selected for higher water use efficiency by selecting for higher yielding ability.

Crop sowing date is also to be considered for a sustainable cereal productivity. Identifying sowing dates involves taking into account both the biological characteristics of the varieties and the rainfall and thermal trends. Sowing dates should be established so that the crop growing cycle is consistent with thermal and soil moisture plant physiological requirements. A useful technique can be to anticipate the time of sowing, always taking into account the specific thermal requirements of the crop. Early sowing allows to better use natural water resources resulting from rain, mainly because it reduces the time of the crop cycle falling in the spring–summer period of drought.

Weed control is also a critical point for the sustainability of cereal production. The damage caused by weeds is due to competition between the cereal and weeds for the use of water, light, nutrients, and living space, with a consequent reduction in yield. In addition weeds also negatively influence the qualitative characteristics of harvested plant parts and foods, namely, reduced grain size with a lower specific weight and lower yield of semolina, contamination of grains by weed seeds, production of toxic substances (mycotoxins) as a result of fungal attack, and production of seeds containing alkaloids which can pollute flour during the process of milling.

The sustainable control of weeds should minimize the use of herbicides while safeguarding yields. To this end, priority should be given to preventive and nonchemical agronomic measures, namely:

– Rotations with weed-cleaning crops (e.g., forage crops or mechanically weeded crops).
– Soil tillage: the distribution of weed seeds and the number of seeds able to germinate along the soil depth is a function of type and depth of tillage.
– The choice of crop varieties with a phase of tillering and developing faster than the weeds; such crops are good competitors for space.
– A slightly higher sowing density allows to occupy space in such a way that weeds are controlled.
– A careful preparation of the seedbed without actually sowing stimulates weed germination. A harrowing will then be performed before the real sowing.
– Mechanical weed control in post-emergence using specific light harrow at early tillering and up to the stage of early rising controls weeds at the seedling stage.

Chemical herbicides will then be used only if the level of weeds exceeds the threshold of economic damage, but specific herbicides should be chosen according to the botanical analysis of weeds which are actually present.

Pests are also responsible of significant yield reductions, especially in monoculture systems. A sustainable pest control should keep the harmful organism populations below the density which results in economic damage, according to the ecological and toxicological aspects related to production processes. The control system should consist in preventive and direct, physical, mechanical, and/or biological strategies, and only if these are not effective in guaranteeing an acceptable containment of pests, the use of chemical plant protection means should be permitted. In this context, it is essential to create conditions that minimize the presence of harmful organisms. Pests considered harmful to cereals are many, but only a few actually have a negative effect on crop profitability. Farmers must carefully evaluate potential damage in their cultivation area, in order to make the most appropriate pest control choices. The main agronomic preventive means are the following: adoption of appropriate crop rotations; choice of a return time of the same crop on a given field longer than 2 years in case of heavy infection; use of healthy seed and if in doubt use of seed treatments with allowed products (this is the least invasive chemical approach); reduction of sowing density, with wider distances between rows; deep burying of straw to reduce the mass of inoculum in the soil; control of weeds as possible hosts of infectious agents; and soil water management to facilitate water drainage and avoid flooding.

5 Precision Farming

This management strategy is increasingly adopted. It uses data of different nature as decision support system in the planning and management of agricultural activities. The main purpose of precision farming is to adapt the inputs and farming practices to the specific local variability existing within a field. This is a new systemic management strategy, which efficiently uses different kinds of information, generated by the evaluation and interpretation of spatial variability, the management of the spatial variability in order to improve the response of crops and environmental quality, the feedback on efficiency and effectiveness of different practices and on the use of resources, and the modeling of site-specific inputs and responses. Precision farming is made possible especially through the image analysis and geo-referenced data, obtained by remote sensing, geophysical survey, and the combined use of sensors at farm level. Through the application of these technologically advanced systems, it will be possible to develop a new model of multidisciplinary agriculture, using machines equipped with “intelligent systems” in relation to the real needs of the cereal area (e.g., Geo-referential Analytic Spraying Traceability).

These techniques help farmers in their decisions, taking into account the local variability of the physical, chemical, and biological properties of the soil, as well as the timing of input application. With these precision systems, therefore, the farmer will handle cereal production treating small areas inside the farm as if they were separate surfaces, so as to equalize, optimize, and maximize the yields. With this management, in fact, resource input is balanced and optimized in order to increase the yields and reduce interventions and costs. Moreover, the environmental impact is significantly reduced, as it reduces the amount of resources used for the production. To measure and interpret the spatial variability, different technologies are used, ranging from geographic information and positioning systems, spatial statistics, and near or remote sensors. The main applications of this innovative technology will address the mapping of yield and quality of the productions, driving aids, and site-specific supply of inputs . The main results include a reduction in use and an increase in efficiency of resources such as water, fuel, and nutrients, as well as a reduction of impacts such as carbon dioxide emission. Thanks to the application of these technologies, an added value to the economy of the cereal sector will be reached.

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Innovative Crop Productions for Healthy Food: The Case of Chia (*Salvia hispanica* L.)

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Abstract Chia (*Salvia hispani*ca L.) is an ancient crop from Central America which has been recently rediscovered as a source of ω-3 and nutraceuticals in seeds. Besides traditional seed consumption, innovative uses of the plant seeds and leaves have been proposed based on the high protein content and the production of mucilage which lends itself to a range of applications. This chapter reviews research on the plant's genetics and breeding, quality, and uses. Agronomic studies which have only recently started worldwide are also presented along with results from case studies in Basilicata.

1 Introduction

There is a growing body of work about chia, *Salvia hispanica* L., a source of plant ω-3 fatty acids and nutraceuticals, since research is targeting new and functional foods worldwide. *Salvia hispanica* L. belongs to the Lamiaceae family, and its center of origin is between Mexico and Guatemala (Cahill 2004). It was a staple crop in pre-Columbian Mesoamerica, but its cultivation was suppressed, and it remained a little-known species for subsequent centuries outside limited areas in Mexico and Central America. Over the past two decades, since evaluation and promotion of the crop by Gentry, Coates, and others (Gentry et al. 1990; Coates and Ayerza 1996), interest in knowledge and uses of chia has grown. Much of the knowledge acquired so far on *Salvia hispanica* L. is related to seed quality and genetic aspects, whereas there is a lack of scientific literature on crop management

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_3

Fig. 1 Seeds of *Salvia hispanica* L. produced in Basilicata, Southern Italy

and physiological aspects as well as on agronomic characterization. *Salvia hispanica* L. is commonly known as "chia"; its height ranges from 60 to about 180 cm, presents a subangular ramified stem, leaves with different degrees of pubescence, blue or white flowers, and very small indescent dry fruits commonly called seeds (Capitani et al. 2013) near ivory white to charcoal with lighter gray mottling (Fig. 1). Biometrical and physical properties of seeds have been studied by Ixtaina et al. (2008) for the purpose of better design of equipment and management related to harvest and processing. Chia is originally a short-day flowering species; the area where it can produce seeds is therefore limited to a restricted range of latitudes, but breeding is starting to produce new genotypes (Jamboonsri et al. 2012) to extend the range of this crop to other temperate areas and regions such as the Mediterranean basin. This chapter reviews findings on genetics, quality, uses and agronomy of the crop since its rediscovery in the 1990s.

2 Genetic Diversity and Breeding

The center of genetic and phenotypic diversity of both wild and domesticated chia populations includes the semi-temperate and temperate highlands of western Mexico and eastward spanning the trans-volcanic belt to Puebla, generally between 1,400 and 2,200 m.a.s.l. (Cahill 2004; Hernández-Gómez and Miranda-Colín 2008;

Miranda-Colin1978). Chia cultivation traditionally occurred in this region, extending into Guatemala, and in a separate area in Honduras and Nicaragua.

Limited chia germplasm is available in gene banks, and the chia that has been collected mostly comes from domesticated rather than wild populations. Two studies have evaluated genetic diversity of chia germplasm using morphological traits and genetic markers. Cahill (2001) compared diverse germplasm sources of chia (both wild and domesticated) using 33 morphological traits as well as RAPD genetic markers. The sources of the accessions used by Cahill included collections from Howard S. Gentry, housed in the agricultural institute in Chapingo, Mexico, and lines he collected as part of his doctoral thesis work. He studied 26 quantitative and seven qualitative traits ranging from leaf and floral measurements to seed color and plant growth parameters. He found relatively little morphological differences among the accessions under study, with the exception of a few major traits related to domestication. He grouped the chia accessions into four categories: wild, cultivated, primitive domesticated, and advanced domesticated. In a second study Cahill (2004) compared genetic diversity among his collection of 38 domesticated and wild chia accessions using Random Amplified Polymorphic DNA (RAPD) markers; levels of RAPD diversity within each group, HG, showed that the highest genetic diversity was found, as expected, in wild accessions (HG = 0.15), with less diversity in all domesticated accessions (HG = 0.10), and a subcategory was identified within the domesticated group, the modern, commercial varieties, exhibiting the least diversity remaining (HG = 0.02). Of the 55 polymorphic RAPD bands observed in this study, 14 were unique to wild accessions, eight bands were found only in domesticated accessions, and one band was unique to advanced domesticated accessions. These results indicate a typical pattern of a narrowing of the genetic base of the species following domestication, with a greatly diminished amount of potential genetic variation existing in current chia lines being grown in modern production areas. Cahill (2003) found a set of traits that changed during the domestication process of chia. These include closed calyces, increased plant branching, decreased pubescence, increased inflorescence length, determinacy in flowering, more pigmentation in stems, and increased plant height. Cahill also found that seed size was larger in cultivated chia than in wild germplasm and was a part of a gigantism syndrome in advanced domesticated chia lines, as well as allelopathy. In a study of inheritance of three qualitative traits in chia, Cahill and Provance (2002) found that genes for open calyces, charcoal seed color, and pigmented stems are dominant over genes for closed calyces, white seed color, and nonpigmented stems.

In another study of genetic diversity in chia, Hernández-Gómez et al. (2008) investigated variation among 22 chia germplasm sources for 23 morphological characters. Multivariate analysis of his data revealed that the chia accessions he used formed six groups, mostly related to different geographical origin. Distinct groups included chia from northern Mexico, Guerrero, Puebla, Central America (El Salvador, Guatemala and Honduras), Oaxaca, and Acatic. This study found differences between wild and cultivated chia for 19 of the 23 characters studied.

Chia has not been the subject of many modern plant breeding efforts. Improved cultivars or populations have been developed primarily by selecting lines from mixed germplasm sources, usually landraces. In general, the domesticated chia variety "Pinta" now dominates cultivation (Cahill 2005), with a few other domesticated populations or selections being grown; for example, Sahi Alba 911, Sahi Alba 912, and Sahi Alba 914 are three white seed lines developed by mass selection. Omega-3 Chia, Inc. has plant variety protection for a variety ("Omega-3") developed in Florida, obtained through mass selection from a mixed population/ landrace, likely "Pinta."

Salvia hispanica L. is a self-pollinating plant, generally setting seed at high frequency in the absence of insects (greenhouse or mesh-covered inflorescences). Hernández-Gómez et al.(2008) found much higher levels of outcrossing (over 22 %) in cultivated chia, than in wild chia (<2 %) in field studies in Mexico. Cahill (2004) reported a much lower outcrossing rate of 0.24 % in his field studies in California using a wild and domesticated line. In Kentucky over three growing seasons, outcrossing in white-flowered chia plants surrounded by blue-flowered chia lines was in the 3–8 % range. Many insects are attracted to chia flowers, and little outcrossing has been observed under greenhouse conditions, so it is likely that entomophily is responsible for transferring pollen rather than wind. Some South American chia growers report better chia crop yields when chia is grown in areas with healthy bee populations.

Cahill and Ehdaie (2005) investigated the inheritance of seed mass in chia. They reported a 16 % increase in seed mass following one cycle of selection, but chia seed mass between wild and domesticated chia lines does not differ as much as that of other oilseed species in Lamiaceae (particularly Perilla frutescens Britt.).

Making crosses in chia is hampered by small flower size and their fragility. Many attempts at emasculation of chia flowers result in rapid floret abscission or poor success. Pollen is shed within a few hours of sunrise under greenhouse conditions. Early morning pollen transfer from plants used as males to spikes of designated female plants over several days to 2 weeks has resulted in successful crosses, with ~10 % of seed from a spike used in crosses being non-selfed (crossed) seed (personal observations). Making chia crosses is considerably easier when dominant phenotypic markers are available. Cahill and Provance (2002) used stem striation/pigmentation as a dominant marker. Breeding efforts at the University of Kentucky have used flower color as a dominant marker. By using white-flowered plants as females in crosses with blue- or purple-flowered plants as males, hybrid plants can be distinguished from self-pollinated young seedlings. Blue flowering plants produce pigmented hypocotyls in the early seedling stage of growth in bright light (1–3 weeks after germination), while white-flowering self-pollinated seedlings from the attempted cross exhibit only light green hypocotyls. Alternatively, seed from attempted crosses can be grown to flowering stage, and blue-flowering plants would be actual hybrids, while white-flowering plants would be selfed (maternal parent) progeny.

Traits of interest in a traditional chia breeding program include seed yield, flowering date, rate of maturity, lodging and shattering resistance, and disease resistance. Hybrid cultivar production could increase chia vigor and seed yield, but would likely require the use of male sterility. The use of molecular markers and other genomics tools may be productive once more genetic information is generated for chia.

With a narrow genetic base in available germplasm, other means of finding genetic variation can be used, such as mutation breeding. Possible use of male sterility for production of hybrid chia as well as novel oil/chemical profiles and plant branching pattern and height are being investigated in populations treated with gamma radiation and chemical mutagens. Additional collections of chia germplasm from its center of origin are needed and should be available to chia breeders.

At the University of Kentucky, in field plots and in greenhouse-grown chia from numerous commercial sources, variation in leaf size and shape, stem pubescence, branching pattern, spike length, seed size, flower color, and seed color have been observed, but very little variation in photoperiod response has been found. Through mutation breeding, a number of new chia lines with a range of responses to day length have been developed (Jamboonsri et al. 2012). Most of these lines are induced to flower under day lengths between 13 and 16 h and a few flower under constant illumination (i.e., they are day-length insensitive). Additional breeding efforts have been focused on studying the inheritance of traits such as photoperiod response, seed color, lodging resistance, and shattering resistance. Selection for improved yield is difficult until seed shattering and lodging problems are addressed.

3 Seed Quality

A series of scientific papers have addressed the quality of chia seeds since the crop's rediscovery. Most of them focus on fatty acids since chia oil has the highest concentration of ω-3 of all natural sources (Palma et al. 1947; Ayerza 1995; Ayerza and Coates 2011; Segura-Campos et al. 2014). Seeds are also a source of proteins, fiber, and nutraceuticals, and there is an increasing interest in those compounds in literature reports.

Also, no significant content of toxic compounds have been found in chia seeds, and there is no evidence of allergic responses (EFSA 2005, 2009) caused by the consumption of chia seeds. The omega-3 chia website (www.chiagrowers.com) reports laboratory analysis where no mycotoxins where found on tested chia samples.

The oil yield of mature chia seeds generally ranges from 29.36 to 33.50 %, depending on the areas of origin, climatic conditions, and on the technique used for oil extraction (Ayerza and Coates 2004, 2009a, b; Ixtaina et al. 2011; Marineli et al. 2014; Rocha Uribe et al. 2011; Silveira Coelho and de las Mercedes Salas-Mellado2014). Moreover, the seed's oil content tends to rise as altitudes of eco-system in which the seeds are grown increase (Ayerza 2009). From a nutritional point of view, the concentration of fatty acids in chia seed oil ranks in the following order: α-linolenic acid > linoleic acid > oleic acid > palmitic acid > stearic acid. In particular, the content of α-linolenic acid (C18:3) is about 60 % of all fatty acids present in oil.

Medical and epidemiological studies have demonstrated that ω-3 fatty acids are essential nutrients and play a role in human health for the prevention of cardiovascular diseases, being antithrombotic, anti-inflammatory, antiarrhythmic, and favoring plaque stabilization. Therefore, the intake of foods containing high amounts of α-linolenic acid is recommended. Also, an important ratio of unsaturated fats to target in the human diet is that of ω-6:ω-3 fatty acids. The ideal ratio ranges from 1:1 to 3:1, but generally in the western diet, it is much higher, even in vegetable oils, where the content of ω-6 fatty acids is high. The ratio is lower than 1 in chia (Ixtaina et al. 2011; Silveira Coelho and de las Mercedes Salas-Mellado2014); therefore, chia seeds or extracted oil can be used as a means to balance the unsaturated fatty acid intake in diets.

However, genotype and environmental conditions can influence the fatty acid composition more than the total oil content in chia seeds (Ayerza 2009, 2011; Ayerza and Coates 2004, 2009a, b, 2011), and namely α-linolenic content of chia seeds varies under differing environmental conditions and ecosystems, even in the case of a common genetic source. In general, it has been observed that as elevation of the seed production location increases, oil saturation decreases since the levels of α-linolenic and linoleic fatty acid increase and palmitic and stearic fatty acids decrease (Ayerza and Coates 2011). The ratio of ω-6:ω-3 fatty acid ratio decreases and that of polyunsaturated fatty acid/saturated fatty acids ratio increases. Also cool temperatures can often positively affect the level of unsaturation of chia fatty acids as for other oil seed crops (Ayerza 2009; Ayerza and Coates 2004, 2011).

In addition to important fatty acid composition, chia seed and oil also represent a rich font of compounds which have beneficial effects on human health such as vitamin B (Bushway et al. 1984) and natural antioxidants such as tocopherols, phytosterols, carotenoids, and phenolic compounds, including chlorogenic acid, caffeic acid, myricetin, quercetin, and kaempferol (e.g., Reyes-Caudillo et al. 2008; Marineli et al. 2014; Amato et al. 2015), and do not represent a hazard for human health (Bresson et al. 2009).

Amato et al. (2015) report the first data on the quality of chia seeds produced in Europe, from an experiment conducted in Basilicata. They found that oil concentration from Basilicata seeds was not significantly different than that of commercially available seeds from Australia and Peru, but characterized by a higher concentration of pigments (chlorophyll and carotenoids) and α-linolenic acid.

Chia seeds are also a source of protein and fiber: Capitani et al. (2012) report that after oil extraction, chia meal contains 19–23 % of proteins and 33.9–39.9 % of dietary fiber. Proteins in whole seeds range from 12 to 26 % (Ayerza and Coates 2004, 2009a, b, 2011). Ayerza and Coates (2009a, b, 2011) report changes with environment of production, and, namely, a highly significant decrease in protein if elevation increases. Its amino acid profile is suitable for the adult diet (Weber et al. 1991).

One of the most promising features of chia seeds is the 5–6 % content of fiber, which can be used as dietary fiber (Ayerza and Coates 2001; Reyes-Caudillo et al. 2008) but are also very interesting for industrial and pharmaceutical uses because of the high content of soluble fiber forming a highly hydrophilic mucilage. A polysaccharide with a molecular weight of $0.8–2 \times 10^6$ Da has been identified by Lin et al. (1994) who proposed a tentative structure as a tetrasaccharide with 4-*O*-methyl-*a*-D-glucoronopyranosyl residues occurring as branches of *b*-D-xylopyranosyl on the main chain and yielding by acid hydrolysis the monosaccharides *b*-D-xylose, *a*-D-glucose, and 4-*O*-methyl-*a*-D-glucoronic acids in the proportion 2:1:1. The fiber is localized in the fruit exocarp (Capitani et al. 2013), namely, in the first three cell layers. After contact with water, hydrated filaments of the mucilage are partially extruded out of the seed and form a transparent "capsule" which remains strongly attached to the fruit outer layers (Muñoz et al. 2012a, b).

4 Leaf and Stem Quality

The composition of the leaves of *Salvia hispanica* L. has not been the object of many studies. Ahmed et al. (1994) studied leaf oil and its composition from leaves and found 52 compounds. They identified 42 of the chemical components and found that oil composition was dominated by β-caryophyllene, globulol, γ-murolene, β-pinene, α-humulene, germacrene-B, and widdrol, but the relative amounts varied as a function of geographical area where the plant was grown, ranging from California to Texas to Argentina.

Peiretti and Gai (2009) reported a concentration of polyunsaturated fatty acids of 62.3–75.2 % of the total fatty acids in the plant biomass, with changes between single components as a function of growing stages: they recorded a decrease of the linolenic acid content from 64.9 % of the total fatty acids at early-vegetative stage to 49.9 % at the budding stage, while other fatty acids increased. They also found an increase in the fibrous fractions and a strong decrease of the crude protein content after the shooting period. Another study (Peiretti 2010) showed increases in dry matter (from 8.4 to 22.4 % of fresh plant weight) during the growth cycle of chia while water soluble carbohydrates increased from 8.6 to 21.3 % of the dry matter. Values of soluble nitrogen in the whole plant ranged from 10.5 to 17.4 %.

Recently research conducted in Basilicata, Southern Italy (Amato et al. 2015), has shown secondary metabolites in leaves and provides the first report of flavonoids in chia leaves, including two uncommon compounds: acetyl vitexin and acetyl orientin which had never been reported before in the Lamiaceae family.

5 Uses

Chia seeds are an important source of ω-3, proteins, and antioxidants, and as such, their first use—traditional and future—is as a functional food or a nutritional supplement. Seeds may be consumed whole, after oil extraction (consuming both oil and meals), or ground as an additive to other food ingredients. They offer advantages over other available ω-3 sources such as the higher content of ω-3 (Ayerza and Coates 2004), the long shelf-life of whole seeds (Ahmed et al. 1994; Amato et al. 2015), and the lack of fishy flavors (Coates and Ayerza 1998). According to Ayerza and Coates (2011), keeping into account the variation in α-linolenic fatty acid contents found in chia seeds between growing environments, an adult with an intake of 2,700 cal would need between 22.5 and 26.5 g/day of seeds or between 6.9 and 7.9 g/day of oil to reach the required daily recommendations of ω-3 fatty acid. Chia can be incorporated into human diets for their protein content and composition, alone or as ingredients to produce a better source of proteins compared to other grains. Oil extracted from chia may be used as a seasoning or in cosmetics (Muñoz et al. 2013). Also, it has been used in ethnic medicine for eye infections (Lu and Foo 2002; Reyes-Caudillo et al. 2008).

Chia seeds and oil can be added as ingredients to obtain functional foods, as tested in bakery products (Pizarro et al. 2013; Marineli et al. 2014; Silveira Coelho and de las Mercedes Salas-Mellado2015). Chia seeds do not contain gluten. Coeliac disease has lately become one of the most important food intolerances, and gluten-free diets are increasingly adopted, but according to Steffolani et al. (2014), they often are unbalanced and poor in fiber, iron, calcium, and rich in saturated fats. Adding chia to gluten-free flours improves their nutritional qualities and does not negatively affect organoleptic characteristics (Steffolani et al. 2014).

Therefore, the use of chia seeds is growing in food industry for the production of bread, bars, cookies, and breakfast products especially in the USA, Latin America, and Australia (Cabrera and Cerna 2014). Steffolani et al. (2014) report that whole or pre-hydrated seeds give better results compared to ground seeds for bread-making, in terms of lower specific volume and higher firmness and color. Cabrera and Cerna (2014) reported that the concentration of chia seeds affects texture and color but not the taste of bread and found the ideal amount of chia seeds is 3 %.

Mucopolysaccharides contained in chia fruits are useful as soluble dietary fiber and result in the production of gel surrounding the seeds when hydrated. This mucilage has been reported to be essentially composed of polysaccharides (de la Paz Salgado-Cruz et al. 2013) and to have exceptional physical properties due to the high soluble to insoluble fiber ratio (de la Paz Salgado-Cruz et al. 2013): it absorbs 27 times its own weight of water, and this amount is affected by the concentration and type of salts (Muñoz et al. 2012a, b). According to Ahmed et al. (1994) hydrated seeds are traditionally used in beverages called “agua fresca” or “chia fresca” in Mexico.

The gel-forming phenomenon occurs in the mouth when fruits are chewed and continues inside the stomach. This gel has important effects on nutrition and health due to:

– A soothing effect on the digestive tract
– The creation of a barrier for enzymes, therefore a slow down and reduction of the breakdown of complex carbohydrates into sugars
– A satiety sensation due to the increase in the volume of the hydrates' mass (Gentry et al. 1990)
– An increase in viscosity of the bolus which then proceeds slowly in the intestinal tract, and this makes digestion more efficient and prolongs the feeling of satiety (Gentry et al. 1990; Capitani et al. 2012)
– Soluble fibers forming the gel act as probiotic and regulate blood sugar and cholesterol levels (Gentry et al. 1990; Capitani et al. 2013)

Thanks to its physical properties chia mucopolysaccharide can be used in many applications, from food to pharmaceutical industry (de la Paz Salgado-Cruz et al. 2013): as a thickening and stabilizing agent in products such as preserves, yogurt, mayonnaise, and sauces (de la Paz Salgado-Cruz et al. 2013). According to Steffolani et al. (2014) this mucilage could be used in baked products as a substitute for eggs or oil.

The use of microscopy, spectroscopy, and image analysis in a study conducted by de la Paz Salgado-Cruz et al. (2013) shows that chia mucilage can be relevant to nanotechnology research and applications since it is formed by a network of microfibrils of 18–45 nm width. They can therefore be considered as nano-aggregates and are likely to have several active sites on their surface. Chia mucilage is therefore suited for many high-technology uses such as the formation of nano-composites or the controlled release of drugs.

Muñoz et al. (2012a, b) proposed the use of chia hydrocolloids to improve the properties of films and showed that films could be made from the mucilage of *Salvia hispanica* L. and whey protein and Dick (2014) developed biodegradable films from chia flours and mucilage. Both works show that resulting materials have low permeability and good mechanical properties. Dick (2014) also proved that chia-based biofilms have an excellent ability to absorb ultraviolet radiations and therefore can protect packaged goods. Chia mucilage has also been used as an experimental model for the study of plant-soil water relations by Kroener et al. (2014).

One technical problem in the use of chia mucilage is related to the difficult separation of the gel from fruit coats since it is firmly attached to the fruit exocarp outer cell layers (de la Paz Salgado-Cruz et al. 2013). According to Capitani et al. (2013) this phenomenon is possibly due to the association of mucilage with the columella and the cell wall, in analogy with findings on *Arabidopsis*. This issue is addressed by separation techniques such as the use of sonication and high pressure filtration (Marin Flores et al. 2008) or lyophilization (Capitani et al. 2013).

The high concentration of health-promoting compounds in chia seeds allows to envisage the incorporation of chia seed into animal feed to increase the linolenic acid concentration and to decrease cholesterol levels in meat and eggs (Norlaily et al. 2012). Ayerza and Coates (1999, 2000, 2001) and Ayerza et al. (2002) remark that chia seeds do not show the disadvantages of other source of polyunsaturated fatty acids in the animal diet, such as fishy flavor and digestive problems.

Ayerza and Coates (2000) studied the effect of a diet including chia seeds on poultry and found a high content of polyunsaturated fatty acids and a low level of cholesterol and saturated fats in egg yolk. In a research on milk cows' diet, Ayerza and Coates (2006) found that chia seeds did not affect production or total fatty acid and cholesterol content, but they caused an increase in the percentage of ω-3 fatty acids.

Meineri and Peiretti (2007) fed chia seeds to rabbits and report that a 10 % of chia seeds increases the digestibility of acid detergent fiber, dry matter, organic matter, crude protein, crude fiber and gross energy. Peiretti and Meineri (2008) found significant increases in polyunsaturated fatty acids in meat as a function of the increase of chia seed ratio in the rabbit diet.

According to other authors, the seed meal after oil extraction can be a good source of protein with adequate amounts of amino acids and as such could be used as a feed supplement (Bushway et al. 1984; Weber et al. 1991)

Regarding leaves and whole plants, Peiretti and Gai (2009) reported that the quality of chia forage is a function of harvest time and is optimal before shooting. Peiretti (2010) suggests that chia has a good potential for ensiling, based on lab-scale experiments showing that the fermentation of chia plants is characterized by a lack of lactic acid and the presence of alcohols and volatile fatty acids. He found that isobutyric acid decreased with increasing wilting level down to null values at dry matter levels of more than 28.5 % of the fresh biomass. Ethnobotanical uses of chia leaves (Cahill 2003) include leaves and vegetative parts of *Salvia hispanica* L. for medicinal purposes.

Ahmed et al. (1994) report that due to their oil composition, chia leaves are of potential interest for extracting flavors and fragrance; they also raise the hypothesis of use as insecticides, based on the observation that the canopy seems to deter whitefly and other insects. Subsequent research, though, has shown attacks by insects as reported below (section on disease and insect control).

6 Agronomic Management

Agronomic management is one of the most important aspects in cropping systems, for the success of crops, but also for the correct management of resources and energetic inputs and sustainability. Reports on agronomic management of chia are only just starting to appear in the scientific literature; most of them are based on experiments and observations conducted in the areas of origin of South and Central America and focus mainly on the response of different genotypes to growing environments in terms of phenology, yield, and quality of seeds (Ayerza and Coates 2009a, b; Ayerza 1995, 2010, 2011, 2013; Lobo Zavalia et al. 2011). Ongoing research in Basilicata, Southern Italy (Fig. 2), provides the first report of seeds

Fig. 2 Plants of *Salvia hispanica* L. in experimental fields in Basilicata, Southern Italy

produced in Europe (Bochicchio et al. 2015) and shows that while quality is comparable to that of other traditional or new production areas (Amato et al. 2015), yields are quite low, although still in line with some of the low-producing areas of origin. This is due to late flowering of the traditional short-day genotypes at the latitudes of South Europe and therefore to the occurrence of autumn low temperatures during grain filling. In order to fully exploit the potential for chia seed production therefore new genotypes fit for high latitudes (Jamboonsri et al. 2012) need to be used in this case. Conversely, a high potential for the production of whole fresh biomass up to 59.71 t ha^{-1} (Bochicchio et al. 2015), and for leaf production, with values of up to 11.06 t ha^{-1} of fresh and 2.02 t ha^{-1} of dry biomass (Amato et al. 2015) have been obtained with short-day genotypes due to the long duration of the vegetative stage.

Soil *Chia* prefers sandy, well-drained soils with moderate salinity and with a pH ranging from 6 to 8.5 (Yeboah et al. 2014). According to some authors this crop has low salt tolerance, and salinity can significantly reduce the seed oil yield (Heuer et al. 2002). However, chia plants adapt well to soils belonging to other texture classes provided they have good drainage and are not too wet (Muñoz et al. 2013; Lobo Zavalia et al. 2011; Baginsky et al. 2014). This crop is semi-tolerant to acid soils and drought (Muñoz et al. 2013; Baginsky et al. 2014).

Climatic Requirements *Chia* is a drought-resistant crop, and it has been suggested as a choice for cropping systems in semi-arid environments (Ayerza and Coates 2009a, b). This plant can grow in arid environments, and it has been proposed as an alternative to existing forage crops (Peiretti and Gai 2009). Minimum and maximum growth temperatures of this crop are 11–36 °C, with an optimum range between 16 and 26 °C. It is well known that this plant is very sensitive to low temperature, and it cannot produce seeds since it is killed by frost before flowers set (Ayerza and Coates 2005). The duration of the crop cycle in most cases ranges from 140 to 180 days (de Kartzow 2013; Coates and Ayerza 1996), but being chia sensitive to day length, the growing cycle strictly depends on the latitude where it is planted (Coates 2011).

Water While being able to grow in dry conditions (Baginsky et al. 2014), *Salvia hispanica* L. benefits from rainfall events ranging from 300 to 1,000 mm during the whole growing season (Yeboah et al. 2014; Coates and Ayerza 1996). The optimal distribution of precipitation for this crop allows a good supply of rainfall during the first phenological phases corresponding to vegetative growth, while drier conditions are required during subsequent phases, especially seed maturation (Yeboah et al. 2014). The crop can be grown in rainfed or irrigated conditions (Coates and Ayerza 1996), but there is a lack of scientific literature on irrigation experimental trials, so there is no exact quantification of evapotranspiration of this crop.

Fertilization There is no published data from specific field experiment on fertilization of chia so far; for this reason information on this aspect is few, fragmentary, and imprecise. *Chia* grows well in soils with a good amount of nutrients, while a low soil nitrogen content seems to strongly reduce yield (Coates 2011). Coates and Ayerza 1996 reported amounts of nitrogen applied in field settings ranging from 21 to 45 units and Pozo Pozo (2010) reports amounts as high as 115 units. According to de Kartzow (2013), though, the recommended doses of N, P_2O_5, and K_2O are 51, 43, and 60 units, respectively; the author also suggests to apply 50 units of calcium sulfate.

First results of research conducted in Basilicata, Southern Italy, has shown that after organic fertilization at sowing nitrogen topdressing has not improved yield, in connection with a higher incidence of lodging (Bochicchio et al. 2015). Amato et al. (2015) also showed that mineral fertilization increased free acidity, chlorophyll, and carotenoids in seeds, whereas it reduced *p*-anisidine value, phenols, and oxidative stability. It also seemed to affect the amount of secondary metabolites in leaves.

Sowing In South America chia is sown at a rate of 5–6 kg ha^{-1} with a variable row spacing, the most frequent is 0.7–0.8 m. Some studies have shown that planting date affects yield, and, namely, earlier sowing results in higher yields probably due to a longer vegetative growth period (Coates 2011). Growth and yield of *chia* depend also on planting method and planting density. A recent study has shown that direct planting instead of transplanting allows to achieve the best yields (Yeboah et al. 2014). As regards plant density, it has been observed that for *Salvia hispanica* L. the greatest variations in seed yield are related to the different planting method and plant density used in the different environment of production (Yeboah et al. 2014), and according to available data for this crop, the higher the planting density, the greater the seed yield. Results of Yeboah et al. (2014) show highest yields at a planting density of 40,000 plants ha^{-1} with narrow-row spacing (0.5 m × 0.5 m).

A field experiment conducted at Atella in Basilicata (Southern Italy) tested the response of chia to sowing densities of 4–125 plants m^{-2} and first results show that seed yield increased with plant density (Bochicchio et al. 2015). In Kentucky we find that 2–3 kg ha^{-1} provides better yields with less lodging.

Weed Control As for many crops, the early stages of growing are critical times for weed competition; this is especially true for *chia* since no herbicide has been found to be fully satisfying for weed control so far. Indeed Coates (2011) indicates that the first 45 days are very sensitive because the pressure of weed is high at a time when the growth rate of chia is very low compared with common weeds. After a good establishment of chia plants, it is possible to control weeds manually and mechanically until canopy closure (Coates 2011). There is an important need to investigate weed control in relation to plant density as highlighted in a study by Pozo Pozo (2010). In a pesticide trial conducted in Chile, Villegas et al. (2012) compared different herbicides and concluded that linuron showed the best behavior in terms of weed control and conservation of *chia*. In another study metribuzin and haloxyfop-methyl-*R* were used to control weeds with good results (Pozo Pozo 2010).

Disease and Insect Control According to Pascual-Villalobos et al. (1997) chia leaves contain essential oils capable to carry a repellent action against insects and thanks to this characteristic Muñoz et al. (2013) report previous observations that this crop can be grown without pesticides or other chemical compounds. Other authors, though, observed insect attacks in particular foliage beetles able to provoke a significant insect infestation of the plant (Yeboah et al. 2014). Moreover, in Southern Italy during the crop seasons 2013 and 2014 (data not shown), insect attack on leaves by whiteflies and aphids were observed. In a recent experimental trial (Yeboah et al. 2014) Fusarium wilt infection on chia has also been observed. Moreover, recently the presence of two viruses infecting chia plants was reported, and the infection was able to determine severe disease symptoms (Celli et al. 2014). Also, Celli et al. (2014) confirmed that the virus was transmitted by whiteflies, and this confirms the presence of species of *Aleyrodidae* family on this crop as was observed in our field trials in Southern Italy. Such reports of the occurrence of common diseases highlight the need to assess the appropriate control methods, including pesticides useful for the pests and pathogens identified on this crop.

Harvesting *Salvia hispanica* L. seeds are harvested mechanically. In low input conditions, average yield is around 600 kg ha^{-1} but can be up to 1,200 kg ha^{-1} (Coates 2011), while in high input conditions with irrigation and fertilization, yields as high as 2,500 kg ha^{-1} have been shown in some experimental trials in Argentina (Coates 2011). During harvest a great problem is the scalarity of flowering and maturation: the central flower head matures and dries out while inflorescences on side branches are still green. Waiting until all seeds are dry can increase the risk of seed loss to rain, wind, or birds (Jamboonsri 2010).

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The Hidden Costs of Livestock Environmental Sustainability: The Case of Podolian Cattle

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Abstract Life cycle assessment (LCA) is currently one of the most widely used methods for assessing the environmental impacts and performance of livestock products. According to this procedure, intensification of animal production is generally advocated to mitigate greenhouse gas emissions compared with extensive grazing systems due to the use of selected breeds, with enhanced productivity, and the significant reductions in CH_4 emissions consequent to the use of concentrates rather than forages. In addition, the impact of intensive systems on land use is much lower. However, free-ranging Podolian cattle show a number of positive environmental effects, such as increased climate stability, improved soil functionality, water quality and footprint and preservation from fires along with maintaining an economically active social community in otherwise unproductive, marginal areas. Other beneficial effects of extensive Podolian farming system include low competition with human nutrition and high level of animal health and welfare. An economic evaluation of these non-commodity outputs should be indirectly estimated by the avoided costs (e.g. reduced veterinary interventions and therapy treatments) or the lack of profits (e.g. direct payments for the enhancement of environmental performance) that would have incurred in their absence. These economic evaluations should be used in order to allocate them as further outputs to be included in the LCA in order to achieve a more accurate estimation of the impact of the Podolian farming system.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_4

1 Introduction

According to The State of Food and Agriculture 2009, the agriculture sector is the world's largest user of natural resources (FAO 2009). Taking into account the entire livestock commodity chain, from land use and feed production, to livestock farming and waste management, to product processing and transportation, the livestock sector plays an important role in climate change, representing 14.5 % of human-induced greenhouse gas (GHG) emissions. Beef and cattle milk production accounts for the majority of the emissions (41 and 20 % of the sector's emissions, respectively). Feed production and processing and enteric fermentation from ruminants are the two main sources of emissions (45 and 39 % of sector emissions, respectively) while manure storage and processing represent 10 % (FAO 2013). Thus, an increased interest in the greenhouse gas (GHG) intensity of food products has induced a lot of discussion in the media regarding the climate impacts of beef production systems.

2 Environmental Impact Assessment

Currently, many different methods are used to assess the environmental impacts and performance of livestock products. Life cycle assessment (LCA) is a well-developed internationally standardised method and management tool (ISO 14040 2006; ISO 14044 2006) for quantifying the emissions, resources consumed and environmental and health impacts of products throughout their entire life cycle, from raw material extraction through transport, manufacturing and use all the way to the end of their life (from cradle to grave). According to ISO 14040 (2006), LCA consists of four phases: (1) definition of goal and scope of the analysis, the functional unit, the impact categories and the system boundaries; (2) life cycle inventory (collection of data that identify the system inputs and outputs and discharges to the environment); (3) performance of impact assessment (calculating the contributions made by the material and energy inputs and outputs tabulated in the inventory phase to a specified suite of environmental impact categories, e.g. using the SimaPro 8.1 LCA software package); and (4) analysis and interpretation of results (aiming to identify hot spots and possibilities of decreasing environmental impacts of the system).

It is becoming increasingly common to express the environmental impacts of the production of human food commodities as carbon footprints (CFPs), taking into account all GHGs that are produced during the life cycle of a product. CFPs are expressed as CO_2-equivalents (CO_2-eq.), CH_4 having a value of 25 and N_2O a value of 298 (Forster et al. 2007). Ruminant products have higher CFP production compared with other food commodities (Williams et al. 2007); in fact, due to the nature of their diet (based primarily on forages) and digestive system, ruminants produce hydrogen and CH_4 during the fermentative digestion of their feed. CH_4

constitutes a loss of energy equivalent to 2–12 % of gross energy ingested (Johnson and Johnson 1995).

2.1 Limitations of the Standard Method of Sustainability Assessment

According to the LCA procedure, intensification of animal production is generally advocated to mitigate GHGs emissions compared with extensive grazing systems. In fact, intensive systems consider the use of selected breeds, with enhanced productivity, associated with significant reductions in CH_4 emissions, related to larger use of concentrates rather than forages (Capper 2012). However, these results focus on emission of greenhouse gases of a single product: beef. On the contrary, for extensive farming systems, the outputs in LCA analysis have to refer not only to material products but also to other non-commodity outputs (OECD 2010) and non-marketable public goods (Tscharntke et al. 2005), named "ecosystem services" (de Groot et al. 2002; Millennium Ecosystem Assessment 2005; Liu et al. 2010) and related to the multifunctional role of livestock, especially in marginal areas.

3 The Multifunctional Role of Podolian Farming System

Rather than resource sufficiency, the concept of sustainability in terms of functional integrity is well suited for extensive livestock farming, where domesticated animals, wildlife, forage, non-forage plants and manure display complex relationships and the capability to coexist as different components of a system. Husbandry of native breeds, such as Podolian cattle (Fig. 4.1), can provide an opportunity for a sustainable use of natural ecosystems and maintain an economically active social community in Southern Italy marginal areas. Podolian cattle, in fact, are a local breed, characterized by a high rusticity and are well adapted to live in a semiarid environment with poor vegetation, as suggested by skin pigmentation, well-developed dewlap and sturdy hooves. Their most common rearing system is based on either no-shelter pasture or pasture with nocturnal shelter (Napolitano et al. 2005). Most often, cows and calves are not supplemented, whereas young adults receive concentrates in the finishing period (Braghieri et al. 2011a, 2013).

According to Liu et al. (2010), ecosystem services include all the benefits that people obtain from ecosystems and they are divided (Millennium Ecosystem Assessment 2005) into four categories: provisioning services (e.g. food and water), regulating services (e.g. regulation of climate through the storing of carbon and control of local rainfall and removal of pollutants by filtering the air and water), supporting services (e.g. soil preservation and nutrient cycling) and sociocultural services (e.g. labour provision, recreation and provision of historic, scientific and

Fig. 4.1 Extensive Podolian farming systems can provide an opportunity for a sustainable use of natural ecosystems and maintain an economically active social community in Southern Italy marginal areas

educational information). Other aspects related to animal production and considered relevant by the public opinion include animal welfare and product quality.

In the next few paragraphs we are going to make a brief analysis, suggesting an economic evaluation of various services provided by Podolian farming system accounting for its multifunctional role in the southern marginal areas of Italy, in order to allocate them as further outputs in LCA analysis.

3.1 Land Use

Nearly one-third of terrestrial lands have agricultural crops or planted pastures as a dominant land use (accounting for at least 30 % of total area), thus having a profound ecological effect on the whole landscape (Scherr and McNeely 2008). According to the Eco-indicator 99 methodology of LCA procedure (PRé Consultants), land or occupation of land is considered an important impact category. This parameter showed a heavy impact when considering extensive farming systems, such as Podolian system (Roma et al. 2009). Although LCA software programmes accurately take into account the appropriate datasets, land use impact evaluation should also take into account the quality of the lands used as pasture that in the Podolian system are marginal (upland and of low fertility); therefore, this farming system may represent a tool to maintain an economically active social community in these areas. As no realistic alternative to this production system exists, these lands would risk desertification. Conversely, the husbandry of these cattle shows a number of positive environmental effects, such as increased climate stability, improved soil functionality, water quality and footprint and preservation from fires. In addition, positive social and cultural functions, such as labour, touristic activities and production of typical products directly linked to the area, are also promoted.

As for climate stability, permanent grasslands store nearly as much carbon as forests (EIP-AGRI2014). Carbon sequestration potential of permanent pastures was estimated between 0.01 and 0.3 Gt (gross tonnes of volume) C year^{-1} (Lal 2004). In addition, a number of management practices, such as maintenance of permanent grassland, adequate grazing pressure, cutting and haymaking, manure application and reduction of tillage, may enhance C sequestration (Lugato and Berti 2008) and decrease rather than increase N_2O emissions (Wolf et al. 2010).

Soil functionality, in terms of good structure, sufficient organic matter and resilience to erosion by wind or water, may be improved by the manure of grazing animals, which represents the most important source of nutrients, and organic matter. When deposited directly on pastures and fields, manure does not increase significantly the amount of methane (Bernués et al. 2011).

Intensive rearing systems show a high water footprint (Steinfeld et al. 2006; Hoekstra and Chapagain 2007) in terms of water use (e.g. water embedded in feed production and farming practices and drunk by animals) and water quality (i.e. pollution due to mismanagement of manure, antibiotics and agrochemicals). On the contrary, water-related problems are comparatively irrelevant in low-input systems based on grazing at low stocking densities and on utilisation of local natural resources.

According to de Groot et al. (2002), economic evaluation of these ecosystem services may be indirectly performed by the avoided costs that would have incurred in the absence of these services. Examples are wildfire prevention practices (e.g. cleaning, cutting and partial deforestation) that have relevant costs in terms of human labour and environmental impact or fertilisation and agricultural practices to avoid desertification.

The new Common Agricultural Policy (CAP) introduces a mandatory "greening" component of direct payments for the enhancement of environmental performance (Regulation EU No 1307/2013). Member States should use part of their national ceilings for direct payments in order to grant an annual payment for compulsory practices linked to agriculture, such as crop diversification, the maintenance of permanent grassland and the establishment of ecological focus areas. Regarding permanent grassland, among other aspects, Member States shall ensure that the ratio of areas of permanent grassland to the total agricultural area declared by the farmers will not decrease by more than 5 % compared to a reference ratio to be established by Member States in 2015.

3.2 Lower Competition with Human Nutrition

There is a growing concern about the use of grains in animal feeding that could be used to produce food eaten by humans (O'Mara 2012). The degree of competition with human nutrition should be another aspect to consider, in terms of sustainable production, as diets in intensive meat systems are mainly based on cereals. Since much of the energy value is lost during conversion from plant to animal matter, it would be much more efficient for humans to consume cereals directly (Gerbens-Leenes and Nonhebel 2005). In addition, when considering the efficiency of food production, the quantity of human-edible energy and protein used in animal feed should be used rather than gross energy efficiency or protein intake/output ratios (Oltjen and Beckett 1996). Although beef production systems are considerably less efficient than monogastric livestock systems in terms of total energy consumed, recalculating efficiencies of energy and protein production on the basis of human-edible food produced per unit of human-edible feed consumed gave higher efficiencies for ruminants than for monogastric animals (Gill et al. 2009). A low degree of competition with humans was found for Podolian beef production (Napolitano et al. 2005). These animals are able to convert vast renewable resources from grassland, pasture and by-products into food edible for humans. The calculation of human-edible returns should be performed using only gross energy (GE) and crude protein (CP) inputs derived from human-edible foods (Napolitano et al. 2005) and used in the different stages of the Podolian farming system (i.e. cow pregnancy, suckling and weaning of calves and fattening phase).

3.3 Animal Health and Welfare

A sustainable animal production system should pursue long-lasting economically competitive activities enabling to minimize any negative effects to the animals, the people, the environment and the community (McGlone and Sutherland 2007). It is obvious that some of these aims are contrasting. For instance, an environmental sustainable farming system should minimize methane emissions by increasing the efficiency of transformation of dietary energy into human-edible products. This approach intends to reduce the amount of fibrous feeds in ruminant feeding while introducing more selected and efficient breeds (FAO 2006). Both strategies may have adverse effects at animal welfare level. The lack of fibre in ruminant nutrition leads to increased levels of disease and abnormal behavioural expressions, such as stereotypies (Fraser 2008). In addition, when native cattle breeds, such as Podolian, are outdoors, they are able to express most of their most relevant natural behaviours, albeit ingesting poor-quality forages while grazing on natural pastures (Braghieri et al. 2011a, b). The substitution of local native breeds with more selected animals may also represent a hazard to animal welfare as these animals are often more susceptible to infectious and production diseases (e.g. Ameni et al. 2007) with potentially higher levels of pharmaceuticals involved in the production process.

Napolitano et al. (2010) report that information about animal welfare is an important determinant of consumer willingness to pay (WTP) for various animal-based products. In addition, many producers certify their products with labels (e.g. Animal Welfare Approved, Humane Farm Animal Care, Neuland, Beter Leven) ensuring high standard for farm animal welfare along all the supply chain and receiving a financial reward for that. The indirect market valuation of this non-commodity output could be either performed assessing consumer WTP (de Groot et al. 2002) or evaluating the premium price for animal welfare-friendly products. In addition, the money saved could be quantified as a result of the reduction in veterinary interventions and therapy treatments.

3.4 Conservation of Biodiversity

As agriculture has intensified, biodiversity conservation depends primarily on areas with extensive management or on unfarmed features around the farm (e.g. uncultivated strips between crops, walls or hedges and farm tracks) providing food, shelter and breeding sites for birds, mammals and insects and the growing of native flowers and plants. Farmland biodiversity also includes the rich genetic diversity of local breeds of farm animals and varieties of crops well adapted to the soils, vegetation and climate of their region. In addition, natural ecosystems provide habitat to wild plants and animals contributing to the conservation of biological and genetic diversity acting as a "storehouse" of genetic information (de Groot et al. 2002). Livestock intensification, with high breeding selection, and the abandonment of marginal farmland caused a loss of biodiversity. On the contrary, autochthonous breeds can be strategic for adaptation to climate changes in terms of resistance to higher temperature and water scarcity, lower diet quality and disease sensitivity (Hoffmann 2010). Apart from wild ancestors, which for cattle are extinct, and few examples of feral populations (e.g. Hernandez et al. 1999), domestic herds kept in natural environments represent the main source of information about natural behaviour. Podolian cattle, one of the most direct descendants of the ancient wild bovine with a genetic relationship with similar breeds from the Balkans, Anatolia and the Middle East, may be considered a valid example of biodiversity preservation. In fact, they have been subjected to a lower selective pressure (artificial insemination has been rarely used) and a higher natural selection (animals kept in natural environments, where food search, avoidance of predators, maternal care, etc. were essential) as compared with other breeds (Napolitano et al. 2005). In addition, as Podolian cows exhibit a higher degree of adaptability to the local phytocoenosis (e.g. ingestion of ferns), they may also contribute to the preservation of crops biodiversity (Braghieri et al. 2011b). Livestock diet selection is a key issue as it can affect the sensory properties and the nutritional composition of animal-based products (Hadjigeorgiou et al. 2005) with positive consequences for human health and for the acquisition of characteristics closely related to the typical rearing environment. This aspect along with some specific genetic characteristics of the Podolian breed can positively influence the nutritional properties of meat (Braghieri et al. 2005; Costa et al. 2013), thus promoting local niche products that can provide higher financial returns for farmers and a wider rural economy.

A major potential driver for biodiversity conservation is represented by the payments to farmers and their communities. According to the new CAP, farmers, probably through a Rural Development Plan (RDP), should be rewarded for the services they deliver to the wider public, even though they have no market value. To this end, a new policy instrument has been introduced in the first pillar (greening) to promote the provision of environmental public goods: the green direct payment, which constitutes a major change in the policy framework. This accounts for 30 % of the national direct payment envelope and rewards farmers for respecting three obligatory agricultural practices, namely, maintenance of permanent grassland, ecological focus areas and crop diversification.

4 Concluding Remarks

An economic evaluation of all ecosystem services, non-marketable public goods and non-commodity outputs produced by free-ranging extensive systems, such as the Podolian farming system, should be indirectly estimated either by the avoided costs (e.g. reduced veterinary interventions and therapy treatments) or the lack of profits (e.g. direct payments for the enhancement of environmental performance) that would have incurred in their absence. These economic evaluations should be used in order to allocate them as further outputs to be included in the LCA in order to achieve a more accurate estimation of the impact of the Podolian farming system.

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Feeding, Nutrition and Sustainability in Dairy Enterprises: The Case of Mediterranean Buffaloes (*Bubalus bubalis*)

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Abstract Buffalo farming is a dairy enterprise emerging in Italy and other European and non-European countries due to the progressive saturation of the dairy market, which requires product diversification. As a response to the increasing demand for dairy buffalo products, most farms are undertaking a progressive intensification of rearing techniques. In particular, feeding rely on different rations according to the physiological stage of the animals. Buffalo heifers are generally offered a total mixed ration based on corn silage and ryegrass hay, which require high amounts of water, chemical fertilisers and fossil fuel. Additionally, lactating buffaloes receive concentrates with an even higher environmental impact, whereas more fibrous feeds are used in the dry period. Although the emission factors for enteric fermentation and manure management in buffaloes appear to be 38.4 % and 20.5 % less than in dairy cows, respectively, the contribution of dairy buffalo farms to global warming has been estimated as higher than that produced by dairy cow farms. Therefore, studies are needed to assess the general environmental impact of this species and identify alternative environmental friendly rearing techniques.

1 Introduction

The water buffalo (*Bubalis bubalis*) is a large bovid spread throughout the world, especially in Asia and in tropical and subtropical regions. The water buffalo population in the world is about 199 million, more than 80 % placed in Southeast

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_5

Table 1 Number of heads and milk production of buffaloes kept in the Mediterranean area

Countries	Head	Milk Ton
Albania	120	10
Bulgaria	9,212	8,081
Egypt	4,200,000	2,650,000
Germany	5,000	Unknown
Greece	1,750	160
Italy	402,659	192,455
Turkey	107,435	4,6989
Total	4,726,176	2,897,695

FAOSTAT (2013)

Asia (FAOSTAT 2013). According to genetic, morphological and productive differences, two types of water buffalo may be recognised: the *swamp buffalo*, from Assam in the west, through Southeast Asia to China in the east, used mostly as draft power and as a meat source, and the *river buffalo*, characterised by high milk yield and more intensive genetic selection, reared in Indian and Mediterranean regions. The total number of animals raised in Mediterranean area is about 4.7 million, representing 2.4 % of the world population. In Egypt there are 4.2 million buffaloes (Table 1), with a milk production of about 2.6 million ton (FAOSTAT 2013), that are mainly used for direct consumption as Egyptians prefers buffalo milk than cow milk for its stronger sensory properties despite the higher price (Helal and Lasheen 2008). European buffaloes, named *Mediterranean buffalo*, are all of the river type and are found in Italy, Romania, Bulgaria, Greece, Albania, Kosovo and Republic of Macedonia, and a few hundred in the United Kingdom, Germany, the Netherlands, Switzerland and Hungary (Table 1). Italian buffaloes are 402,000, with a milk production of about 192,000 tons (Table 1), processed into Mozzarella cheese. In Italy buffaloes were particularly selected and officially recognised as *Mediterranean Italian breed* in 2000. The largest amount of heads is concentrated in Campania (Caserta and Salerno), although many buffalo farms may be found in Latium (Latina and Frosinone provinces) and in Apulia.

The Italian buffalo herd increased to about 52 % from 2005 to 2013, due to the increasing economic interest for its typical cheese, called “Mozzarella di Bufala Campana”, which in 1996 was recognised by the Protected Designation of Origin (PDO), at European level. The average annual production of Mozzarella is about 37,000 t, mainly consumed in Italy. In recent years, other dairy products, such as ricotta and caciocavallo, have acquired the interest of consumers. The increasing demand of products of buffalo origin may be attributed to the progressive saturation of the dairy market, which requires product diversification.

The aim of the present chapter is to briefly describe the main features of modern buffalo farming techniques and identify weaknesses and strengths in terms of environmental sustainability.

2 Farming and Feeding Systems

The Italian buffalo farming system in Italy has changed from the extensive use of meadows and pastures to intensive farming, with loose housing (e.g. cubicles) and milking routine (machine milking twice a day) similar to dairy cattle.

As to reproduction, natural mating is still the most common practice. However, efforts by the National Association of Buffalo Breeders (ANASB) aim to spread the use of biotechnologies, such as artificial insemination and embryo transfer, for a more accurate and effective genetic improvement of the breed. At our latitudes, buffaloes can be considered seasonal animals and an increasing length of daylight negatively affects their reproductive performances. In fact, about 90 % of calvings are concentrated in late summer and at beginning of autumn. Consequently, the production of milk and mozzarella is concentrated in the cold months, while in Italy most of the market demand for mozzarella cheese is concentrated in summer. In order to reverse the calving season, the out-of-breeding-season-mating technique may be gradually introduced (Zicarelli 1997). It consists in removing bulls from the herd in October and releasing them again in the herd between March and the end of September so that most of parturitions occur between the end of January and the beginning of August.

The feeding system of dairy buffaloes is intensive and similar to dairy cow feeding. Most of farms are organised with three feeding rations, according to the buffalo physiological state: lactation period, dry period and heifer growth period. The forage ration used for the lactation phase and for heifer growth is usually based on farm production of corn silage. The forages are composed for 60 % by corn silage and ryegrass hay. The cultivation of 1 ha of maize for animal feed requires approximately 5,000 m^3 of water and about 300 kg of urea and 100 kg of P_2O_5 as fertilisers, with relevant consequences on water footprint and environmental impact. Ryegrass (*Lolium multiflorum* L.) for hay production is the crop commonly used in succession to corn in buffalo farming. The concentrates are largely used only during the lactation phase. The unifeed technique, which provides all the dietary components mixed together in one feed using mixing wagons, is widely adopted for buffalo feeding. Grazing practices are not widespread due to the poor availability of optimal pastures in terms of quantity and quality. However, a recent study has shown that grazing may be a valid alternative to intensive rearing systems for growing heifer (Fig. 1), with no significant effects on the age of puberty and with interesting cost savings and reduced environmental impact (Sabia et al. 2014).

The dry phase is characterised by a higher use of straw and the inversion of the ratio of calcium to phosphorus. The use of agricultural by-products is not very frequent. However, the inclusion of dried stoned olive pomace in a ration for lactating buffaloes did not produce any significant difference in terms of milk yield while improving some qualitative parameters (Terramoccia et al. 2013).

Fig. 1 Buffalo heifers grazing on a Mediterranean natural pasture

2.1 Feeding Behaviour

The dry matter intake of dairy buffaloes (16 kg DM/animal/day) is generally lower than that of dairy cattle (Terramoccia et al. 2005). However, these animals show a higher digestibility of protein and fibre as compared with cattle and sheep (Bartocci et al. 2005) with lower emissions in the environment. When kept on pasture, buffalo heifers show productive and reproductive performances similar to those shown by confined animals whose diet is based on mixed rations (Sabia et al. 2014). They eat a wide variety of plants, although they only occasionally ingest non-herbaceous plants; buffaloes are, therefore, considered grazers rather than browsers (Napolitano et al. 2007). The adaptation to a highly variable diet has also led to a high resistance to unbalanced diets, particularly in terms of protein excess; as a result, these animals are rarely affected by lameness of nutritional origin (Napolitano et al. 2013).

3 Nutritional Requirements of Dairy Buffaloes

The nutritional requirements of dairy buffaloes are influenced by several factors related, in particular, to the following three physiological stages: growing period (i.e. heifers), lactation period, dry period. In each phase, the identification of feeds with high nutrient digestibility could reduce the emissions resulting from enteric rumination and increase buffalo farming environmental sustainability (Sabia et al. 2015).

3.1 Lactating Phase

The standard lactation of buffalo cows is 270 days with an average milk production of about 2,200 kg. The peak of maximum production is reached at 50–60 days from calving. Nutritional needs are related to the output of buffalo cows during lactation. The dry matter content of buffalo milk (18.5 %) is much higher than that of cow milk (Claps et al. 2007) and in order to standardise milk production according to fat and protein contents, Di Palo (1992) developed a specific equation. Using this equation Proto (1993) observed that for the production of 1 kg of standardised buffalo milk, 0.44 Milk Forage Unit (MFU) are necessary. According to Zicarelli (1999), the energy content of the feed ration for lactating buffaloes may vary from 0.85 to 0.90 MFU/kg DM and the percentage of crude protein (CP) should be 14–15 %. In fact, this author suggests that 2.47 g of CP per 1 g of milk protein are acceptable levels for a balanced ration; while in early lactation, when the levels of dry matter intake are lower, this value should be increased by 10 % (Campanile et al. 1995).

3.2 Dry Phase

The dry phase is the period between the end of lactation and the subsequent calving. Although this phase may be considered unproductive by farmers, it is fundamental to obtain satisfactory productive performances in the subsequent lactation. During this period, buffaloes should be provided with a ration capable to fulfil both maintenance requirements and the requirements for an optimal foetal growth, which are particularly high in the last months of pregnancy. The requirements recommended by Proto (1993) for the dry phase of buffaloes are about 0.65 MFU/kg DM for energy and 10.5 % for CP. In addition, Terramoccia et al. (2005) suggested the use of fresh forages or hay with high biological value and the integration with at least 15 %/kg DM of concentrates. An appropriate ration for this phase should have a low rumen fermentation rate, which promotes the production of volatile fatty acids and improves the proliferation of cellulolytic bacteria. During this phase, a decrease of the absorption process with a drop in the rumen papillae activity is noticed.

3.3 Heifer Growth Phase

In many countries growing heifers are reared exclusively on very poor pasture and hay. However, this is not the proper approach from an economic and animal welfare point of view, as the heifer has to reach puberty in the best physical condition. Thus, in order to reduce their unproductive period, heifers have to be fed with proper diets, to obtain high daily gains, and anticipate sexual maturity, conception and first calving. However, the studies on the rearing systems to be used to increase growth rates and reduce the age of puberty of buffalo heifers achieved contrasting results. Borghese et al. (1997), when comparing various intensive rearing systems at different energy levels with a pasture system, found that heifers fed a total mixed ration showed an earlier age of puberty compared with grazing animals. Conversely, Terzano et al. (1996) observed that grazing heifers reached puberty earlier than animals fed corn silage ad libitum, although the latter showed a higher weight at puberty. Similarly, Sabia et al. (2014) found no significant differences in terms of age of puberty between buffalo heifers reared in intensive or extensive conditions, although the weights of puberty were higher in confined animals.

4 Sustainability of Dairy Buffalo Farming

Water buffaloes, like other ruminants, are very efficient as they are able to convert feed with low nutritional quality into products with higher nutritional values. However, the contribution of methane derived from ruminal fermentations to agriculturally greenhouse gas emissions (GHG) has led to increasing efforts to develop strategies for the reduction of ruminant methane production (Martin et al. 2010). According to the Kyoto Protocol (1997), 37 industrialised countries and the European Community, during the first commitment, agreed to reduce GHG emissions to an average of 5 % against 1,990 levels; during the second commitment period, parties agreed to reduce GHG emissions by at least 18 % below 1,990 levels in the 8-year period from 2013 to 2020. Livestock production is responsible for 8–10.8 % of GHG emissions as assessed by International Panel of Climate Changes (IPCC). In Italy, according to the report of the Institute for the Protection and Environmental Research (ISPRA), the emission factor for enteric fermentation in buffaloes appears to be 38.4 % less than the dairy cow, whereas for manure management the emission factor is 20.5 % less in buffaloes compared with dairy cows (Cóndor et al. 2008).

However, few studies have been conducted on environmental impact assessment of dairy buffalo farms. Recently, Pirlo et al. (2014) observed that the environmental impact of dairy buffalo farms, expressed in terms of global warming, was 5.07 kg of CO_2 eq per 1 kg of normalised buffalo milk. This value is nearly five times higher than that produced by dairy cow farms (O'Brien et al. 2012). This difference may be attributed to the fact that dairy buffalo farms require energy inputs for the production and the purchase of raw materials similar to those of dairy cows, but lower outputs in terms of milk production can be obtained. Another aspect of buffalo farming with a potentially high environmental impact is manure management. Faugno et al. (2012) found that buffalo manure has less nitrogen content than dairy cow manure. In addition, they suggested that immediate incorporation is the best technique of manure spreading in terms of sustainability, albeit more expensive. Martiniello et al. (2010) observed that the use of buffaloes manure increases dry matter yield of forage crops compared to traditional management as the carbon–nitrogen ratio in buffalo manure is able to promote biomass production.

Sabia et al. (2014) suggested that the use of an extensive system based on grazing for some unproductive phases of animal rearing (e.g. heifer growth) could reduce the environmental impact of dairy buffalo farms. In particular, free-ranging animals benefit from forages directly taken from pasture, thus potentially decreasing the emission of pollutants contributing to global warming, acidification and eutrophication potential, while also reducing non-renewable energy use. A further beneficial effect of buffalo heifer free-ranging system is the marked reduction in consumption of feed potentially edible by humans, as most of the plants growing in natural pastures are not directly usable in human nutrition. Obviously, buffalo heifer free-ranging system requires a higher level of land occupation. However, for marginal natural pastures there are no uses other than breeding of local ruminant species, which also implies a higher level of quality in land use (e.g. biodiversity conservation, animal welfare).

5 Conclusion

Buffalo farming is an emerging enterprise in Italy and other European and non-European countries in a dairy market progressively becoming saturated. Therefore, further studies are needed to assess the environmental impact of this species and identify alternative environmental friendly rearing techniques.

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Sustainability of Sheep and Goat Production Systems

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Abstract Sustainability of sheep and goat production systems has been investigated in this chapter in terms of environmental, social, and economic sustainability. Strategies to reduce waste from animal husbandry activities and the negative impact of animal husbandry on environment have been described. Social sustainability has been analyzed in relation to animal welfare and human–animal relationship. Economic sustainability of sheep and goat production systems in the Mediterranean countries has been addressed in terms of animal management plans to improve animal health, quality of products, and increase profitability of animal production systems. In particular, strategies to change the basic standard for sheep and goat productions into high standard of nutritional, hygienic, and technological quality have been analyzed.

1 Introduction

Sustainable development aims to meet human needs by preserving the natural environment so that these needs can be met both in the present and in the future (Peacock and Sherman 2010). The field of sustainable development can be divided into three concepts: environmental, social, and economic sustainability.

Environmental sustainability is linked to energy use, biodiversity and genetic conservation, and environmental management; when applied to farm animals, environmental sustainability is associated to the negative impact of husbandry on air, soil, and water pollution. Waste from animal husbandry comprises fecal and urinary output, and production of fermentation and respiration gases, such as carbon dioxide (CO_2) and methane (CH_4). In the waste usually high amounts of water, nitrogen (N), and other inorganic molecules are found.

The link between animal production and natural environment is acquiring more importance for the sustainability of the farm system (de Rancourt et al. 2006).

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_6

Consumer concerns about the quality and sustainability, including ethical aspects, of the production cycle of animal food products is increasing. Social sustainability concerns politics, social institution, culture, tradition, and civil society. In this chapter social sustainability is discussed as animal welfare and human–animal relationship. In particular, the concerns about life quality of farm animal in relation to human–animal relationship to optimize animal production are presented.

In the Mediterranean area small ruminant farming systems represent one of the most important agricultural activity connected to the utilization of marginal lands, with prevalence of pastoral system, low level of mechanization, and production of typical products, mainly cheeses. Although small ruminant farming systems are largely diffused in all the Mediterranean countries, the level of animal management is far from an acceptable level of animal health, quality of products, and profitability.

1.1 Environmental Sustainability of Sheep and Goat Production System

Ruminant livestock produce about 80 million tons of methane (CH_4) accounting for about 28 % of anthropomorphic emissions each year (Beauchemin et al. 2008). CH_4 is physiologically produced as a by-product of digestion; at farm level CH_4 is emitted both from direct ruminant fermentation and from manure. Methane production by ruminants is influenced by animal size, dry matter intake, carbohydrates, and other components of the diet (Wilkerson et al. 1994). The increasing level of concentrate in the diet of ruminants causes changes in the fermented substrate from fiber to starch and a decline in ruminant pH with a reduction of the proportion of dietary energy converted to CH_4. However, the increased level of concentrate in ruminant diet should be limited at 50 % of the diet to avoid negative effects on milk quality. A number of nutritional management strategies to reduce enteric CH_4 production have been reported, among which are increasing the level of grain and lipids, and supplementation with ionophores in the diet. Furthermore, a number of feeding strategies to reduce CH_4 emissions in animal production systems have been proposed, such as feeding maize and cereal silages instead of grass silage, improved pasture management, inclusion of legumes, yeast and enzyme, feed additives, or plants characterized by secondary compounds with potential CH_4 suppressing properties (Beauchemin et al. 2008).

Nitrogen losses originate mainly from the imbalance and the asynchrony between the rate at which carbohydrates and proteins are degraded at rumen level (Tamminga 1996). The imbalance between the simultaneous availability of net energy and amino acids in the rumen is the main cause for NH_3 ruminal losses; ammonia, after its conversion into urea in the liver, is found in blood and milk, and is excreted in urine. Apart from the contradictory results on the relationship between CP level of diet and milk yield and composition, the concentration of urea in the milk is always regarded as a good indicator of efficient use of dietary protein by the animals, and it is currently used to evaluate and to adjust the diet (Cannas 2002). The efficiency of dietary N utilization for milk protein synthesis is rather low in dairy sheep and goat (15–35 %) (NRC 1988), and the use of high protein level diets for sustaining milk production in lactating animals is widely studied. High protein level diet can result in a number of deleterious events: reducing environmental sustainability of sheep and goat farming, causing an increase of N output to the environment, and high levels of ammonia pollution in animal houses, which originates from animals' urine and feces and can be injurious to both livestock and stock persons' health. An increased N excretion in urine and feces, as a consequence of poor dietary N absorption, can result also in high growth of microorganisms. Sevi et al. (1999, 2006) suggest that the efficiency of utilization of dietary N in the lactating ewe increases with decreasing protein levels in the diet from 16 to 13 %, especially when limiting amino acids (lysine and methionine) in the ration are encapsulated to prevent bacterial deamination in the rumen. Sheep fed with a moderate protein level excrete more N than sheep fed with low protein level of the diet. On the contrary, the low protein level of the diet results in lower amount of feces, in less wet feces, and in higher NH_3 release in the urine. The choice of a proper ventilation regimen in small ruminant housing is critical for the control of environment and for removing aerial pollutants, which originate from animals and their excreta. In particular, low ventilation rates can fail in removing efficiently the moisture and gases, which originate from the respiratory activity of animals and the decomposition and fermentation of manure, resulting in increased relative humidity and higher air concentrations of ammonia and carbon dioxide. Very high ventilation rates, instead, can result in higher air dust concentrations, probably due to reduced humidity levels and to turbulent air currents maintaining dust particles suspended in the air for a longer time. Ventilation rate is based on the length of ventilation cycles and on air speed. During summer, dairy sheep need an average ventilation rate of about 65 m^3/h/head achieved by giving most ventilation cycles during the hottest hours of the day (Sevi et al. 2002, 2003b). However, also overnight air exchange for removing gases, mostly ammonia, originated from excreta decomposition and fermentation are of great importance. Furthermore, combining a moderate protein level of the diet (16 %) with low ventilation rates result in excretion of 40–64 % of higher volumes of urine and 40–79 % greater amounts of total water.

Litter management by using paraformaldehyde and bentonite is an effective strategy for reducing emissions from manure. Paraformaldehyde is a polyoxymethylene containing 90 to 98 % formaldehyde, which has a recognized bacteriostatic effect on the microorganisms naturally present in droppings. Litter treatment with paraformaldehyde was shown to influence milk hygienic quality reducing somatic cell count and microbial cell load of 10 and 15 %, respectively. The use of paraformaldehyde for litter disinfection markedly increased protein (10 %) and fat (20 %) content in sheep milk with a consequent improvement of milk coagulation performance. Addition of paraformaldehyde to the bedding is a procedure that may be applied at intervals suitably far apart to be not economically prohibitive. Its use, however, would remain limited to circumstances in which there are difficulties in processing or marketing milk of low hygienic quality which could not be easily resolved using other cheaper methods (Sevi et al. 2000). In a subsequent study (Sevi et al. 2003a), the effects of litter renewal intervals on the yield and quality of ewe milk were evaluated as an alternative strategy to litter treatment with antimicrobial products. Bentonite has been used to reduce the levels of airborne particulates in livestock housing and improve the hygienic quality of ewe milk. Bentonite is mainly composed of clay minerals and has a high water-absorbing capacity. It is relatively inexpensive and there are no reports of it having adverse effects on the health of either ewes or people. Litter renewal of litter at 4 weeks intervals can sustain health status of the mammary gland and improve ewe performance at the same levels as litter treatment with bentonite.

1.2 Livestock Sustainability: Human–Animal Relationship and Sheep and Goat Welfare

During the second half of the 20th Century, in the industrialized nations, production of meat increased; the increase regarded mainly poultry and pig production systems fed on grain and concentrated diets. The increase was less pronounced in sheep and goat production. In the developing countries production of bovine meat and sheep and goat meat increased more than threefold from 1961 to 2001 (Fraser 2008). The increased production was characterized by an increase in the number of animals and in a reduced number of farms rather than in an increase in the number of farms. In the industrialized countries, these events coincided with a cultural change in the way of looking at farm animal particularly on confinement production system. Such concern was addressed to preserve animal welfare by a scientific approach to the matter. In intensive production systems of sheep and goats, a number of researches have been conducted to define technical parameters in animal housing to control their impact on animal welfare and production (Sevi et al. 2009). Stocking density is a critical factor in sheep and goat housing because space allocation is known to affect both the performance and welfare of livestock. Space allowance reduction from 2 to 1 m^2/head showed interesting effects on feeding behavior in goats. In horned goats, a reduction of feeding activity and of resting time is found; a slighter reduction of the same parameters in goats without horns is observed (Loretz et al. 2004). In ewes confined in a space allowance of 1.5 m^2/head, a reduced humoral immune response is observed compared with ewes housed at a space allowance of 3 m^2/head. Furthermore, ewes that have free access to an outdoor area display an increased cell mediated immune response compared with ewes enclosed indoor (Caroprese et al. 2009).

Among structural housing parameters in sheep and goat buildings, inadequate airspace may be a limitation to high efficiency of production and good health in farmed livestock. This could be of practical interest when sheep are raised in warm climates and do not benefit from efficient ventilation system. Ventilation regimen, indeed, has a main role in sustaining the welfare by affecting thermal exchanges between the animal's body surface. With a pending high heat load situation, a moderate ventilation rate (65 m^3/h per ewe) improves the well-being of the lactating ewe compared to a low ventilation rate (35 m^3/h per ewe), as suggested by behavioral, endocrine, and immune indicators. Under such conditions, a fan ventilation system, programmed to operate over upper critical air temperature (30 °C) and relative humidity (70 %), has been proved to be economically unattractive, because it involves about a threefold greater energy cost and does not lead to remarkable improvements of ewe welfare and productivity compared to a moderate ventilation regimen (65 m^3/h per ewe) (Sevi et al. 2002). Under heat stress, feed intake decreases especially when sheep are fed on low quality feed due to both the effort of reducing heat production and the slower feed transit through the digestive tract (Costa et al. 1992). Feed administration in late afternoon is beneficial in minimizing the impact of thermal stress on ewes' immune function and udder health (Sevi et al. 2001a).

One of the main factors in influencing the welfare of an animal is the quality of the human–animal relationship. A poor human–animal relationship can lead to chronic fear of humans and to handling difficulties, injury, and stress and, as a consequence to impaired growth, reproductive performance, and product quality (Hemsworth and Coleman 1998; Jones 1997). The nature and frequency of the relationship are different in sheep and goat farming system according to the management system, i.e., shepherding, intensive system, extensive systems. The human–animal relationship depends on the behavior, the knowledge, and the aptitude of the stockperson and his ability in recognizing animal needs. Frequent interaction between the animal and the stockman with repeated animal manipulation is a potential stress factor for sheep and goats. It is considered that sheep and goats are rustic animals; as a consequence, usually stockman handle them roughly, especially those with less experience or aptitude. On the contrary, it is well known that small ruminants have ancestral predatory fear, a gregarious nature, and a difficulty of adaptation to unfamiliar environments and integration with unknown groups. As a result, sheep and goat suffer if handling is excessive or inappropriate when rearing practices change suddenly or when regrouping and relocation occur suddenly or frequently (Sevi et al. 2001b). In lactating ewes, member exchange among groups increases aggression and altered immune response; also relocation results in a reduced immune response. An useful tool to minimize the stress related to artificial rearing is gentling, a friendly approach of the stockman towards the newborn animal. Several studies have highlighted that gentling strongly encourages the lamb and the kid reared without their mothers to positively interact with the stockman, whereas gentling has no beneficial effects on dam-reared animals. In artificially reared lambs, gentling improves their immune reactivity, making it comparable to that of dam-suckled lambs and reduced their plasma cortisol responses to handling (Caroprese et al. 2006). The genetic predisposition may play an important role in building positive human–animal relationship, and lamb gentling results in an improvement in the quality of human–animal relationship particularly in more reactive breeds. In particular, breeds that are more sensitive to disturbance by human handling more promptly build a positive relationship with humans possible because a higher disturbance generates a need to be reassured through social support (Caropresse et al. 2012).

The results obtained from these and other studies were used to regulate, manly in the European Union, a number of laws regarding production systems, transport, and slaughter of sheep and goat reinforced by EU directives. More recent evolution focused on voluntary certification of animal welfare to achieve standard of production recognized by retails and suppliers.

1.3 Economic Perspectives of Sustainable Sheep and Goat Farming

In the last 30 years, a progressive decline of the traditional pastoral system based on transhumance has been observed (Manrique et al. 1996). As a consequence of the decrease in rural populations and in traditional farming systems, sheep and goat livestock systems need to be changed to improve animal welfare, and to increase the animal productive efficiency, and food quality with particular regard to food safety (Gibon et al. 1999; Ronchi and Nardone 2003).

The reduction of veterinary costs linked to the enhanced animal health status and the increase of biological efficiency in terms of quantity and quality of milk and meat production can be considered as the strategies to improve the economic profits of a sustainable sheep and goat production. Veterinary and particularly parasitic diseases are one of the most important issues affecting health management in extensive small ruminant breeding being responsible of productivity losses. Infections can be considered deleterious for sheep and goat welfare and productivity, increasing mortality, management costs, and requirements for the use of anthelmintics. A sanitary program aiming to reduction of drugs requires high standard of welfare of animals and adequate management practices to improve farmers' income.

The need for increasing flock profits conforming to the quality standards is dependent on husbandry systems aiming to improve small ruminant welfare and health animal status. Extensive farming has proved to be beneficial to the welfare needs of lactating ewes but exposure to climatic extremes and seasonal fluctuations of pasture can threaten the welfare of extensively managed flocks. The gradual diffusion of semi-intensive husbandry systems led to the increase in highly productive dairy breeds. In this perspective, the maintenance of high standard of welfare of animals can markedly improve their biological efficiency. Under more intensive farming conditions, sheep and goats' welfare is influenced by the micro-environment control, the choice of proper housing, and building conditions to avoid crowding, aggressive behavior, increased ambient pollution, and poor animal health.

Farm management and health status of sheep and goat are mainly responsible for the quality of animal-based food products. Sheep and goat husbandry is strictly associated with rural societies contributing to the manufacture of local typical products which are expression of the regional cultural tradition.

Although products from small ruminants are intended to be free of chemical contaminants, the basic standard for sheep and goat productions lack high standard of nutritional, hygienic, and technological quality. Milk must have a desirable chemical composition and must be of satisfactory hygienic quality. This is essential in relation to public health, the suitability of milk for processing, and the quality of milk products. The health of the udder can have a profound effect on the quality and processing characteristics of milk. The most widely used indicator of udder health is somatic cell count (SCC), a measure of the number of white blood cells, known as leucocytes in milk. An elevated SCC usually indicates the presence of mastitis. Mastitis is caused by pathogenic bacteria entering the mammary gland via the teat canal and multiplying within the udder sinuses or epithelia or in the teat duct. Mammary inflammation during mastitis causes a range of physical, microbiological, and chemical changes in milk. The microorganisms found in raw milk may come from several sources: organisms from the udder, the environment (e.g., water, soil), milking equipment, bulk milk storage tank, tank in processing plant (Fajardo-Lira and Nielsen 1998).

In the Mediterranean area, due to the reproductive seasonality of sheep, ewes are usually in their later stage of lactation in late spring and summer. Lactation is thus often shortened given that dairy factories stop collecting milk from farms since it is produced in smaller amounts and its coagulating behavior is deteriorated. Indeed, a number of events can occur in summer, which have a deleterious effect on coagulating properties of sheep milk and, namely, (1) the use of fat and nitrogen reserves to supply energy through gluconeogenesis at the expense of the mammary gland (Amaral-Phillips et al. 1993), (2) a plasma mineral imbalance, especially due to a reduction in sodium, potassium, calcium, and phosphorus and to an increase in chloride concentrations (Kume et al. 1987), (3) an increased milk pH, due to high amounts of CO_2 dissipated via the panting (Habeeb et al. 1992), (4) an increased plasmin (PL) activity, the main endogenous proteinase in milk (Bianchi et al. 2004), (5) an increased bacterial load in milk, due to enhanced multiplication and growth of microorganisms in the litter (Sevi et al. 2001a). A worsening in milk coagulating behavior in ewes reared in pens without shading areas and receiving feed during the warmest part of the day has been observed (Sevi et al. 2001a). Under moderate heat stress, also a low ventilation rate has deleterious effects on milk yield and on clotting properties of milk (Sevi et al. 2003c). When collected for cheese making, the bulk milk from ewes in less ventilated houses has higher microbial load and somatic cell count compared to milk from ewes in more ventilated houses. As a result, a weaker caseous matrix of the curd releasing higher concentration of fat and protein in the whey was observed (Albenzio et al. 2005).

Profitability of dairy farms largely depends on milk casein content and milk hygienic quality in terms of pathogen, spoilage bacteria, and somatic cell count, giving that sheep and goat milk is almost totally destined for cheese making as raw milk. Milk yield and casein content increased to around 10 %, as well as the coagulation properties of milk (+8 %) when ewes are housed with a space allocation of 2 m^2 per animal (Sevi et al. 1999). A stocking density of 1 m^2 per ewe has deleterious effects on the hygienic quality of milk. Higher levels of airborne microorganisms also affected the mammary system of the animals with higher microbial cell loads and somatic cell counts being recorded in milk from ewes housed under high stocking density conditions. Milk produced by high densely stocked ewes, which are housed on a straw litter treated with bentonite, displayed lower concentrations of bacteria in their milk together with lower airborne microorganism loads. An increase of milk yield (3 %), of milk fat (10 %) and casein content (5 %), and of milk clotting time (8 %) was recorded. When no litter treatment is used, higher SCC (+40 %) was found in milk due to greater bacterial colonization of the udder. Adequate airspace allocation of 7 m^3/animal leads to increase in milk yield (20 %) and milk casein content (10 %) and improves renneting ability and hygienic quality of milk mainly in terms of somatic cell count (−10 %) (Sevi et al. 2001c).

Protein supplementation in grazing dairy ewes is a popular strategy for upgrading sheep nutrition in order to reduce the variability and improve ewe milk yield and composition. Feeding strategies together with several other management practices may improve the overall quality of milk for cheese making. Bulk milk produced by the ewes receiving a low crude protein diet (13 %) displayed higher casein (10 %) and low urea contents (−20 %). Therefore, the choice of a proper dietary crude protein level plays a main role in sustaining protein synthesis in the mammary gland (Sevi et al. 2006). The use of appropriate supplements in the diet of small ruminants can succeed in improving the nutritional features of animal-based food. This goal besides adding functional properties to animal-based food can meet the recently growing consumer demand both for quality food products and more ethical food production. Adequate supplementations in the diet of sheep and goat have been proved to sustain their welfare during stressful conditions such as thermal stress, the transition period. The use of flaxseed in the diet of lactating ewes under heat stress succeeds in increasing milk yield and ameliorating nutritional milk composition particularly in terms of milk fatty acid profile (Caroprese et al. 2011).

Lamb meat is valuable from a nutritional point of view for its high CLA content which can exert positive effects on human health (Schmid et al. 2006). The proportion of saturated and unsaturated fatty acid in meat from lambs subjected to different regimes highlights a better fatty acid profile in meat from artificially reared lambs from a nutritional and health promoting point of view. In particular, unsaturated fatty acids are considered hypolipidemic by reducing both plasma cholesterol and triglycerides, and a low intake of saturated fat as well as an increased polyunsaturated to saturated fatty acid ratio are associated with a lower risk of human coronary heart disease (Oriani et al. 2005). The addition of probiotics to milk replacer play a role in modulating the health status of lambs. Meat from artificially reared lamb fed milk replacer containing probiotic showed an improved fatty acid profile for human diet, in terms of higher CLA and lower SFA content (Santillo et al. 2011).

2 Conclusions

Human induced climate changes, and subsequent global warming, are involving also European countries located within the temperate zone. As a result, the importance of sheep and goat farming is expected to increase gradually in comparison with cattle farming in both rural and industrialized countries. In fact, sheep and goats are more tolerant to climate extremes, in terms of production, reproduction, and resistance to diseases, and less competitive with humans for crops and grains than cattle. So that the role that sheep and goat farming are about to play is achieved in a fully sustainable way; the effort of research and the production world is invoked. It must aim to find feeding strategies and management practices for reducing emissions from sheep and goat farming, to identify dimensional and physical parameters, and management practices for sustaining flock welfare, and to raise the profitability of sheep and goat farming by reducing the impact of veterinary costs and increasing the commercial value of sheep and goat products.

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The Role of Local Sheep and Goat Breeds and Their Products as a Tool for Sustainability and Safeguard of the Mediterranean Environment

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Abstract This chapter is a survey of recent studies on native sheep and goat breeds with special emphasis on their role as a tool of sustainability. After a short overview, strategies for adding value to the local breeds are described together with a synthesis of measures in support of animal biodiversity in marginal areas of Mediterranean environment. In this direction, three case studies are reported in which the added value of local breeds arising from a typical and/or traditional product is investigated. The first one is on native sheep breeds from Apulian region and the PDO *Canestrato Pugliese* cheese, and it indicates that *Altamurana* and Apulian Merino breeds produce milk and cheese having nutritional characteristics and sensory properties distinguishable from non-native breeds. The second and third studies regard local goat breeds and local cheeses, *Caciotta* and *Ricotta* cheeses. As it appears from our discussion, *Girgentana* breed produces milk and *Caciotta* and *Ricotta* cheeses with distinguishable fatty acid profile, nutritional index and sensory properties compared to other breeds. These peculiarities add value to the *Girgentana* breed and therefore give a support in favour of this breed, amplifying its sustainable use. Finally, we point out that the high quantity of sialyloligosaccharides found in local *Garganica* breed compared to foreign breed appears as an interesting promising feature in the study of adding value to local breeds.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_7

1 Sheep and Goat Breeds, a Tool for Sustainability

More than two decades have passed since the principle of sustainable development received nearly universal agreement at the 1992 Earth Summit after its definition by FAO (FAO 1989).

The sustainability shows multi-dimensional structure embracing survival, resilience and efficiency, and it relies on three pillars described as the economic, environmental and social factors. The usual representation of this multi-dimensional structure is by the Venn diagram in which sustainability is represented as the set intersection of three sets, namely economic resilience, environmental integrity and social well-being. This is to be integrated with the good governance (FAO 2014), which is the fourth dimension of sustainability.

In a Mediterranean environment, the descriptors of Sustainable agriculture are numerous and interconnected. The main descriptors of the economic factor include the use of local breeds, disease resistance, forage self-sufficiency, forage quality, milk and cheese quality, typical and/or traditional products, environmental labelling, direct sales and eco-agritourism. Those of the environmental factor include biodiversity in terms of plants, animal breeds and habitat, landscape and its visual value, as well as, fire risk and the use of abandoned biomass, GHG emission and carbon sequestration. The social factor focuses on those aspects which are linked to the farmers (age, dignity, interests and future possibilities) and animal welfare (Lombardi 2005; Battaglini et al. 2014).

In this context, local breeds appear to be the major component of animal farm biodiversity, thanks to their excellent adaptation to specific environmental conditions. Furthermore, local breeds are linked to traditional products of special qualities and to several practices that are part of cultural heritage. Therefore, every effort to add value to local breeds is important, especially as a contribution to the prospects of their conservation through sustainable use.

As recently suggested by Papachristoforou et al. (2013), the available strategies to increase the value of local breeds with special attention on sheep and goats can be grouped into three interconnected categories: (1) linking local breeds to traditional products and/or to tourism/agritourism activity; (2) promoting the use of local breeds in specific farming systems like organic production, through the conservation of grazing/silvo-pastoral systems, small low-input farms and hobby farms; (3) general strategies like marketing, legislation, organisation of stakeholders and raising public awareness.

Local breeds, less frequently used in intensive systems but still preserved in situ in marginal territories, represent an important resource for maintaining animal biodiversity (Oldenbroek 2007). In marginal areas of Italy, the most important livestock activity is represented by the rearing of local breeds in connection with local tradition. In Italy, there is a population of about 7,874,108 sheep and 960,950 goats, and about 65.8 % and 69.5 % of these populations are distributed in Southern Italy, respectively (ISTAT 2009).

In Southern Italy, sheep and goat flocks are located in the marginal areas, in hilly rocky, shrub lands and mountain areas, where the production is based on the utilisation of natural pasture with a low stocking rate per hectare. In the extensive rearing system, the daily milk yield and its composition are strongly affected by annual and seasonal variation of feed availability. Especially in the mountains, herbage availability is often low but its quality is high (Rivoira 1976). At the same time, this rearing technique guarantees high ecosystem sustainability, improving the role of agriculture in the environmental preservation as well as the maintenance of rural areas, providing a means to enhance the value of family labour (Morand-Fehr and Boyazoglu 1999; Sepe et al. 2011).

The endurance of rural human population in less favoured areas assures the safeguard and survival of biodiversity, which can then be transferred to locally made "typical" products. A "typical" product is a result of several factors including raw material, transformation process and sensory characteristics. All these peculiarities are closely related to the geographical origin and to the social and cultural traditions of the production area (Scintu and Piredda 2007). In this respect, it is strategic to support the multi-purpose sheep and goat breeds still existing in the Mediterranean and marginal area of Southern Italy.

The *Altamurana* and *Gentile di Puglia* (Apulian Merino) sheep breeds, native of Apulia region (Table 1), and *Jonica* and *Girgentana* goat breeds (Table 3) are maintained in nucleus form in CRA-ZOE (Consiglio per la Ricerca e la sperimentazione in Agricoltura—Unità di ricerca per la Zootecnia Estensiva), in Basilicata region, both for research purposes and preservation of these endangered breeds.

In the past, the milk from these two sheep breeds (especially *Altamurana*) was used for the production of *Canestrato Pugliese* cheese. At this time, endorsed by the Status of protected Designation of Origin (PDO, CE Reg, n. 1107/96) and produced in Bari and Foggia provinces, the ripened *Canestrato Pugliese* cheese has almost entirely been made with milk of *Comisana* and *Sarda* sheep breeds both non-native of Apulian region (Table 1).

Concerning the caprino cheeses, *Caciotta* cheese is one of the several innovative products available in Southern Italy, made with goat milk and ripened for 20–30 days. On the other side, *Ricotta* cheese is a soft cheese and it appears to be the oldest and the best known whey cheese made mainly with goat milk.

The special, and often superior, characteristics of local breeds compared to non-native breeds in their native environment provide the basis for promoting their use in several production systems that guarantee the sustainability of resources and the quality of products.

In this context, we focus on the relationship between animal biodiversity and production quality, in terms of gross composition, fatty acid (FA) profile, volatile organic compounds (VOCs) and sensory properties in milk and "typical" and local cheeses obtained from native and non-native sheep and goat breeds.

Cheese characteristics and their differentiation are affected by quantitative and qualitative presence of FA in raw milk (Kim Ha and Lindsay 1993; Buchin et al. 1998). The different classes of fatty acids (saturated, unsaturated), single

Table 1 Sheep breeds

Sheep breed—L.G.	Population size (heads)[a]	Diffusion areas in Italy[b]	Prolificacy (%)	Fertility (%)	Lamb at 90 days (kg)	Wool (kg)	Lactation (days)	Lactation yield[c] (kg)	Fat[d] %	Protein[d] %
Altamurana	847	Puglia	112	90	21	–	100	78 ± 21[e]	8.10	6.78
Comisana	44,669	South, Centre, North Italy	180	95	22	–	200	159 ± 48[e]	7.13	6.32
Gentile di Puglia (Apulian Merino)	6,800	Puglia, Molise, Basilicata, Abruzzo	120	90	22	5.5 ♀ 7.5 ♂	180	90 ± 10	8.13	7.07
Sarda	441,427	Sardegna, Centre and South Italy	110–150	96	10.5 (30 days)	–	150–200	173 ± 51[e]	6.91	6.16

L.G. Genealogical book
[a]Registered heads, June 2014, ASSONAPA
[b]In order of population size
[c]Multiparous ewe
[d]Claps et al. (2008)
[e]Italy: Milk recording activity, official statistics, AIA (2013)

fatty acids (conjugated linoleic acid and alpha-linolenic acid) and lipids (cholesterol) are of particular interest and may affect consumers' health (McGuire and McGuire 2000).

Milk fat is an essential prerequisite to flavour development (Marilley and Casey 2004). The triglyceride structure can affect the flavour of the cheese produced when pregastric lipases are used in cheesemaking (Kim Ha and Lindsay 1993). It is known that the development of goat milk flavour is due to volatile branched chain fatty acids but also to the structure of triglycerides and to the lipolytic action of the milk lipoprotein lipase (Chilliard et al. 2003). The volatile flavour compounds in cheese originate during ripening mainly from lipid degradation and they are determinants in the flavour of traditional sheep and goat cheeses. The flavour intensity is closely related to short- and medium-chain free FA content of products (Fernández-García et al. 2006). Large differences in texture and taste were observed among cheeses issued from milk differing by the genetic variant of αs1-casein in goats (Coulon et al. 2004). Recently, many studies have focused on the relationships among FA profile (Di Trana et al. 2004, 2005; Addis et al. 2005; Bonanno et al. 2013), volatile organic compounds (Claps et al. 2010), polyphenols content (Di Trana et al. 2014b) of milk and dairy products and different forages or natural pasture ingested by small ruminants. These studies showed that it may be possible to categorise the type of forage or feeding system (grazing or stable) utilised by sheep and goats.

Having positively tested in milk and its derivatives, the possibility of transferring, directly or indirectly, some of the constituents from diet to dairy products shows that such a transfer is an important tool of traceability. These results amplify and strengthen the mutual relationship among plant biodiversity, grazing system and nutraceutical properties of dairy products from small ruminants. Interconnection and overlapping between local know-how and scientific knowledge of all elements and/or factors related to the animal and to the environment enforce the sustainability and safeguard the Mediterranean system.

It should be stressed that the new system must be innovative and not a sort of reshuffle of old traditional systems so that the research can act as a powerful tool to add value to native breeds by creating new knowledge and providing scientific evidence on particular biological characteristics. Participation of local breeders and incorporation of scientific knowledge from several disciplines are further important tools (Dubeuf 2014).

Political strategies and European legislation can be adopted to support directly and/or indirectly local farm and native breeds. Regarding the future, the new CAP (2014–2020) draws up measures, on a European basis, supporting mountain and Mediterranean areas and environmental sustainability. In particular, in the second pillar (rural development), resources are assigned for the implementation of regional programmes in the animal biodiversity sector Reg. 1305/2013. These guidelines on a domestic basis are implemented by Mipaaf (Ministry of Agriculture and Forestry), and the regions draw up tools such as the rural development plan (RDP) on seeking their realisation.

In our discussion on the role of native sheep and goat breeds and their products, as a tool for sustainability, we have focused our attention on four sheep breeds and four goat breeds: two endangered native sheep breeds (*Altamurana* and Apulian Merino) and goat breeds (*Jonica* and *Girgentana*) from Southern Italy and two non-native breeds, *Comisana* and *Sarda* sheep breeds, and *Maltese* and Red Syrian goat breeds, respectively.

2 Sheep Breeds and *Canestrato Pugliese* Cheese

In this section, we report an example that can be considered a case study. The study was carried out at the CRA-ZOE experimental farm of Foggia (41°27′N; 15°33′E), located at 76 m a.s.l in the Apulia region (Southern Italy). The maximum and minimum environmental temperatures and relative humidity during the different seasons were 23 °C, 11 °C and 68 % in spring, 30 °C, 17 °C and 64 % in summer, 19 °C, 9 °C and 76 % in autumn and 13 °C, 3 °C and 78 % in winter. The average annual rainfall was 391 mm, mainly occurred in autumn. Temperature humidity indexes were 64, 78, 68 and 57.5 in spring, summer, autumn and winter, respectively. The botanical composition of native pasture included 18.9 % *Graminaceae*, 12 % *Leguminosae*, 13.5 % *Compositae*, 11.2 % *Labiatae*, 0.3 % *Caryophyllaceae* and other botanical families being represented in lower percentage.

A flock set-up of four breeds of mature sheep was used. In order to compare local and non-native breeds, the flock was set-up with two native breeds, *Altamurana* (A) and *Gentile di Puglia* (Apulian Merino) (G), and two non-native breeds, *Comisana* (C) and *Sarda* (S), the most important Mediterranean sheep breeds and native of Sicily and Sardinia regions, respectively (Table 1). All animals were homogeneous for days in milk (75 ± 11 DIM) and body condition score (2.75). The flock grazed on native pasture during the day and was housed in shaded open pens during the night. All sheep were supplemented with 0.6 kg/day of concentrate in two equal meals at milking.

2.1 Canestrato Pugliese Cheesemaking, Sampling and Analysis of Milk and Cheese

Three cheesemakings of *Canestrato Pugliese* were carried out for each breed in CRA-ZOE's experimental dairy for three consecutive days.

Canestrato Pugliese Cheese

Italian Pecorino, uncooked hard cheese, recognised with Protected Designation of Origin: it is produced in Bari and Foggia provinces (Apulia region) exclusively from raw, but also thermised or pasteurised, whole sheep milk. The cheese derived its name and traditional shape from the rush basket "Canestro", in which the curd is ripened. During ripening, usually the rind is rubbed with a mixture of oil and vinegar. The cheese has a cylindrical shape, 10–14 cm height, 25–34 cm in diameter, and weighs 7–14 kg (PDO, CE Reg. n. 1107/96). Paste is pale yellow coloured, more or less intense depending on age; compact texture, somewhat crumbly, poorly melting, not very elastic, with just visible eyes; characteristic spicy taste fairly marked.

The flowchart of *Canestrato Pugliese* cheese manufacture is shown in Fig. 1. Cheese was ripened for 6 months in a natural cave at CRA-ZOE of Bella.

Milk samples were collected at milking time, and cheese samples were obtained at the end of the ripening period. Milk and cheese samples were analysed for pH, chemical composition and fatty acid (FA) content. Volatile Organic Compounds (VOC) and sensory profile were evaluated on cheeses. Basic chemical composition was measured according to standard methods as previously reported (Pizzillo et al. 2005). FA separation and quantification was carried out using a gas chromatograph as reported by Di Trana et al. (2004). The Health-Promoting Index (HPI) was calculated as the ratio between the unsaturated FAs content and lauric acid, palmitic acid and 4 x miristic acid contents (Chen et al. 2004). VOC content was assessed by multiple dynamic headspace extraction and GC-MS (Ciccioli et al. 2004). The cheese sensory profile was evaluated, at room temperature, by ten panellists using a 0–9 point graduated scale for each attribute.

Changes in milk and cheese chemical compositions, FA profile and VOC profile were analysed by ANOVA procedure (Systat 7 1997). Analysis included the effect of sheep breed (Apulian Merino, *Altamurana*, *Comisana* and *Sarda*). Sensory profile data were normalised before submitting them to ANOVA repeated measures procedure. Significance was declared at $P < 0.05$ and tendencies at $0.05 < P \leq 0.10$; differences between means were tested using Fisher's LSD test. In order to ascertain the discriminant effect of the sheep breed on products, milk and cheese data

Fig. 1 Flowchart of *Canestrato Pugliese* cheese

Ewes'milk (raw milk of each brred)
↓
Heating of milk at 37°C
↓
Addition of liquid calf rennet 20 ml/100 kg
↓
Coagulation of milk after 25 min at 37°C
↓
Cutting of the curd (size of the curd after cutting = 0.5-1.0 cm)
↓
Heating the whey (45°C for 2 min)
↓
Removal of the whey, moulding and pressing
↓
Hold curd at 22°C for 24 h
↓
Salting of the curd by spreading over the surface
↓
Ripening at ca. 12°C for 2 and 4 months (environmental humidity ca. 90%)

were pooled *per* breed and submitted to a multivariate approach by Stepwise Discriminant Analysis (Systat 7 1997).

2.2 Results and Discussion

Milk chemical composition was affected by sheep breed (Table 2). The native G and A breeds showed higher dry matter and fat percentage than C and S breeds. Milk from G breed was characterised by higher protein content followed by A, C and S breeds. Ash content was higher in A and C breeds than others. There were no significant differences among breeds on pH data. These results are in line with a previous study on G and A sheep breeds (Claps et al. 1999).

The *Canestrato Pugliese* cheeses from milk of G, C and S breeds were characterised by a higher content of protein and ash compared to the cheese from A breed. The breed effect on dry matter and fat reported above for milk was not observed in cheese. Breed affected chemical composition, but higher percentages of fat and ash in milk do not always lead to cheeses with a superior level of these compounds (Table 2).

A significant breed effect on milk and cheese quality was reported by Kawecka and Sosin-Bzducha (2014), using two indigenous Polish breeds, the Coloured Mountain Sheep (CMS) and the Podhale Zackel (PZ), reared under the same environmental conditions. These authors showed a higher crude protein, casein, urea, and solid non-fat contents in milk from CMS compared to PZ. Cheese obtained from CMS milk had about a 6 % lower fat content compared to cheese made from PZ milk. An effect of the month of grazing season was also found but only for milk composition. The breed x grazing season interaction affected all parameters of cheese chemical composition, while it was negligible for most of milk composition parameters.

Table 2 Effect of sheep breed on chemical composition, fatty acid content and nutritional index of milk and *Canestrato Pugliese* cheese (Claps et al. 2008; Di Trana et al. 2009)

Product	Milk					Cheese				
Breed[1]	G	A	C	S	SEM	G	A	C	S	SEM
Chemical composition (%)										
pH	6.70	6.54	6.64	6.45	0.09	5.40^{a}	5.12^{b}	5.07^{b}	5.41^{a}	0.02
Dry matter	19.85^{a}	20.32^{a}	18.38^{b}	18.42^{b}	0.43	62.56	62.88	62.78	62.48	0.56
Fat	8.13^{a}	8.10^{a}	7.13^{b}	6.91^{b}	0.06	24.87	25.29	24.67	23.41	0.59
Protein	7.07^{a}	6.78^{b}	6.32^{c}	6.16^{c}	0.09	22.4^{a}	19.15^{b}	20.28^{ba}	20.31^{ba}	0.78
Ash	0.95^{b}	0.99^{a}	0.98^{a}	0.96^{b}	0.01	6.40^{a}	5.74^{b}	6.14^{a}	6.21^{a}	0.24
Fatty acids[2] (g/100 g FA)										
SFA	70.51	69.54	70.72	71.36	0.47	71.01	69.86	71.65	70.80	0.49
MUFA	24.22^{b}	25.69^{a}	24.53^{b}	24.75^{ab}	0.43	23.87^{b}	25.74^{a}	23.08^{b}	23.57^{b}	0.40
PUFA	5.27^{a}	4.78^{b}	5.44^{a}	5.56^{a}	0.14	5.32^{a}	4.64^{b}	5.42^{a}	5.38^{a}	0.13
omega-3	1.09^{a}	0.88^{b}	1.14^{a}	1.17^{a}	0.03	1.09^{a}	0.84^{b}	1.08^{a}	1.06^{a}	0.03
omega-6	2.05	1.83	2.04	2.06	0.08	2.12^{a}	1.87^{b}	2.19^{b}	2.18^{b}	0.07
Total *trans*	2.23^{a}	2.30^{a}	2.14^{b}	2.09^{b}	0.04	2.28^{a}	2.21^{a}	1.91^{b}	1.86^{b}	0.11
CLA	0.81^{a}	0.74^{b}	0.85^{a}	0.86^{a}	0.03	0.81^{a}	0.70^{b}	0.83^{a}	0.88^{a}	0.03
Nutritional index										
HPI	0.41^{b}	0.44^{a}	0.42^{b}	0.40^{b}	0.03	0.38&	0.40$^{\$}$	0.39&	0.39&	0.04

Means within row with different superscripts differ at$^{a, b, c}$ $P < 0.05$; &, $^{\$}P < 0.10$

[1]*G* Apulian Merino; *A* Altamurana; *C* Comisana; *S* Sarda breeds

[2]*SFA* saturated fatty acids; *MUFA* monounsaturated fatty acids; *PUFA* polyunsaturated fatty acids; *CLA* conjugated linoleic acid; *HPI* health promoting index; *SEM* standard error mean

A negligible breed effect on milk chemical composition was observed in Boutsiko and Karamaniko, two native sheep breeds of North Western Greece (Kondyli et al. 2012).

A few studies have been published in attempt to elucidate the effect of breed on cheese chemical composition. Comparing some hard cheeses produced in various parts of Spain from different ewe breeds, Gonzalez Viñas et al. (1999) observed no significant differences in the physicochemical composition. The sheep breed effect on milk composition and coagulation properties for Niza production, a traditional Portuguese PDO cheese, was evaluated comparing two autochthonous breeds (Merino and Saloia) with the non-native Assaf breed that is commonly reared in Portugal (Martins et al. 2009). The milk composition showed higher solid content in Merino and Saloia breeds resulting in higher potential cheese making yield as far as 75 % and 27% , respectively, when compared to the corresponding value of that of Assaf milk. The lower solid content of Assaf milk led to lower curd firmness while the milk from Merino and Saloia breeds showed superior firming rates and reached higher final curd firmness in agreement with physical and chemical characteristics of milk. The results emphasise the different cheese making aptitude of the milk from the two Portuguese autochthonous breeds.

Some studies have showed that FA profile of cheese was very similar to that of milk (Addis et al. 2005; Nudda et al. 2005). In our investigation, the sheep breed affected milk and cheese FA profile, and both showed a similar trend (Table 2). In milk and cheese, G and C breeds showed a higher content of polyunsaturated FA (PUFA) and omega-3 compared to A breed, which instead increased the content of monounsaturated FA (MUFA). No differences were found in saturated FA (SFA) content, and slight differences were detected for milk omega-6 contents. Total *trans* FAs were higher in milk and cheese from native G and A breeds compared to the others.

Comparing three Italian sheep breeds (*Massese*, *Sarda* and *Comisana*), Duranti and Casoli (1988) detected breed effect on milk FA profile, in particular, on short-chain FA percentages and on unsaturated/saturated FA ratio. Later on, study about *Altamurana*, Apulian Merino and *Sarda* breed confirmed the breed effect on the majority FA of milk (Signorelli et al. 2008). As regards CLA (conjugated linoleic acid *cis*-9, *trans*-11), the higher content was found in milk and cheese from G, C and S breeds compared to A breed. Comparing three dairy sheep breeds (*Garfagnina*, *Massese* and *Sarda*), Secchiari et al. (2001) observed the breed effect on milk's total CLA isomers content, with a higher CLA content in local *Garfagnina* and *Massese* breeds compared to *Sarda* breed. In contrast with our results, other authors have not found a sheep breed effect on milk CLA content, probably due to the wide variation in milk CLA level among individuals consuming the same diet (Tsiplakou et al. 2006; Signorelli et al. 2008). Evaluating CLA isomer content in milk from Polish Želazneñska and Wrzosówka sheep, Rozbicka-Wieczorek et al. (2013) detected a higher but not significant level of CLA in milk from Želazneñska ewes. Talpur et al. (2009) found different FA profiles in milk from indigenous Pakistani sheep breeds (Kachi and Kooka) reared under the same feeding and housing conditions. Kooka breed showed a better profile with lower

SFA and higher CLA contents than Kachi breed. The variability among breeds might be useful in the improvement on milk and derived products' quality.

From the human health point of view, when comparing the autochthonous A breed with the C and S breeds, we observed health-promoting properties of milk and cheese from A endangered breed. The milk HPI from A breed was higher than that observed in the other breeds. This result was confirmed in the cheese, though the difference was slight. In our further investigation, we observed a higher HPI in *Canestrato Pugliese* cheese, 4 months ripened, produced with A breed milk than the same product obtained from *Sarda* breed milk (Claps et al. 2011).

In North Western Greece, a study was carried out in farms located in the semi-mountainous (600–800 m a.s.l.) region of Ioannina, using two small sized native breeds, Boutsiko and Karamaniko, which are endurable and adaptable to the environmental conditions, frugal in eating and having the same yearly milk production as other indigenous breeds (Voutsinas et al. 1988). The sheep breeds grazed in semi-mountainous and mountainous pastures, so as to eliminate any differences due to different feeding. The breed effect was observed for butyric, stearic, CLA and vitamin A contents, with Boutsiko breed having higher levels than Karamaniko one, while the breed effect was negligible for the major FAs (Kondyli et al. 2012).

Some studies on local sheep breeds were performed in Romania to evaluate their effect on milk FA profile (Mierlita et al. 2011a, b). Merino of Transylvania, Tsigay and Turcana are three Romanian sheep breeds on the verge of extinction for their low productivity. Turcana and Tsigay milk are used to produce some high quality traditional cheeses ("cas", "telemea" and "branza de burduf") due to their fat and protein content. Mierlita et al. (2011a) reported that Turcana sheep produced more milk than Merino of Transylvania, Tsigay breeds. In addition, Turcana milk was richer in fat and protein content and had a better HPI value, due to its lower SFA level and higher PUFA content, especially in CLA, than other milk. The healthiest FA profile of Turcana milk was also found when comparing Turcana with Spanca, another indigenous Romanian breed (Mierlita et al. 2011b). The higher concentrations of *trans*-11 C18:1 (VA), C18:1 n9c and *cis*-9 *trans*-11 CLA in Turcana milk were related to its more intense VA desaturation and conversion into *cis*-9, *trans*-11 CLA. These results support the sustainable use of animal genetic resources to improve ewe milk fat quality.

The study conducted in Poland by Kawęcka and Sosin-Bzducha (2014) is one of the few studies carried out simultaneously on milk and cheese made from different breeds of sheep: the Coloured Mountain Sheep (CMS) and Podhale Zackel (PZ). "Oscypek" cheese manufactured from PZ breed showed lower SFA, atherogenic index values and higher MUFA and omega-3 FA contents than cheese from CMS breed. The differences in the FA profile of products observed in response to breeding and grazing season may represent the basis for producing different flavoured niche cheeses. The authors indicate that these local sheep breeds have a high potential for sustainable use.

Also, the study by Esposito et al. (2014) was aimed at recovering the dairy aptitude in *Appenninica* sheep, a native breed in Central Italy. The characterization of the Apennine Pecorino cheese made from raw milk was performed using as test pecorino made from raw milk of *Sarda* breed. These sheep breeds were maintained in the same rearing conditions. The breed effect was evident for some FAs and aromatic compounds, while it was negligible for cheese chemical composition. Cheese of *Apennine* breed showed greater content of *cis*-10 pentadecenoic acid and lower content in α-linolenic acid and γ-linolenic acid compared to cheese of *Sarda* breed.

In our study, the discriminant analysis performed on FA composition of milk and *Canestrato Pugliese* cheese highlight that A and G autochthonous breeds were well discriminated from *Comisana* and *Sarda* breeds. Canonical scores plot (Fig. 2) show on the left A and G breeds and on the right C and S breeds not well separated. The variables contributing to discriminant analysis were the main classes of FAs (SFA, MUFA, PUFA, omega-3, omega-6 and total *trans*) and single FA (oleic acid, *trans* vaccenic acid and CLA). These results suggest that local breeds, independently from diet, possess the potential to link a specific product to a breed. With a multivariate approach by Principal Components Analysis, Ighina et al. (2007) on four Alpine sheep breeds (*Frabosana*, *Delle Langhe*, *Savoiarda* and Lacaune) showed and confirmed that the breed has an influence on milk FA composition and CLA content when animals are fed the same diet.

Milk volatile compounds originate from the feed and/or from microbial metabolism. Some compounds present in plants, such as terpenes, can be transferred to the milk through inspiratory lung or feeding. Most of the volatile compounds are microbially produced from the catabolism of milk component and depend on the composition of the endogenous microflora in the raw milk and/or from starters (McSweeney 2004). The physicochemical characteristics of cheeses from different breeds are linked to the development of volatile flavour compounds, particularly from lipid degradation during ripening (McSweeney 2004). As suggested by Engels et al. (1997), the FAs are important components in the flavour of many cheese types; the Volatile Organic Compounds (VOC) in cheese, such as esters, methyl

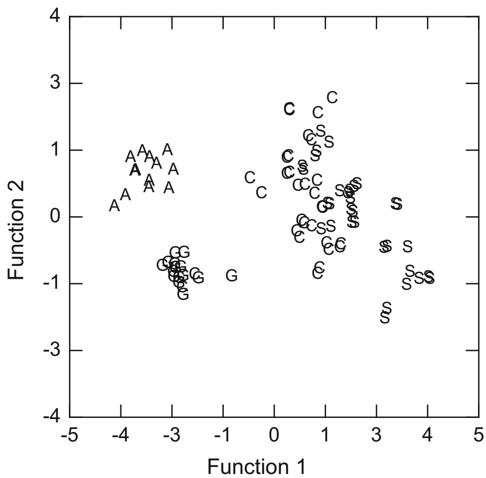

Fig. 2 Distribution plot of milk and *Canestrato Pugliese* cheese using two canonical discriminant functions (Claps et al. 2008; Di Trana et al. 2009). (*G*) *Apulian Merinos*, (*A*) *Altamurana*, (*C*) *Comisana* and (*S*) *Sarda* breeds

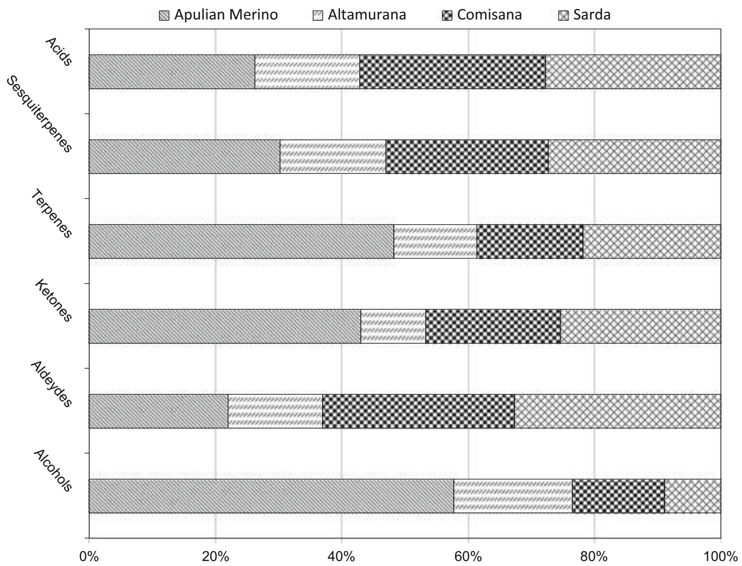

Fig. 3 Effect of sheep breed on percentage of volatile organic compounds in *Canestrato Pugliese* cheese (Claps et al. 2008; Di Trana et al. 2009)

ketones and secondary alcohols, arise from the lipolysis of myristic and palmitic acids.

In our study, the sheep breed affected VOC profile of cheese (Fig. 3). In the cheese from G breed, aldehydes and acids excluded, a higher content of alcohols, ketones, terpenes and sesquiterpenes than A and C breed was detected. The highest content of the acid class of VOC found in *Canestrato Pugliese* cheese does not agree with a previous study performed on the same cheese (Di Cagno et al. 2003). These differences may be due to the use of non-starter lactic acid bacteria culture and different procedure to measure VOC profile.

A different VOC profile was found in Pecorino produced by two different breeds, *Apennine* and *Sarda*. Cheese from *Apennine* breed showed a greater level of 8-nonen-2-one and a smaller quantity of diacetyl, 1-butanol, 3-methyl-2-buten-1-ol and 2,3-butanediol than other breed (Esposito et al. 2014). The breed effect on VOC profile was also detected by Ferreira et al. (2009) on Portuguese “Castelo Branco” POD cheeses manufactured with milk from different sheep breeds (Merino da Beira Baixa, Assaf, and Crusade). The same authors reported that the discriminant analysis of volatile fraction of PDO Castelo Branco cheese can be used to evaluate breed origin.

The sensory profile of *Canestrato Pugliese* cheese showed that the breed affected some parameters of cheese sensory properties (Fig. 4). G and A cheeses had higher scores of “pecorino”, “bitter”, “spicy” tastes and “colour” than C breed. No differences were found among breeds for “salty” and “fermented odour” tastes.

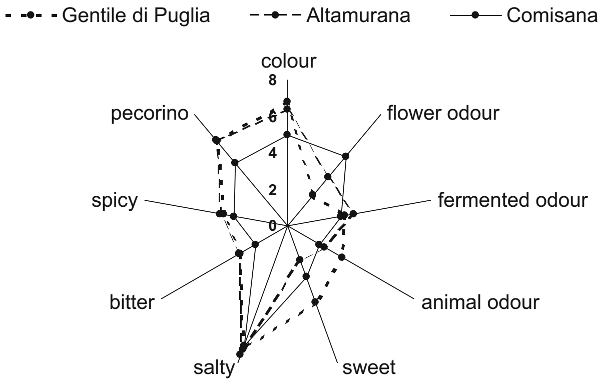

Fig. 4 Effect of sheep breed on sensory profile of *Canestrato Pugliese* cheese (Claps et al. 2008; Di Trana et al. 2009)

The relationship between ovine breeds and sensory characteristics of *Canestrato Pugliese* cheese was reported in our previous studies (Claps et al. 1999; Taibi et al. 2000). The present study suggests that the panel test could discriminate between cheese made from *Comisana* breed and cheeses from native breeds (*Altamurana* and Apulian Merino) by the colour and smell.

Regarding sheep, few studies have been conducted about the influence of breed on cheese sensory profile. Comparing cheeses produced in various parts of Spain from different ewe breeds, Gonzalez Viñas et al. (1999) indicated that the diversity of cheese sensory profile arises from their chemical composition and indirectly by animal breed. The breed effect on cheese sensory analysis was highlighted by Ferreira et al. (2009) in a study on “Castelo Branco” cheeses manufactured with milk from different breeds (Merino da Beira Baixa, Assaf, and Crusade). The results from descriptive analysis and triangle tests confirmed that these cheeses showed significantly different sensory characteristics.

2.3 Conclusion

The results indicate that chemical composition and FA profile of milk and cheese and VOC compounds and sensory properties of *Canestrato Pugliese* cheese vary according to sheep breed. Milk and cheese from Apulian Merino and *Altamurana* breeds have nutritional characteristics and sensorial properties distinguishable from other breeds. The Discriminant Analysis of FAs, the VOC profile and sensory attributes are interconnected tools able to discriminate the origin of the cheese. The differences among breeds for milk FA profiles, according to the reviewed literature on cheese characteristics, are likely to affect cheese quality and could be an indicator of typicality in order to adding value to local and endangered *Altamurana* and *Gentile di Puglia* (Apulian Merino) breeds.

3 Goat Breeds and *Caciotta* Cheese

In this paragraph, we report an example that can be considered a case study. The study was carried out at the CRA-ZOE experimental farm of Bella-Muro (40°38′N; 15°49′E), located at 360 m a.s.l in the Basilicata region (Southern Italy), during spring. The maximum and minimum environmental temperatures and relative humidity were 13 °C, 5 °C and 70 % in spring, 24 °C, 14 °C and 64 % in summer, 16 °C, 8 °C and 71 % in autumn and 7 °C, 1.3 °C and 77 % in winter. Average annual rainfall was 752 mm, mainly distributed in autumn. Temperature humidity index was 57, 72, 62 and 50 in spring, summer, autumn and winter, respectively. In autumn–winter, the contribution of botanical families in the native pasture was 92 % *Graminaceae*, 1 % *Leguminosae*, 7 % *Forbs* and the main species present were *Lolium perenne* (60 %), *Dactylis glomerata* (25 %), *Phleum pratense* (5 %). In spring-early summer, the botanical composition was 28 % *Graminaceae*, 3 % *Leguminosae*, 68 % *Forbs* and the main species were *Cichorium intybus* (15 %), *Asperula odorosa* (12 %), *Phleum pratense* (10 %), *Crepis* sp. (9 %), *Galium verum* (9 %), *Convolvulus arvensis* (8 %), *Lolium perenne* (8 %) and *Daucus carota* (7 %).

A flock set-up of four goat breeds, *Girgentana* (G), *Jonica* (I), *Maltese* (M) and Red Syrian (R) breeds (Table 3), were used. *Girgentana* breed, native of Sicily, and *Jonica*, native of Apulian and Basilicata regions, were compared with two non-native breeds: *Maltese* and Red Syrian.

Mature goats from each breed were selected on the basis of homogeneous days in milk (110 ± 10) and body condition score (2.60 ± 0.25). All goats grazed on native pasture and they received hay *ad libitum* plus a small amount of mixed grain in two equal meals at morning and evening milking.

This diet reflects the common feeding regimen of grazing goats in Mediterranean environments according to the herbage allowance at pasture.

3.1 *Caciotta Cheesemaking, Sampling and Analysis of Milk and Cheese*

Three cheesemakings of *Caciotta* cheese for each goat breed were carried out for three consecutive days in CRA-ZOE experimental dairy.

Table 3 Goat breeds

Goat breed	Population size (heads)[a]	Diffusion areas in Italy[b]	Prolificacy %	Fertility %	Kid at 40 days (kg)	Lactation (days)	Lactation yield[c] (kg)	Fat %	Protein %
Girgentana—L.G.	1,776	Sicilia, Umbria, Basilicata	180	90	8.0	210	252 ± 126[d]	3.9[e]	3.5[e]
Jonica—L.G.	836	Puglia, Basilicata	170	95	13.2	210	290 ± 112[f]	5.3[f]	4.0[f]
Local—R.A. (Cilentana Grigia)	129	Campania	150	90	9.0	180	200 ± 20	3.6[g]	3.3[g]
Maltese—L.G.	3,487	Sicilia, Sardegna, Basilicata, Lazio, Calabria	80	96	11.0	210	292 ± 102[d]	4.3[f]	3.6[f]
Rossa di Siria (*Red Syrian*) R.A.	2,138	Sicilia, Basilicata, Calabria	210	95	11.0	210	178 ± 69[d](570 in Sicily)[f]	4.1[f]	3.6[f]

L.G. genealogical book; R.A anagraphic logbook
[a]Registered heads, June 2014, ASSONAPA
[b]In order of population size
[c]Multiparous doe
[d]Italy: Milk recording activity, official statistics, AIA (2013)
[e]Todaro et al. (2005)
[f]Noè et al. (2005)
[g]Pizzillo et al. (2005)

Goat Caciotta Cheese

Caciotta cheese (from the *left*): Pure, thyme-spiced and wine-ripened cheese

Whole goat milk cheese. It weighs 500–600 g, and it is ripened for 20–30 days; the shape is cylindrical, 15 cm in diameter and 11 cm high; the rind is ivory coloured, the texture is compact, the paste is semi-soft, with rare eyes or eyeless, and white-ivory coloured. The odour is pleasantly acidic-fermented, the taste is sweet, typical and slightly goaty. This cheese can be flavoured with various ingredients. For example, with thyme (Thyme-spiced Goat Caciotta cheese): the rind is barely formed and covered by thyme leaves, which give the typical aroma to the cheese. Moreover, with wine: in this case (Wine-ripened Goat Caciotta cheese[1]), the rind is dark-red coloured because of the ripening in Aglianico del Vulture grape vinasse, which gives the typical red plonk colour and aroma to the cheese. When correctly ripened, the flavoured rinds are edible and enrich the taste and nutritional value of the cheeses with the aromas, the antioxidant compounds and vitamins contained into the leaves and vinasse.

The flowchart of cheese-making process is shown in Fig. 5. *Caciotta* cheese was ripened for 1 month in a natural cave at CRA-ZOE of Bella.

Milk samples were collected during the morning and evening milking, and cheeses were sampled at the end of the ripening period. Chemical composition, pH, FA content and C14:1/C14:0 ratio were measured both in milk and cheese samples. VOC and sensory profile of *Caciotta* cheese were evaluated. Methods used for analytical assessments are given in previous section (see Sect. 2.1).

Changes in chemical composition, FA profile, VOC profile and textural properties of milk and *Caciotta* cheese were analysed by ANOVA procedure (Systat 7 1997) including the breed effect (*Girgentana*, *Jonica*, *Maltese* and Red Syrian). Data of sensory profile were normalised before submitting them to ANOVA repeated measures procedure. Significance was declared at $P < 0.05$, and tendencies were declared at $0.05 < P \leq 0.10$; differences between means were tested using Fisher's LSD test. In order to ascertain the discriminant effect of the breed on

[1] Goat cheese type pointed out by CRA-ZOE with Aglianico del Vulture, a Lucanian red wine (www.entecra.it).

Fig. 5 Flowchart of *Caciotta* cheese

Goats'milk (raw milk)
↓
Heating of milk at 37°C
↓
Addition of liquid calf rennet 20 ml/100 kg
↓
Coagulation of milk after 25-30 min at 37°C
↓
Cutting of the curd (size of the curd after cutting = 1.0-1.5 cm)
↓
Partial removal of the whey and moulding
↓
Stewing at 37°C for 3 h until pH 5
↓
Cooling to 4-6°C
↓
Salting the mould for 3 days
↓
Brushing
↓
Ripening at ca. 8-10°C for 20-30 days (environmental humidity ca. 90%)

products, FA data of milk and cheese were pooled *per* breed and submitted to a multivariate approach by Stepwise Discriminant Analysis (Systat 7 1997).

3.2 Results and Discussion

Goat breed affected the chemical composition of milk (Table 4). Milk from *Maltese* breed was characterised by higher contents of dry matter, fat and protein compared to the milk from the other breeds. Milk from *Jonica* goats showed higher contents of dry matter, fat, protein and ash than milk from R and G breeds. There were no significant differences among breeds on pH data. In the same study, the goat breeds affected also caseinic nitrogen (CN) and non-proteic nitrogen (NPN) fractions, M goats showing a CN content 30 %, 14 % and 16 % higher than in the milk from R, I and G goats, respectively (Claps et al. 2007). Milk dry matter from the non-native R breed did not differ significantly from milk dry matter of G breed.

A negligible breed effect on chemical composition of *Caciotta* cheese was observed (Table 4). Cheese made from milk of M breed was characterised by higher dry matter and fat contents compared to cheese from the other breeds, though the differences are not significant. The pH and ash values were statistically higher in cheese from M breed.

As FA profile is concerned, some studies in sheep (Addis et al. 2005; Claps et al. 2007) and cow (Sinclair et al. 2007) have shown that the FA profile of cheese reflects that of milk. In our study, breed had an effect on FA profile of milk and *Caciotta* cheese and both showed a similar trend. The levels of PUFA, omega-3, CLA and total *trans* FA were higher in milk from G breed than in that from the other breeds. SFA, MUFA and omega-6 contents in milk did not change among

Table 4 Effect of goat breed on chemical composition (%), fatty acid content (g/100 g FA) and index of milk and *Caciotta* cheese (Claps et al. 2007; Di Trana et al. 2009)

Product	Milk					Cheese				
Breed[1]	M	R	I	G	SEM	M	R	I	G	SEM
Chemical composition										
pH	6.57	6.61	6.51	6.66	0.02	4.78^{a}	4.43^{b}	4.27^{b}	4.40^{b}	0.06
Dry matter	13.83^{a}	12.17^{c}	12.90^{b}	11.10^{c}	0.18	53.69	53.27	51.75	50.06	1.46
Fat	4.70^{a}	3.47^{c}	4.30^{b}	3.97^{b}	0.15	27.25	24.00	26.00	24.38	1.12
Protein	3.91^{a}	3.34^{c}	3.66^{b}	3.13^{d}	0.05	18.07	21.00	18.56	18.95	0.98
Ash	0.74^{b}	0.73^{b}	0.84^{a}	0.73^{b}	0.001	5.56^{a}	4.07^{cb}	3.37^{b}	4.81^{ca}	0.28
Fatty acids[2]										
SFA	70.61	71.35	70.66	70.18	0.40	70.26	71.28	71.11	70.69	0.43
MUFA	24.90	24.12	24.83	24.54	0.33	25.18	24.54	24.61	24.00	0.39
PUFA	4.48^{b}	4.53^{b}	4.52^{b}	5.28^{a}	0.09	4.56^{b}	4.18^{c}	4.28^{abc}	5.31^{a}	0.08
Omega-3	0.94^{b}	1.02^{b}	0.096^{b}	1.15^{a}	0.02	1.08^{a}	0.91^{b}	0.94^{b}	1.18^{a}	0.03
Omega-6	2.04	2.18	2.12	2.02	0.05	2.00^{a}	1.74^{b}	1.91^{ab}	1.96^{a}	0.05
CLA	0.56^{c}	0.61^{bc}	0.65^{b}	0.71^{a}	0.01	0.54^{c}	0.62^{b}	0.64^{b}	0.74^{a}	0.01
Total *trans*	1.34^{b}	1.32^{b}	1.38^{b}	1.74^{a}	0.03	1.43^{a}	1.42^{a}	1.42^{a}	0.79^{b}	0.05
Index										
Δ^9 desaturase activity	0.037^{b}	0.038^{a}	0.036^{c}	0.033^{d}	0.00	0.037^{b}	0.038^{a}	0.036^{c}	0.033^{d}	0.00
Health promoting index	0.43	0.43	0.41	0.44	0.01	0.45^{a}	0.42^{c}	0.40^{bc}	0.43^{ac}	0.01

Means within row with different superscripts differ at $^{a,\ b,\ c,\ d}P < 0.05$

[1]*M* Maltese; *R* Red Syrian; *I* Jonica; *G* Girgentana breeds

[2]*SFA* saturated fatty acids; *MUFA* monounsaturated fatty acids; *PUFA* polyunsaturated fatty acids; *CLA* conjugated linoleic acid; *SEM* standard error mean

breeds. Indeed, the *Caciotta* cheese made from milk of *Girgentana* breed contained more PUFA, omega-3, omega-6 and CLA and less total *trans* FA. The different FA profile among breeds might be a useful tool in quality improvement of milk and derived products. These results agree with our previous study (Di Trana et al. 2006a, b) in which we found significant differences in FA profile of milk from *Girgentana*, Cashmere, Red Syrian and *Maltese* breeds.

The Δ^9-desaturase activity index (calculated as C14:1/C14:0 ratio) was significantly affected by goat breed in both milk and cheese. This index was higher in R breed compared to M, I and G breeds. The results suggest the breed effect in expression of Δ^9-desaturase enzyme in the mammary gland as observed in our previous study (Di Trana et al. 2006a, b) in addition to the effect of animal species observed by Addis et al. (2005).

In the Canary Islands, Fresno et al. (2001) found significant differences between soft cheeses made from Majorera and Tinerfeña goats; chemical composition only affected the soft cheese. Later studies (Alvarez et al. 2008; Fresno and Alvarez 2007), considering other Canary goat breeds (Majorera and Palmera), demonstrated significant gross chemical differences. Cheeses from Majorero milk presented better values for fat and protein parameters but less moisture content and pH. The FA profile was very similar between breeds although sensorial features had many differences. Fresh cheeses made with Majorera goat milk presented higher roughness, firmness and friability values than cheeses from the other breeds but lower elasticity and solubility. Hard cheeses from Palmero breed were more elastic and rough than others, although firmness, friability and solubility values were lower.

In a Pakistani study, a significant effect of breed was reported in cow (Talpur et al. 2006) and goat (Talpur et al. 2009) milk. Comparing Kamori and Pateri goats kept under the same feeding and housing condition, authors reported a better FA profile with lower SFA and higher CLA content in Kamori milk. As regards cow breeds with identical dietary intake, the milk of Red Sindhi breed showed a higher content of MUFA, PUFA and CLA compared to White Thari milk.

Soryal et al. (2005), comparing the milk of Egypt Nubian and Alpine breeds, reported significant differences in fat, total protein, casein and total solids, with Nubian goat having higher contents. This gross milk composition affected cheese yield, but it did not change cheese composition and sensorial scores. Moreover, only oleic acid and unsaturated fatty acids were affected by breeds, with Alpine milk having higher content.

In Portugal, goat milk is mainly used for traditional cheesemaking, sometimes also mixed with ewe milk, or for direct household consumption but on a very limited scale. Trancoso et al. (2010) undertook a study with the main Portuguese indigenous breeds (Serrana Transmontana, Serrana Ribatejana, Serpentina, Charnequeira and Algarvia) and a foreign breed reared in Portugal (Saanen) in order to compare their milk composition, particularly concerning the micronutrients. The results showed that the Serrana breed could be distinguished from the others and there was a significant difference between both ecotypes (Serrana Transmontana SRT, Serrana Ribatejana SRR). SRT and SRR milk showed higher and lower levels of milk chemical constituents, respectively, compared to milk of the other breeds. Milk from the foreign breed Saanen (SA) did not differ significantly from milk of the indigenous breeds, leading to suggestion that breed might not be as important for milk composition as geographical region and production system.

In Ethiopia, Mestawet et al. (2012) evaluated the cheese production potential and suitability of indigenous breeds by comparing four goat breeds, two indigenous (Somali and Arsi-Bale), one non-native (Boer) and one crossbreed (Toggenburg × Arsi-Bale). They observed a breed effect on milk characteristics. In fact, the indigenous goats had a lower milk yield than the improved European goat breeds. However, they showed higher values in major milk components than most of the non-native breeds. In particular, Arsi-Bale goats had significantly higher protein content (4.8 %) than the others. Superior chemical composition observed in milk from indigenous Ethiopian goats revealed their potential for cheese production.

Due to a large number of FA in milk and *Caciotta* cheese, data were pooled *per* breed and analysed using a multivariate approach. Discriminant analysis, performed simultaneously on FA profile of milk and *Caciotta* cheese, clearly separates the goat products obtained from different breeds. A canonical scores plot of the two canonical discriminant functions showed M at the bottom, G on the left, I on the right and R in the centre (Fig. 6). However, R and I breeds did not show a strong distance. The most important FAs that contributed to the separation among breeds were short-chain FAs, medium-chain FAs, saturated FAs, monounsaturated FAs, omega-3, omega-6 and CLA. Under our experimental conditions, these results support the differences of milk and cheese among breeds consuming the same diet.

During cheese ripening, biochemical reactions lead to the formation of cheese aroma. Flavour compounds are produced from three major milk constituents: lactose, lipids and proteins. Aroma development in cheese products results from the metabolic activities of cheese bacteria, by glycolysis, lipolysis and proteolysis

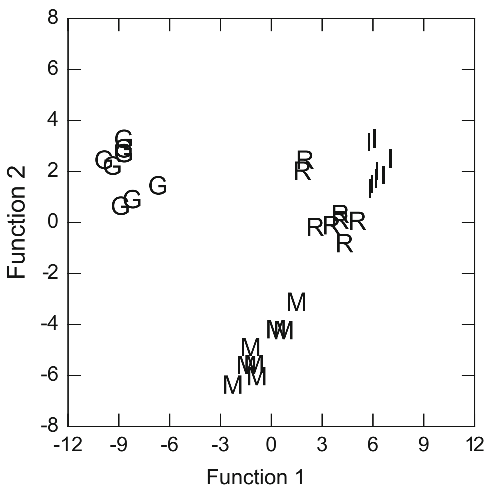

Fig. 6 Distribution plot of milk and *Caciotta* cheese using two canonical discriminant functions (Claps et al. 2007; Di Trana et al. 2009). (*G*) *Girgentana*, (*I*) *Jonica*, (*M*) *Maltese* and (*R*) Red Syrian breeds

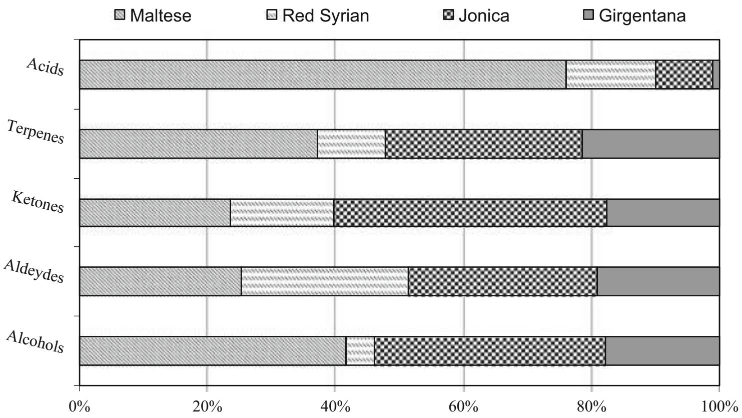

Fig. 7 Effect of goat breed on percentage of volatile organic compounds in *Caciotta* cheese (Claps et al 2007; Di Trana et al. 2009)

(Marilley and Casey 2004). The Volatile Organic Compounds (VOCs) profile provides a "fingerprint" (Mariaca and Bosset 1997) of what happens during ripening.

In our study, goat breed affected the VOC profile of *Caciotta* cheese. Detected headspace compounds were grouped according to their nature in acids, alcohols, aldehydes, ketones and terpenes. Significant differences were found among individual classes of aromatic compounds whose higher values were observed in M cheese, with the exception of ketones (Fig. 7). The acid class was wider in cheeses from M and R breeds compared to I and G ones.

The main source of this class is lypolysis, but it can also be the result of the lactose metabolism, directly from acetyl-CoA or formed from amino acid conversion (Tavaria et al. 2004). This class is involved in cheese aroma like "sweet" and "goaty" flavour note or in a rancidity defect when it is present in very large amounts (Tavaria et al. 2004). As alcohol class is concerned, the butan-1-ol compound is linked to "sweet, fruity" flavour note (Ferreira et al. 2009). In our study G and I cheeses showed low and high incidence of acids and alcohols compounds, respectively. Both compounds seem connected to the high "sweet" taste observed in G and I cheese and "flower" taste in cheese from G breed (Fig. 8).

The terpene class in cheeses is of plant origin and not of microbial origin (Belitz and Grosch 1986). The greater incidence of terpenes in the M, I and G cheeses than R ones suggests different grazing behaviour of goat breeds. The differences of the VOC content among breeds seem to be linked to the different grazing behaviour and intake of botanic species of goat breeds at pasture (Fedele et al. 2005; Claps et al. 2010) as well as to their genetic characteristics (see Sect. 3.3) such as wide casein polymorphism (Coulon et al. 2004).

The characteristic "goat" flavour, and its link with animal breed, was shown many years ago by Ronningen (1965). A subsequent study (Skjevdal 1979) showed a stronger taste in cheese made with Norwegian goat milk than Saanen milk. Cheese volatile fraction and consequently sensory characteristics are affected by climatic

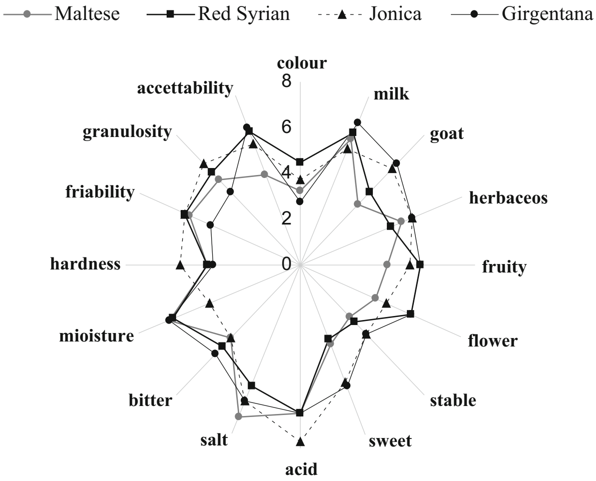

Fig. 8 Effect of goat breed on sensory profile in *Caciotta* cheese (Claps et al. 2007; Di Trana et al. 2009)

conditions and raw milk quality, which depends on the animal species, breed, feed, farming and adventitious microflora of the raw milk (Collomb et al. 1999; Tavaria et al. 2002). In our study, the breed affected all parameters of *Caciotta* cheese sensory properties (Fig. 8). *Girgentana* cheese showed a significantly higher value of “milk odour”, “bitter”, “sweet”, “fruity” and “herbaceous” taste than others. *Girgentana* cheese had a lower value of granulosity and friability than the other breeds, probably due to its fat and protein content, as observed for ricotta cheese (see Sect 4.2). The higher value of “herbaceous” taste for G and I cheeses might be explained by the greater incidence of terpenes in these cheeses compared to R ones.

3.3 Goats and Genetic Variants of Casein Fractions

Goat casein genes show a high level of polymorphism due to the presence of several alleles in different loci in some populations. In particular, the αs1-casein (CSN1S1) locus shows 17 alleles (Grosclaude and Martin 1997; Martin et al. 2002), the β-casein (CSN2) and αs2-casein (CSN1S2) loci 8 alleles each (Marletta et al. 2007; Ramunno et al. 2001) and the κ-casein (CSN3) locus shows 21 alleles (Prinzenberg et al. 2005; Gupta et al. 2009). Except for the CSN3 gene, the polymorphism is not only due to qualitative differences but also to quantitative differences since some alleles affect the level of expression of the gene itself.

According to the level of synthesised αs1-casein, the CSN1S1 alleles have been divided into strong (A, B1, B2, B3, B4, C, H, L and M), medium (E and I), low (D, F and G) and null (01, 02 and N), producing about 3.6 g/l; 1.6 g/l; 0.6 g/l; 0 g/l of casein, respectively. The CSN1S1 alleles have also a different influence on cheese flavour. In fact, Grosclaude and Martin (1997) report a less pronounced goat flavour in cheese obtained from AA milk compared to cheese obtained from FF milk.

Table 5 Allelic frequencies at the αs1-casein (CSN1S1), β-casein (CSN2) and αs2-casein (CSN1S2) loci in goat populations reared in southern Italy. Data were obtained from different authors

	Red Syrian	*Girgentana*	*Jonica*	*Maltese*
CSN1S1				
A	0.303[a]	0.590[b]–0.351[a]	0.350[c]	0.249[a]–0.414[c]
B	0.096[a]	0.065[b]–0.129[a]	0.305[c]	0.108[a]–0.157[c]
E	–	–	0.064[c]	0.004[a]–0.057[c]
F	0.325[a]	0.290[b]–0.186[a]	0.282[c]	0.327[a]–0.371[c]
N		0.047[b]–0.040[a]	–	0.011[b]
CSN2				
A	0.111[a]	0.071[a]	0.207[d]	0.142[a]–0.129[d]
C	0.547[a]	0.556[a]	0.700[d]	0.464[a]–0.819[d]
0′	0.053[a]	0.096[a]	0.093[d]	0.088[a]–0.052[d]
CSN1S2				
A	0.243[a]	0.535[a]–0.722[e]	0.291[c]	0.153[a]–0.286[c]
B	–	0.023[a]	0.014[c]	0.086[c]
C	0.186[a]	0.055[a]–0.051[e]	0.355[c]	0.130[a]–0.264[c]
E	0.012[a]	0.002[e]	0.005[c]	0.038[a]–0.107[c]
F	0.254[a]	0.101[a]–0.225[e]	0.332[c]	0.382[a]–0.250[c]
D	–	0.006[a]	–	–
0	–	–	0.005[c]	0.004[a]–0.007[c]

[a]Gigli et al. (2008)
[b]Mastrangelo et al. (2013)
[c]Sacchi et al. (2005)
[d]Chessa et al. (2005)
[e]Palmeri et al. (2014)

The CSN2 alleles are divided in normal alleles (A, A1, B, C, D and E), producing a normal quantity of α-casein (about 5 g/l), and 0 and 01 alleles characterised by the absence of synthesis of α-casein.

The CSN1S2 alleles are characterised by a normal (A, B, C, E, F and G) (2.5 g/l), weak (D) (1.5 g/l) and null (0) (0.0 g/l) production of as2-casein.

The level of total milk casein is important both for its impact on cheese-making properties (strong alleles are associated with better technological properties of milk, fat percentage and fatty acid composition (Remeuf 1993; Valenti et al. 2010; Zullo et al. 2005)) and for particular dietary requirements (El-Agamy 2007). As a consequence, particular attention must be paid to casein polymorphism in breeding programmes to obtain a milk rich in casein suitable for cheesemaking or a milk deprived of a casein fraction to be used for hypoallergenic diets. In this context, local goat populations, characterised by a high genetic variability at the casein loci (Table 5), could be the start point of both selection programmes in order to reach different destinations of the final product.

The genotyping of CSN1S1, CSN2 and CSN1S2 loci in *Maltese* and Red Syrian populations reared in Basilicata showed results characterised by a good, though slightly different from those shown in Table 6, genetic variability: CSN1S1 A (0.571) F (0.212) B(0.125) E (0.038) N (0.054) and CSN1S2 “strong alleles” (0.958), 0 (0.022) in Red Syrian; CSN1S1 A (0.659) F (0.305) B(0.012) E (0.012)

Table 6 Haplotype frequencies at casein loci in goat populations reared in southern Italy. Data were obtained from different authors

	Red Syrian	*Girgentana*	*Jonica*	*Maltese*
I[a] (10.5 g/l)	0.320[b]	0.530[b]	0.539[c]	0.240[b]–0.400[c]
II (5.5 g/l)	–	0.005[b]	–	0.007[b]
III (8.1 g/l)	–	–	0.044[c]	0.024[c]
IV (7.5 g/l)	0.321[b]	0.250[b]	0.250[c]	0.380[b]–0.368[c]

[a]Rando et al. (2000) Quantitative haplotypes observed at the goat calcium-sensitive casein loci
[b]Gigli et al. (2008)
[c]Sacchi et al. (2005)

N (0.012) and CSN1S2 "strong alleles" (0.989) 0 (0.011) in *Maltese* (our unpublished results).

Test for casein haplotype could be more useful as the four casein genes are closely linked in a 250 kb DNA segment on chromosome 6. Association of strong alleles at the calcium-sensitive casein loci will lead to milk rich in total casein (10.5 g/l), while association of strong and weak allele should decrease the total casein content (Rando et al. 2000).

The analyses of casein haplotypes showed that haplotype I (Rando et al. 2000) which should produce the maximum level of total casein (10.5 g/l) had higher frequencies in *Girgentana* and *Jonica* breeds than in Red Syrian and *Maltese* breeds. So, Gigli et al. (2008) suggest that although their milk should be more suitable for cheesemaking, the largest number of haplotypes has been found in *Maltese* breed. Interestingly, in *Maltese* breed Sacchi et al. (2005) found a specimen heterozygote for a haplotype that should produce only 2.5 g/l of total casein.

3.4 Goat Breeds and Oligosaccharide Fraction

All the special characteristics and qualities that add value to local breeds should be exploited in order to find new roles for the breeds. The oligosaccharide fraction appears to be an interesting and promising feature.

Goat milk contains smaller casein micelles and fat globules, higher concentration of some whey proteins and oligosaccharides than bovine milk (Silanikove et al. 2010). The fraction of oligosaccharides (OS) in goat milk is becoming increasingly important for its known bio-functional role in consumers. Oligosaccharides, 3–10 monosaccharide residues, are either acid containing N acetylneuraminic acid (sialic acid) or neutral. OS promote bifidobacteria growth in the neonate and play a role as intestinal mucosal cell protectors against pathogens. In addition, they play an essential role in neonatal brain development (Gopal and Gill 2000). Goat colostrum and milk have shown an OS profile similar to that of human milk and a highest content of sialyloligosaccharides (SOS) in comparison to milk from other ruminants; Puente et al. (1996) found four times as much sialic acid in goat milk as in cow milk. In the last decade, OS were characterised (Viverge

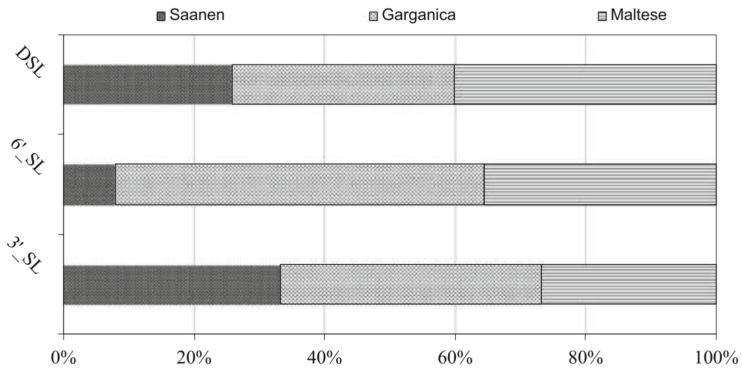

Fig. 9 Effect of goat breed on percentage of sialyloligosaccharides in milk (Claps et al. 2014)

et al. 1997) and quantified (Martinez-Ferez et al. 2006) in goat milk, and Baro Rodriguez et al. (2005) isolated and identified 25 oligosaccharides in Murciano-Granadina goat milk.

Recently, some studies have focused on the comparison of milk OS between goats with and without the genetic ability to synthesise αs1-casein (Meyrand et al. 2013), on the effect of genotype, at αs1-casein locus, and diet on SOS in goat milk (Di Trana et al. 2014a) and on the SOS content and their variation in the colostrum and milk of several goat breeds (Claps et al. 2014). In our study, the goat breed affected the content of three SOS: 3′-sialyllactose (3′-SL), 6′-sialyllactose (6′-SL) and disialyllactose (DSL). Differences in SOS compounds were found from colostrum to milk in *Garganica* and Maltese breeds. *Garganica* breed, a local breed of Gargano promontory in Apulian region, showed the higher values of 3′-SL and 6′-SL, while *Maltese* breed exhibited the higher content of DSL (Fig. 9). The same trend was observed comparing these data with unpublished data on Saanen breed. Although further studies are required, goat milk from native breeds appears to be an attractive natural source of human-like oligosaccharides for infant and health-promoting formulas, due to its composition and content.

3.5 Conclusion

Milk and cheese from *Girgentana* breed are distinguishable for FA profile, nutritional index and sensory properties compared to other breeds. Cheese from *Girgentana* breed shows a VOC profile that is confirmed by the corresponding sensory profile. The genetic types of goat and the genetic variants of casein fractions could have influenced the sensory profile of cheeses. The results are due to the presence in raw material of molecules produced by animals (fatty acids and casein) and also caused by grazing behaviour. These characteristics are the basis of the complex and multifactorial mechanism making the product "typical". These peculiarities add value to the *Girgentana* breed and therefore give a support in favour of this breed amplifying its sustainable use. The high quantity of SOS found in local breed *Garganica* compared to foreign breed appears an interesting and promising feature for adding value to local breeds.

4 Goat Breeds and *Ricotta* Cheese

In this section, we report a further example that can be considered a case study. Among products made from whey, *Ricotta* cheese is likely the earliest. It is considered as a high-moisture product, and it is essentially a co-precipitate of proteins with a mild flavour and soft texture.

Goat Ricotta Cheese

Whole goat whey cheese. It weighs 200–500 g and is consumed fresh; its shape is cylindrical, 11 cm in diameter and 8 cm high; there is no rind, the texture is compact but creamy, the paste is spreadable, eyeless and pure white coloured. Its odour is pleasantly lactic, no goaty; its taste is sweet, lactic, sapid and cloaking, slightly goaty.

This study was conducted under the same condition as for goat breed and *Caciotta* cheese case (see Sect. 3). The experimental flock was set-up with goats belonging to the *Local* (L), *Girgentana* (G), Red Syrian (R) and *Maltese* (M) goat breeds (Table 3). The flock management and feeding system are reported in the previous case (see Sect. 3) study.

4.1 *Ricotta Cheesemaking, Sampling and Analysis of Milk and Cheese*

Three *Ricotta* cheese-making trials for each breed were conducted. A simplified flowchart of cheese-making process is shown in Fig. 10. Thirty-six samples of whole milk, whey and *Ricotta* cheese were analysed for their chemical

Fig. 10 Flowchart of *Ricotta* cheese

Whey
↓
Straining of whey
↓
Heating at 90°C
↓
Coagulation at 85-90°C
↓
Standing of Ricotta cheese for about 10-15 min
↓
500g of Ricotta cheese was packaged in polyethylene bags
↓
Cooling
↓
Purchase

composition, FA profile, textural properties and sensorial properties. The analytical methods and assessment procedure are previously reported (see Sect. 2.1).

Changes in milk, whey and *Ricotta* cheese of chemical composition, FA profile, textural properties and sensory profile were analysed by ANOVA procedure (Systat 7 1997). The statistical analysis evaluated the effect of *Local*, *Girgentana*, *Maltese* and Red Syrian breeds. Data about sensory profile were normalised before submitting them to ANOVA repeated measures procedure. Significance was declared at $P < 0.05$; differences between means were tested using Fisher's LSD test.

4.2 Results and Discussion

The average gross composition of milk, whey and *Ricotta* cheese for each breed is shown in Table 7. The breed effect was more evident in *Ricotta* cheese than in whey and milk.

The main effects of goat breed in *Ricotta* cheese were found in dry matter, fat and lactose contents. The milk produced by R breed showed higher fat content when compared to the M and L breeds. G milk exhibited intermediate values. As concern the whey fraction, G, R and L breed had a higher content of dry matter than M breed. Ricotta cheese from the *Girgentana* breed showed a higher dry matter and lactose content and an intermediate fat content than the same product from R and M breeds. The *Ricotta* cheese from *Local* breed exhibited an interesting chemical composition with high fat and dry matter content. *Ricotta* cheese did not reflect the milk gross composition in terms of fat and dry matter. According to Pintado and Malcata (1996), differences between milk and *Ricotta* cheese are related to heating time and heating temperature during *Ricotta* cheesemaking.

The FA profile of *Ricotta* cheese was significantly affected by breed (Fig. 11). The cheese made from *Girgentana* breed contained significantly lower SFA content than other breeds. Compared to the L breed, G, R and M breeds had a higher content of MUFA, because of the higher oleic acid level. A higher PUFA content was

Table 7 Effect of breed on pH and chemical composition of milk, whey and *Ricotta* cheese (Pizzillo et al. 2005)

Product	Milk %					Whey %					Ricotta cheese %DM				
Breed[1]	G	R	M	L	SEM	G	R	M	L	SEM	G	R	M	L	SEM
pH	6.54	6.51	6.57	6.58	0.03	6.44	6.46	6.35	6.28	0.08	6.27	6.43	6.41	6.32	0.07
DM[2]	12.34	11.46	11.96	12.07	0.36	8.05^{a}	8.03^{a}	7.51^{b}	8.04^{a}	0.26	32.13^{a}	28.62^{b}	29.89^{b}	32.07^{a}	1.58
Fat	3.78^{ba}	4.10^{a}	3.52^{b}	3.59^{b}	0.24	1.58	1.82	1.64	1.72	0.11	64.56^{b}	61.63^{c}	66.83^{b}	71.75^{a}	3.73
Protein	3.33	3.33	3.13	3.29	0.09	1.14	1.15	1.05	1.02	0.06	20.77	24.00	21.03	19.81	1.42
Lactose	4.48	4.16	4.55	4.46	0.16	5.62	5.81	5.57	6.29	0.42	11.55^{a}	11.11^{a}	8.87^{b}	5.89^{b}	2.15

Means within row with different superscripts differ at $^{a,\ b,\ c}P < 0.05$
[1]*G* Girgentana; *R* Red Syrian; *M* Maltese; *L* Locale breeds; *SEM* standard error mean
[2]*DM* dry matter

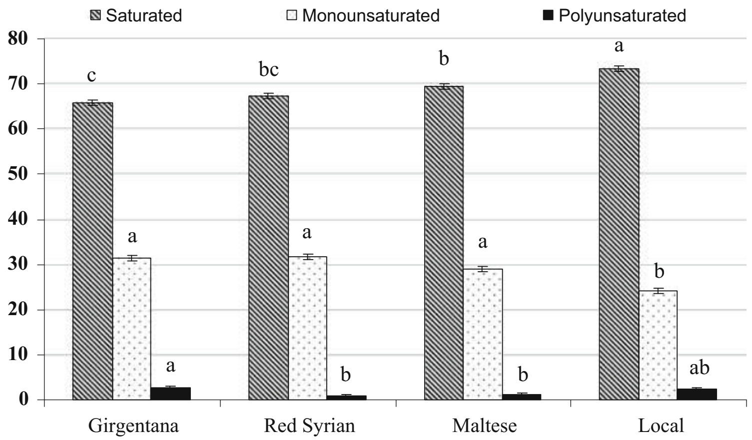

Fig. 11 Effect of goat breed on fatty acid composition (% FAME) of *Ricotta* cheese (Pizzillo et al. 2005). [a, b, c]$P < 0.05$

detected in *Ricotta* cheese from *Girgentana* breed compared to others because of the higher linoleic and arachidonic acid levels. Indeed, Ricotta cheese from G showed a level of linoleic acid 2.4, 2.7 and 1.1 times higher than R, M and L breeds, respectively, while its arachidonic acid content was 6.4, 1.6 and 1.9 times higher than the others.

As reported in previous studies (Di Trana et al. 2006a, b; Impemba et al. 2005), the breed affected the Δ^9-desaturase activity index (ratio C18:1/C18:0), G breed having higher index value followed by R, L and M breeds. The product:substrate ratio indicates increased enzyme activity in G breed. The high level of MUFA and PUFA present in *Ricotta* cheese from *Girgentana* goat could encourage the use of this breed.

In goat dairy products, taste plays an important role in consumer acceptance (Ribeiro and Ribeiro 2010). Within the textural and colour properties of *Ricotta* cheese, the adhesiveness only was affected by breed; *Girgentana* breed exhibited a significant higher adhesiveness than *Local* breed, while no differences were detected among the others. The lower value of adhesiveness, detected in *Ricotta* cheese made from whey of *Local* breed, may be due to the higher fat/protein ratio exhibited by this product (Roland et al. 1999). The sensory attributes are shown in Fig. 12. The breed affected some sensory properties of *Ricotta* cheese such as “softness”, “greasiness” and “granulosity”. Higher “softness” and “greasiness” and lower “granulosity” and “goat” attributes were found in cheese from G and L breeds than others.

In our case, the “goat” flavour scores of *Ricotta* cheese made from R and M milk may be related to the different ratio of lipolysis and/or different frequencies of the as1-casein locus alleles (see Sect. 3.3). Large differences in texture and taste among cheeses issued from milk of different breeds and/or within breed are linked to the genetic variant of as1-casein in goats (Coulon et al. 2004). The characteristic “goat”

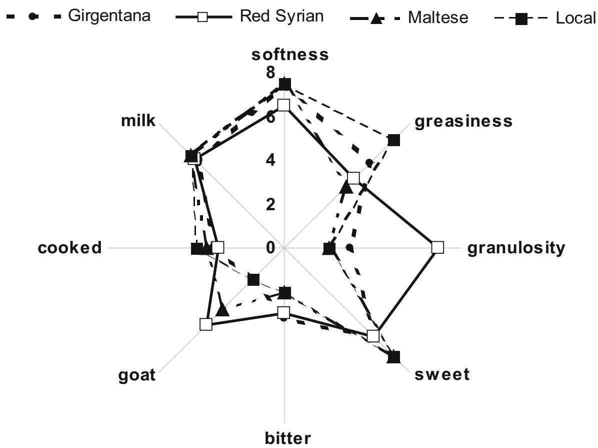

Fig. 12 Effect of goat breed on sensory profile of *Ricotta* cheese (Pizzillo et al. 2005)

flavour of goat milk products originates from milk fat and from the rate of fat hydrolysis; moreover, Grosclaude et al. (1994) have emphasised on the genetic dependence (see Sect. 3.3) of the variation of goat flavour intensity.

4.3 Conclusion

The results indicate that sensory properties and FA composition of *Ricotta* cheese vary according to the goat breed. The higher MUFA and PUFA levels, found in *Ricotta* cheese made from whey of *Girgentana* goats, are beneficial to human nutrition. Moreover, the greater “softness” and the lower sensor scores for “granulosity” and “goat” odour exhibited by this product could satisfy consumer demand for a cheese with adequate sensory and nutritional properties. The peculiarities of the *Girgentana* breed may motivate the use of this breed, and they are a tool for amplifying the sustainable use.

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Innovative Use of Jenny Milk from Sustainable Rearing

Carlo Cosentino, Rosanna Paolino, Mauro Musto, and Pierangelo Freschi

Abstract Thanks to its chemical composition and nutrient profile, jenny milk is usually recommended for the needs of newborn, heart and cholesterolemic patients. Nevertheless, the future use of this product is still to be defined. In the present, contributions of two promising ways of milk valorisation were discussed: natural cosmetics and new cheese productions. The results of our studies showed that face creams made with jenny milk allow a better skin hydration and moisturisation compared to conventional cosmetics. Moreover, the addition of small amounts of jenny milk is able to prevent late blowing defects in cow and in ewe cheese making. The provision of these findings to farmers may have important socio-economic and ecological implications.

1 Why a Growing Interest Towards Donkey Rearing?

The Pan-European Strategy on Biological and Landscape Diversity has encouraged the institution of new protected areas of regional and of national parks aimed to safeguard the extensive agriculture and the sustainable rearing of autochthonous breeds in order to reduce the abandon of rural areas. These areas, which include parks, reserves and marginal areas, have an economy mainly based on agriculture, livestock production and forestry. Among these activities, livestock production in general and the raising of autochthonous livestock breeds in particular contributed significantly to create traditional agricultural landscapes supporting a greater variety of plants and wild animals. Therefore, to maintain and valorise this biodiversity, it is fundamental to preserve and/or reintroduce autochthonous breeds into these areas. This, in turn, may have positive implications for protecting and conserving the natural heritage of these areas (Signorello et al. 2004).

In this context, the pastoral activity and semi-extensive farming of donkey, if properly managed, may exert a positive influence on biodiversity. Donkeys are

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_8

grazers as well as browsers (Aganga and Tsopito 1998). Their teeth and lips allow them to graze close to the ground; thus, they can efficiently graze short vegetation. These animals are non-selective grazers (Aganga et al. 2000), preferring thistles, rushes and other coarse vegetation to more palatable grasses. Thus, donkeys are capable of controlling some invasive plant species and those with less appetite (Cosentino et al. 2012).

In recent years, there has been a renewed interest towards the products (milk and meat) and social practices (rural tourism, onotherapy, etc.) that this species can offer, although donkey's breeding is still poorly widespread (Vincenzetti et al. 2008). Concerning milk production, it is well known that jennies provide milk that shows the closest similarity to human milk (Malacarne et al. 2002). Thanks to its nutritional characteristics, jenny milk has several applications: in paediatric sphere, in patients affected by cow's milk protein allergy and intolerance, as best alternative to human milk in infant food and in geriatric field for the treatment of ageing diseases (Tesse et al. 2009; Caffarelli et al. 2010). According to the literature, this milk has low levels of casein allergens and high levels of lactose, of unsaturated fatty acids (linoleic and linolenic) and of lysozyme. This enzyme is practically absent in other species (cow, goat, sheep, human) (Miranda et al. 2004) and has important physiological functions like inhibition of certain microorganism growth, anti-inflammatory and antitumoural activity and increase of defence system in early childhood (Monti et al. 2007; La Torre et al. 2010; Nazzaro et al. 2010; Simos et al. 2011). Some jenny milk whey proteins (α-lactalbumin, in particular, and β-lactoglobulin) stimulate cytokine production with a considerable in vitro anti-proliferative activity (Erdmann et al. 2008; Criscione et al. 2009; Mao et al. 2009). Moreover, thanks to some of its characteristics (vasodilator function, high calcium content and low energy value), it is indicated in patients affected by heart disease, osteoporosis and atherosclerosis (Hernández Ledesma et al. 2006; Iacono and Scalici 2011).

Another promising valorisation strategy of jenny milk is the use of this product in cosmetic preparations. Nowadays, the cosmetic trade is mainly focused towards products made with natural ingredients, and it is oriented to a sustainable consumption without preservatives addition. This has led many companies to increase the use of natural ingredients in existing preparations or to create new products (Lundov et al. 2009; Parente et al. 2011). Because of their natural origin, milk components correspond in many fields to the needs of cosmetology. Proteins and other components of milk have a strong absorption capacity and water retention, encouraging a high degree of hydration of the skin and preventing the degradation of the epidermal cells (Temuujin et al. 2006; Simos et al. 2011). Moreover, milk proteins with a glycosylated part could be largely used in all products developed to fight against skin ageing. Among these, for example, lactoferrin, which has a high iron-chelating property, could prevent free radical production by the skin after long periods of exposure to the sun (Cotte 1991; Girardet et al. 2004).

In cosmetic preparations, jenny milk is often used as basic constituent. Minerals, vitamins, fatty acids, bioactive enzyme and coenzyme, lactose and whey proteins contained in jenny milk prevent skin-ageing process, thanks to the hydrating and restructuring action of the dermal intercellular substance (Cosentino et al. 2011; Orsingher 2011). It is known that these properties are principally due to the high lysozyme and to the antioxidant action of fatty acids contained in jenny milk (Polidori et al. 2009a; Tesse et al. 2009; Simos et al. 2011; Al-Saiady et al. 2012; Cosentino and Paolino 2012; Cosentino et al. 2012).

With regard to donkey meat, recent studies (Polidori et al. 2008a, b, 2009b) demonstrated that this product may be used as an alternative to other red meats and for the sausages production. The donkey meat has an important chemical and nutritional value: besides, it has a low content of fat and of cholesterol, a high protein and unsaturated fatty acid contents and high amounts of potassium, phosphorus, sodium and magnesium. Maniaci et al. (2009) showed a high acceptability for sausage made from only donkey meat compared to sausage made with only Sicilian pig meat and mixed. Marino et al. (2009), in a study on donkey dried beef, found a low percentage of saturated fatty acids and a high content of polyunsaturated fatty acids, with higher amounts of ω-3 compared to dried beef obtained with cow meat.

Another important aspect related to the raising of donkeys is the possibility of using this species in important social practices, such as pet therapy. Thanks to its quite temperament, donkey can play an important role for the treatment of certain personality disorders (Patti and Gaziano 2007). To exploit this important "ability", in Italy, in recent years, the number of rehabilitation centres and social farms considerably increased (Cirulli and Alleva 2007; Rossaro 2009).

2 Main Characteristics of Donkey Farms in Basilicata Region

2.1 Donkey Population

In the early of the twentieth century, Italy was the second European country with the largest number (almost one million) of donkeys (Cosentino et al. 2010). This result was due to the creation of new farms raising donkeys as well as to the numerical consolidation of the pre-existent rearing.

The number of donkey farms has historically been higher in south of Italy, where the species has played an important role in the rural life being a useful travelling companion between rural and urban residence. This is particularly true for the Basilicata region, where the species is quite spread, but a well-defined autochthonous genetic type is still absent. Until the 1920s, the Pugliese was the most common breed of donkey. Indeed, it included several subraces (such as Martina Franca, Marchigiana, Romagnola, Calabrese and Lucana) sharing many morphological characters, including the dark colour of coat (Baroncini 1987). Although some of these subraces were appreciated for their rusticity, a reduction of their consistency occurred over the years in Basilicata. However, in recent years, following a national trend, there has been a renewed interest towards this species, especially thanks to some regional policies aimed at promoting the reintroduction of autochthonous breeds and the adoption of extensive and sustainable rearing systems, in order to prevent the abandonment of rural areas and to preserve the naturalistic heritage of the region (Signorello et al. 2004; Regione Basilicata 2011).

The study of Cosentino et al. (2010) provided important information relating to the different aspects of farms raising donkeys in Basilicata. According to the authors, most of the farms are small sized and family owned, with the farmer playing a key role in the defence and government of rural areas (Mauri 2007). A total of 660 donkeys (1.3 % of the national population) are reared in the farms localised in Basilicata. About 90 % of the farms are situated in the mountainous areas of the region (ISTAT 2002, 2011), where there is the greatest number of donkeys (82 %). Over the past 10 years, there was a reduction of the number of subjects (from 830 to 660), with the concurrent increase of the average number per farm (from 2.7 to 4.68). The highest number of donkeys has been recorded in the province of Potenza, where 403 donkeys are reared in 104 farms. In the province of Matera, instead, there are 257 subjects reared in 37 farms. The farms can be divided into the following classes: equestrian with mares (64), reproduction (9), meat with mares (21) and work (47).

With regard to protected areas of Basilicata, about 50 % of the donkeys are reared in the Regional and National Parks (National Park of Appennino Lucano Val d'Agri Lagonegrese, 130 subjects; Pollino National Park, 68 subjects; Regional Park Gallipoli Cognato, 78 subjects; Regional Park of Matera Chiese Rupestri, 43 subjects). A high number of donkeys were found in some municipalities of the Parks, such as Calciano (49), Lauria (40), Matera (36), Anzi (33) and San Martino d'Agri (28).

2.2 *Morphological and Biometrical Characteristics of Local Population*

In the past decades, a number of studies on morphological and biometrical characteristics of the species have been carried out to establish for the Italian breeds the standards for the anagraphic registers (Cecchi et al. 2007). Other studies, instead, investigated the genetic relationship among the Italian populations (Di Rosa et al. 2007).

An important contribution to the definition of the morphometric characteristics of donkeys reared in Basilicata is that of Cosentino et al. (2010). In their study, the authors recorded some morphometric and biometric characteristics of 52 donkeys reared in semi-extensive farms. Their results showed significant gender differences in terms of withers height, depth and width of chest, shin circumference and sternum height. In most of the cases, the colour of coat was blackish, whereas in others, it was grey mouse with both shoulders stripe and bay dark.

The local population of donkeys had a small size with the cephalic region more accentuated than trunk. The biometric indexes and the zoometric measurements indicated a longilinear or dolichomorphic type. These are probably due to the little interest of small farmers or owners of one or few donkeys in applying rigorous techniques of breeding or controlled mating according to morphology and genealogy (Jordana and Folch 1998).

Overall, the local population can be considered suitable to the milk production, pet therapy and transport in the mountain paths, just as other breeds like Martina Franca, Amiata and Ragusana (Monti et al. 2007; Conte and Passantino 2008).

3 Qualitative Characteristics of Jenny Milk

Producing jenny milk may be an interesting, profitable and alternative activity for farmers, mainly in southern marginal areas. However, in Basilicata, there are still few farmers that produce jenny milk. This is mainly due to poor farm consistency, which, in turn, makes it difficult to start this type of production. Moreover, the regional land conformation does not help the market of the milk, and the cost of production is much higher than cow milk for limited daily production. Overcoming these kinds of difficulties is fundamental to exploit all the commercial opportunities that jenny milk can offer.

Considering its unique nutrient profile, jenny milk may be easily employed to satisfy the nutritional requirements of newborn, heart and cholesterolemic patients. In particular, cow milk allergy, heart ageing and cholesterolemic diseases are considered to be increasing problems, and, for these reasons, the acquisition of new knowledge on jenny milk is very important in clinical and nutritional aspects. However, little is known about qualitative and quantitative characteristics of jenny milk. Although the species is a seasonal polyestrous, in south of Italy, jennies foal every season, probably because of small photoperiod oscillations between different seasons, and, consequently, milk is available all year (Giosuè et al. 2008). During lactation, this species has a low but constant daily production (Malacarne et al. 2002; Polidori et al. 2009a). Production level is influenced by several aspects, such as stage of lactation, milking technique, presence of the foal and foaling season (Dell'Orto et al. 1993; Oftedal et al. 1983). In particular, during milking, the presence of foal and the stage of lactation influence fat and protein content. Moreover, lactose content is constant during lactation, being independent of breed, milking time and stage of lactation (Guo et al. 2007). Jenny milk composition is similar among subjects from different continents, except for fat content (Blasi et al. 2008; Ivanković et al. 2009).

Cosentino et al. (unpublished data) evaluated some aspects of donkey rearing that include the influence of lactation stage (30, 90 and 150 days from foaling) and of foaling season (spring and summer) on some qualitative aspects of jenny milk, in a farm situated at an altitude of 700 m a.s.l. in a protected area of Appennino Lucano National Park. The research was carried out on 23 jennies belonging to a local population and aged between 7 and 10 years. These jennies foaled in two different periods: spring and summer (12 and 14 jennies, respectively). Milk samples were collected monthly, in the periods March–August in spring group and July–November in summer group. During the trial period, jennies were confined in boxes with a large paddock, in order to avoid the effect of grazing on qualitative characteristics of milk. Animals were offered a diet consisting of ad libitum oat hay and of an integration of 3 kg of concentrate, characterised by the following mixture: 37 % flaked corn, 30 % oats, 9 % locust bean crushed, 8 % wheat bran, 8 % dehydrated alfalfa, 6 % beet pulp dried and 2 % minerals and vitamin supplement. Diet was dispensed twice a day: during milking and in the evening. From the second month after delivery, jennies were milked by mechanical milking (40 kPa vacuum level, 60 pulse per min), at 11:00 am. From 8:00 am to the end of milking, foals were separated from mares, but were kept in the adjacent box maintaining the visual and the acoustic contact.

Immediately after collection, on milk individual samples were measured: pH and titratable acidity, protein, fat, lactose, dry matter and ash content. In addition, somatic cell count (SCC), expressed as somatic cell score (SCS, $\log_{10}n \times 1{,}000$/mL), was determined.

The groups showed a milk production trend similar to that observed in literature by other authors (Giosuè et al. 2008; Santos and Silvestre 2008). Milk production, protein, ash, SCS and pH resulted highest in summer at 30 days; protein and pH resulted highest in summer also at 90 and 150 days, respectively (Table 1). Ash content in tendency decreased during lactation. The highest mineral content, at the start of lactation, is particularly important for the first growth stage of the young foal (Csapó-Kiss et al. 1995). During lactation, pH values varied significantly between groups. SCS values observed from other authors ranged from 3.94 to 4.34 (Beghelli et al. 2009; Finocchiaro and Conte 2009; Ivanković et al. 2009). In spring group, protein content was high at the start of lactation, decreased to a minimum at 90 days and increased at the end of lactation, as observed by Guo et al. (2007); instead, summer lactation showed two peaks at 30 and at 90 days. Protein content resulted lower than the values reported by other authors that studied the effects of seasons on jenny milk characteristics: 19.3 g/L in spring and 18.1 g/L in summer in Sicilian breeds (Giosuè et al. 2008) and 16.5 g/L in spring and 14.3 g/L in summer in Croat breed (Ivanković et al. 2009). Fat content was significantly highest in summer group at the end of lactation. The average fat content of jenny milk was similar to mare milk and was much lower than other mammals; other authors observed values in the range 0.01–1.8 %. Lactose content and dry matter resulted significantly the lowest in summer only at 30 days. In the other periods, lactose was not influenced by the considered factors, as reported in literature (Oftedal and Jenness 1988; Santos and Silvestre 2008); dry matter content was in agreement with values reported in the literature for equine milk (Malacarne et al. 2002; Miranda et al. 2004); Ivanković et al. (2009) observed in Croat jenny values that ranged from 8.61 to 9.13 %. Titratable acidity (SH°) resulted highest in summer lactation at 90 and at 150 days, value lower than in cow's milk, attributable to the low content in casein and in phosphate (D'Auria et al. 2005; Guo et al. 2007).

Table 1 Jenny milk parameters (mean ± SE)

Parameters	Days post-foaling					
	30		90		150	
	Spring	Summer	Spring	Summer	Spring	Summer
Milk production (L/day)	1.05 ± 0.03^{a}	1.47 ± 0.12^{b}	1.38 ± 0.15	1.13 ± 0.18	0.91 ± 0.11	0.93 ± 0.12
Protein (g/L)	12.65 ± 0.18^{a}	13.76 ± 0.84^{b}	12.00 ± 0.18^{a}	12.90 ± 0.18^{b}	12.50 ± 0.09	12.70 ± 0.09
Fat (g/L)	4.00 ± 1.30	4.10 ± 0.7	2.10 ± 0.20	1.60 ± 0.10	2.30 ± 0.28^{A}	4.80 ± 0.65^{B}
Lactose (g/L)	60.60 ± 0.37^{A}	50.20 ± 1.30^{B}	58.50 ± 1.20	58.50 ± 0.70	59.10 ± 0.28	58.00 ± 0.37
Dry matter (g/L)	81.09 ± 1.20^{A}	72.60 ± 3.50^{B}	74.90 ± 1.20	77.00 ± 0.28	77.75 ± 0.50	79.30 ± 1.80
Ash (g/L)	3.80 ± 0.09^{A}	4.60 ± 0.18^{B}	3.80 ± 0.20	3.90 ± 0.20	3.80 ± 0.10	3.90 ± 0.10
pH	6.80 ± 0.03^{A}	6.95 ± 0.05^{B}	6.86 ± 0.04^{A}	6.70 ± 0.05^{B}	6.77 ± 0.02^{A}	7.02 ± 0.01^{B}
TA, SH°	2.48 ± 0.16	2.32 ± 0.15	2.09 ± 0.12^{a}	2.32 ± 0.14^{b}	1.86 ± 0.12^{a}	2.32 ± 0.20^{b}
SCS, $\log_{10} n \times 1{,}000$ (mL)	3.31 ± 0.03^{A}	4.37 ± 0.06^{B}	3.62 ± 0.03	4.28 ± 0.08	3.90 ± 0.04	4.30 ± 0.02

Means within periods with different superscripts significantly differ: a, b = $P < 0.05$; A, B = $P < 0.01$

3.1 Cosmetics Made with Jenny Milk

The first representation of the donkey species was found in Egypt in a bas-relief of 2500 BC, and from the time of Herodotus (V century BC), donkey began to be appreciated for the therapeutic properties of its milk (Melani 1998; Paolicelli 2005). Some historical texts, such as the *De Materia Medica* of Dioscoride and the *Naturalis Historia* of Pliny the Elder, describing various uses of milk in cosmetics, and Ovid also, in his *Medicamina Faciei Femineae*, suggest beauty masks made with donkey milk (Virgili 1989).

Today, thanks to the properties of milk components, there are several products made from milk of different species in the cosmetic market. Cow milk preparations (face and body creams, cleansing milk and tonic) are the most known by consumers. However, there are cosmetics made from other ruminants like camel (Kalejman 2011), sheep (Drader 2005) and goat (Ribeiro and Ribeiro 2010) or from monogastric species like horse and donkey (Medhammar et al. 2012; Song 2012; Cosentino et al. 2013a). Mare's milk is considered as an ingredient in Mongolian cosmetics because of its high content of polyunsaturated fatty acids, which make it readily absorbed by human skin (Temuujin et al. 2006). It is known that jenny milk properties are principally due to the high lysozyme and to the antioxidant action of fatty acids contained in jenny milk (Tesse et al. 2009; Al-Saiady et al. 2012; Cosentino and Paolino 2012; Cosentino et al. 2012).

Notwithstanding the beautifying benefits of the jenny milk have been historically acclaimed (since Cleopatra), few studies have been conducted on its perceived quality in cosmetics or on its actions about skin-ageing process hydrating and restructuring the dermal intercellular substance (Orsingher 2011; Paolino and Cosentino 2011).

Cosentino et al. (2014) preliminarily evaluated whether the use of a face cream made from milk jenny affected the perception of some sensory aspects. The test was conducted on 80 regular female consumers of cosmetic cream, subdivided according to their skin type: dry (25), normal (30) and oily (25). Consumers were given two types of creams: a control and a treated cream, with the latter created by adding pasteurised jenny milk (30 % on total weight). Both creams were packaged in 50-mL containers and given to consumers with a ballot consisting of 11 questions about attributes of appearance, fragrance and effectiveness and the overall satisfaction of each cream. Consumers tested both face creams at home, for a period of 15 days; they were asked to apply the face cream every evening and to rate the attributes presented in the questionnaire for each face cream at the end of trial. The results showed that treated cream resulted appreciated by dry skin consumers for the following sensory aspects: spreadability, total appearance, smoothness, moisturisation and total effectiveness (Fig. 1). The overall judgement also resulted highest for face cream made with jenny milk. The other consumers expressed a good acceptability for both tested creams. These results confirm that jenny milk could be a cosmetic component suitable for all skin types thanks to its balancing skin moisture (Salimei and Fantuz 2012). A recent study on a face cream containing

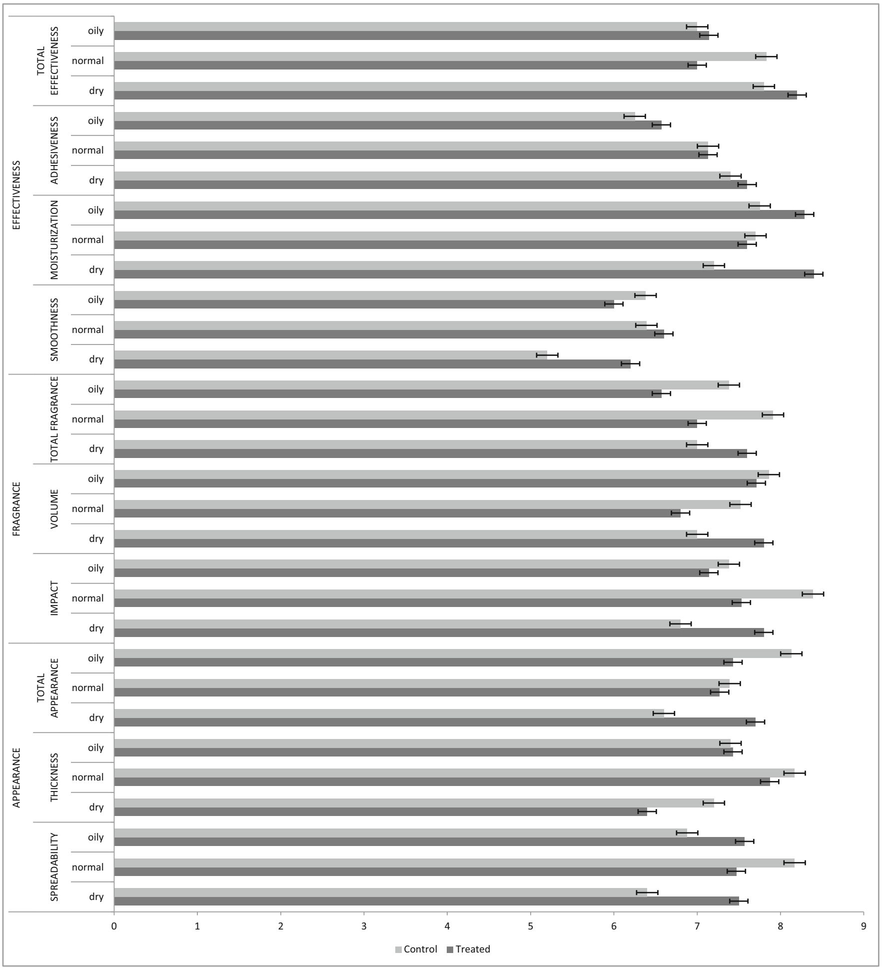

Fig. 1 Sensorial aspects of control and treated (made with jenny milk) face creams at the end of the trial (mean ± SE)

lyophilised jenny milk (Orsingher 2011) showed a lot of benefits, such as wrinkle reduction, new collagen formation, restoration of the skin's natural defences against external agents, prevention of inflammatory processes in the case of dermatitis and increased elasticity. These results are probably related to the effectiveness of jenny milk components like proteins, minerals, vitamins, essential fatty acids and lysozyme, which allow the skin a balanced nourishment and a proper hydration (Guo et al. 2007). Lactose, particularly high in jenny milk, is an important emollient and moisturiser (Temuujin et al. 2006; Polidori et al. 2009a).

The beautifying properties in calming the irritation symptoms (Blasi et al. 2008; Vincenzetti et al. 2012) and in restructuring skin-ageing process (Nazzaro et al. 2010; Al-Saiady et al. 2012) of its whey proteins (β-lactoglobulin and lysozyme) and of its essential amino acids are also well known. For this reason, it could be much more profitable if use in higher water content cosmetics (body and after-shave lotions, shampoos, hair conditioners and cleansing milk), in which a larger use of milk is possible.

These results clearly show that jenny milk could be a valuable and innovative ingredient for cosmetics. The marketing of cosmetics made with jenny milk could help to preserve local donkey genotypes and the marginal areas in which they are reared. A major challenge for the marketing of these kinds of products is the consumer's knowledge about jenny milk and sustainable farms. In this context, packaging may have an important communicative function thanks to iconic and textual elements (Topoyan and Zeki 2008). The measurement of packaging attributes is very difficult because a package generally induces a wide variety of stimuli: visual, tactile and even olfactory. For example, visual and tactile stimuli affect the consumer choices at time of purchase.

Cosentino et al. (2011) evaluated consumer knowledge on some qualitative and quantitative aspects of jenny milk cosmetics. Their main aim was to identify some packaging factors that influence consumer liking. The study was conducted using the quantitative method by interviews with a one to one questionnaire, consisting of 18 questions, that has been randomly administered to 450 people residing in the test area. The age of sample was in mean 40 years, since people in this age range are the most strongly concerned to counteract skin-ageing process and the appearance of wrinkles. The results showed that about 70 % of the surveyed consumers were willing to purchase a product labelled as "new generation cosmetics", probably because this cue refers to innovation and modernity in their imagination. These cosmetics could absorb a significant portion of the market for natural cosmetics based on milk. Descriptive survey put in evidence that customers knew jenny milk and expressed willingness to buy cosmetics made with this kind of milk in the future. Few consumers were already familiar with jenny milk cosmetics and had already bought this kind of product. In general, consumers showed a willingness to buy cosmetics in low price classes. However, many consumers were willing to pay more for these cosmetics if produced in sustainable rearing system and in the respect of animal welfare.

More recently, Cosentino et al. (2013a), in a study on the acceptability of different types of packaging for exalting the quality of cosmetics with jenny milk, found that consumers preferred the one evoking the concept of natural. A total of 300 consumers, aged in mean 33 years, evaluated the preferences by using a scale of values from 1 to 5. In order to identify the most preferred packaging, the naming, the type of packing paper and the communication aspect of packaging were studied (Fig. 2). The naming has been developed starting from the concepts of delicacy and of naturalness, with the direct representation of the product source, like the donkey with a specific soft brown tone coat. The name "Asinella" was the most preferred by a jury of 50 habitual cosmetic consumers; the farmers also identified it as the best choice (Fig. 2).

Fig. 2 Types of packaging

Consumers were asked to evaluate different types of packing paper: matte, glossy and glossy embossed with texture (Fig. 2). Matte paper was the most preferred, because it evoked the perception of natural, more than the glossy paper, which is usually used by the competitors (Asilac, Milk drops and Dahl). In addition, consumers were more willing to buy cosmetics packaged with matte paper.

The communication aspect of packaging proposed was A, “Asinella”; B, “Asinella” + “Natural product”; and C, “Asinella” + “Natural product” + “Made in Basilicata” (Fig. 2). Consumers considered packaging information important to induce to purchase and judged the message of type B more persuasive than the other two communication forms of packaging, probably for the reliability of the product. They also considered the most persuasive combination in purchasing the name “Asinella”, with the text label “Natural product”. From the consumer perspective, naming is an important quality cue and makes it easier to infer quality. In addition to this parameter, traceability systems, branding and labelling can help consumer's choice (Grunert 2002).

3.2 Jenny Milk as Inhibitor in Cheese Making

Late blowing defects on ripened semihard and hard cheese are an important problem with a high negative economic impact in dairy production. The causes depend on both technological and microbiological factors. Technological factors include milk quality, heat treatment, hygiene practices, manufacture technology, compositional parameters and ripening temperature/moisture, which influence cheese making and ripening (Bogović Matijaŝić et al. 2007). Microbiological factors are the most difficult to control, because undesirable microorganisms, such as coliforms, yeasts, heterofermentative lactic acid bacteria and spore-forming bacteria, may cause early or late blowing defects in cheeses (Little et al. 2008; Gómez-Torres et al. 2014). Late blowing defect in semihard and hard cheeses has been attributed to the outgrowth of strains of *Clostridium* spp. (mainly *C. butyricum* and *C. tyrobutyricum*), capable of fermenting lactic acid with production of butyric acid, acetic acid, carbon dioxide and hydrogen (Garde et al. 2012). *Clostridium* spores are ubiquitous, much more resistant to heat, chemicals, irradiation and desiccation than vegetative cells, and its growth in cheese is affected critically by different factors such as salt concentration, pH, ripening time and temperature as well as by the presence of other microorganisms (Garde et al. 2011).

Many studies have attempted to prevent late blowing by physical treatments (bactofugation or microfiltration prior to processing), or by the use of additives (nitrate or lysozyme), or by the addition of strains of lactic acid bacteria (LAB) producing bacteriocins, active peptides displaying a bactericidal mode of action towards specific Gram-positive bacteria (Wasserfall and Teuber 1979; Vissers et al. 2007; Martìnez-Cuesta et al. 2010; Schneider et al. 2010).

Among the above prevention methods, the use of lysozyme as a commercial additive is the preferred one since 1983. Lysozyme, which is typically extracted from hen egg white (HEW, 3.5 % of the egg white proteins), has been approved as a preservative (E1105) in the entire European Community, according to the Directive No. 95/2/EC (*quantum satis* in ripened cheese) (Pellegrino and Tirelli 2000; Scharfen et al. 2007; Schneider et al. 2011). In Italy, the use of lysozyme is quite widespread: this enzyme has been employed in the process of making several cheeses, such as Grana Padano cheese, grated hard cheese mixtures (Iaconelli et al. 2008; Panari and Filippi 2009) and semihard goat and ewe cheeses (Dragoni et al. 2011; Schneider et al. 2011). The content of lysozyme from egg in cheese ranges from 50 to 350 μg/g of cheese, with the maximum of 400 μg/g of cheese depending on the type of cheese and the production process (Pellegrino and Tirelli 2000; Ávila et al. 2014).

In recent years, the use of lysozyme from egg as a prevention agent has waned, since some studies have shown its allergenic effect in consumers allergic to egg, due to its content in ovomucoid, ovalbumin and conalbumin (Frémont et al. 1997; Pérez-Caldero et al. 2007). In the last decade, a number of severe allergic reactions have been recorded due to the presence of lysozyme E1105 in semihard cheeses. Frémont et al. (1997) found patients allergic to eggs to show a severe reaction after eating Gruyere cheese. Kerkaert et al. (2010) reported that 5 out of 21 case studies of allergic reactions to eggs were attributed to the presence of this additive in cheese and that this additive was likely responsible for episodes of severe edema (Pérez-Caldero et al. 2007). For these reasons, in the recently changed EC legislation, the use of lysozyme as an additive has to be declared on the label (EC legislation in Europe 2003/89/EC, Directive 2000/13/EC).

Jenny milk may be a possible alternative to the use of lysozyme from egg during cheese making. In fact, jenny milk is characterised by a high lysozyme content, ranging from 1.0 to 3.7 mg/mL, according to the lactation stage and the production season (Zhang et al. 2008; Vincenzetti et al. 2012). The content of lysozyme in jenny milk is much higher than cow (0.13 μg/mL), ewe (0.20 μg/mL) or goat milk (0.25 μg/mL) (Fratini et al. 2006; Scharfen et al. 2007; Cosentino and Paolino 2012). Moreover, in jenny milk, lysozyme shows the highest activity at an optimum temperature of 37 °C and is stable up to a temperature of 50 °C, decreasing to 50 % of activity at 70 °C. Recently, Galassi et al. (2012) described the addition of jenny milk as a substitute for egg lysozyme to prevent late blowing in Grana Padano cheese. The authors found that the addition of 10 L of jenny milk in 500 L of cow milk reduced significantly physico-chemical and microbiological defects of cheese. Cosentino and Paolino (2012) studied the effect of lysozyme from jenny milk on blowing defects in artisanal ewe cheese caused by clostridia and coliforms, usually present in ewe cheese produced in traditional cheese factories. When adding jenny milk to ewe milk, no late blowing defect on cheese was observed (Fig. 3). Therefore, lysozyme contained in jenny milk was found to be an important inhibitor agent against coliform bacteria, although its addition to ewe milk did not affect the number of *Clostridium butyricum* spores (Cosentino and Paolino 2012; Cosentino et al. 2013b). The lower content of coliforms in treated ewe cheese was in agreement with results from the literature on reduced growth of *C. butyricum* in Grana Padano (Iaconelli et al. 2008; Dragoni et al. 2011) and Gouda cheese (Bester and Lombard 1990). Martìnez-Cuesta et al. (2010) observed a higher contamination of *Clostridium* in Manchego control cheese compared with that treated with lysozyme HEW.

Cosentino et al. (unpublished data) also evaluated whether increasing additions of jenny milk to pasteurised cow milk reduced the late blowing defect in semihard cheese caused by *C. tyrobutyricum*. To verify this hypothesis, the authors made two types of cheeses, control and treated, with the latter being deliberately contaminated with approximately 3 log spores/mL milk of *C. tyrobutyricum* CLST01, in order to induce butyric acid fermentation and consequent blowing defect. Both control and treated cheeses were made by adding different aliquots of jenny milk to cow milk. The addition of jenny milk resulted in a sporostatic effect on both control and treated cheeses. Visual and odour inspections during ripening demonstrated that all cheeses contaminated with *C. tyrobutyricum* developed signs of late blowing

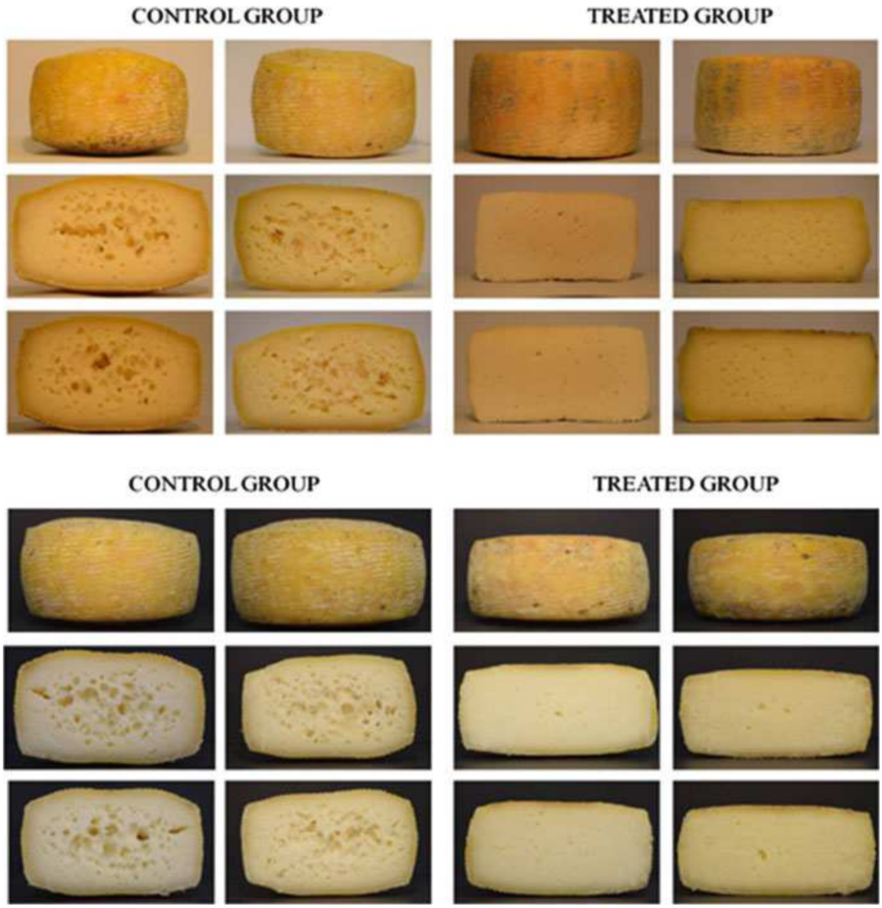

Fig. 3 Signs of late blowing defects in ewe cheese (from first to third row) and cow cheese (from fourth to sixth row) at the end of ripening

defect, except the cheese containing the highest aliquot of jenny milk. This product presented a uniform texture without cracks and splits (Fig. 3). The content of lysozyme was high in both control and treated cheeses (1.57 and 1.52 mg/kg, respectively). Ávila et al. (2014) found that 40 µg/mL of lysozyme was the concentration required to completely inhibit the growth of vegetative cells of *C. tyrobutyricum* strains. Cosentino et al. (unpublished data) also found that the acceptability of cheeses was not affected by the addition of jenny milk, since consumers did not found differences between the products made with only cow milk and those made also with jenny milk. These results are in line with the findings of Galassi et al. (2012).

4 Conclusions

The 21st agenda item of World Summit carried out in Rio in 1992 emphasised the intrinsic value of biological diversity and its ecological, genetic and socio-economic components, recognising that the fundamental need for the preservation is the in situ safeguard of ecosystems and of natural habitats. In recent years, diversity preservation has become an important topic, as shown by different strategies and action plans, such as "Countdown 2010" and "Forests 2011" for European and national governments and for productive sectors.

In this context, the jenny rearing finds its ideal placement thanks to its peculiarities capable to fulfil the requirements of a wide range of consumers, from newborn nutritional needs to those of elderly people.

The present contribution provides a wide discussion of the above aspects, highlighting alternative ways of valorisation of this precious animal production. Among them, one of the most promising is the use of jenny milk for making innovative products (new cheese productions and natural cosmetics), which, in turn, may led to the expansion of donkey rearing for milk production, even in more vulnerable areas, such as Natura 2000 Network sites.

Acknowledgements These researches were supported by:

Onocosmesi Project "Conservation and Preservation of the species mules through the exploitation of marginal areas in onocosmesi products from milk of donkey" by the Agriculture, Rural Development, and Mountain Economics Department of Basilicata Region

MIBAF Project by PIF—Rural Development Programme Basilicata Region 2007–2013, Fund FEASR, Board 1, Measure 124–PIF Green Farms: "Together to raise, transform, marketing and grow in quality with Green Farms"

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Sustainable Agricultural Practices in Disease Defence of Traditional Crops in Southern Italy: The Case Study of Tomato Cherry Protected by *Trichoderma harzianum* T-22 Against *Cucumber Mosaic Virus* (CMV)

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Abstract Nowadays, crop production is at risk due to global warming, especially in Mediterranean areas where the increase of air temperature and/or reduction of precipitation is relevant. Climate changes that are occurring can severely prejudice plant defensive mechanisms during host-pathogen interactions by modifying growth and physiology of the host plant. In particular, viral diseases cause serious economic losses destroying crops and reducing agronomic productivity, and, in some cases such as tomato crops, they become the limiting factor production of both open field and under greenhouse cultivation systems. This is because plant viruses are obligate parasites and require living tissue for their multiplication and spread. Therefore, they are able to interfere with plant metabolism and compete for host plant resources, so determining a decrease of plant growth and productivity. Severe outbreaks of *Cucumber mosaic virus* (CMV) and other viruses caused disruption of tomato plants in the Mediterranean region and in Southern Italy since the 1970s. In such a scenario, it is necessary to introduce new strategies for controlling plant pathogens and parasites in order to help maintain ecosystems and to boost sustainable agriculture. The aim of this work is to give an up-to-date overview on the recent breakthroughs in the use of microorganisms on plants for improving crop yields, quality and plant tolerance against pathogens. In particular, here we report a case study regarding an innovative strategy to control a viral disease (CMV) in tomato, based on the use of rhizosphere microorganism (*Trichoderma harzianum*, strain T-22) as an antagonist biocontrol agent (BCA).

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_9

1 Introduction

In the Mediterranean basin, horticultural crops have a great economic relevance. If we think of the Mediterranean diet, which is considered as one of the healthiest amongst world cuisines, above all since November 2010, when it was inscribed on the representative list of the intangible cultural heritage of humanity of UNESCO, tomato (*Solanum lycopersicum*) is certainly the vegetable most widely consumed. In Italy, in particular in the South, tomato is not only the first vegetable employed for fresh consumption, but it also represents the principal ingredient of many dishes, and it is above all used cooked to prepare sauces. The importance of tomato consists in its nutraceutical properties, due to the presence of an antioxidant substances mixture, such as lycopene, ascorbic acid, phenolic compounds, flavonoids and vitamin E. For this reason, nowadays tomato is cultivated both in open field and under greenhouse conditions in order to be always available for both fresh consumption and industrial processing.

Unfortunately, crop production is at risk due to global warming, especially in areas where the increase of air temperature and/or reduction of precipitation is relevant. In addition, climate changes can prejudice plant defensive mechanisms and increase the risk of illness, through growth and physiology alteration of the host plant and also by modifying host-pathogen interactions. In particular, viral diseases cause serious economic losses destroying crops and reducing agronomic productivity. In many Mediterranean coastal areas, several viral infections have become the limiting factor in the tomato production of both open field and under greenhouse cultivation systems. For example, in Italy, Spain, Portugal and Greece, the cultivations are at risk due to *Tomato spotted wilt virus* (TSWV) infections (Pappu et al. 2009). Another important example is *Tomato yellow leaf curl virus* (TYLCV), which caused serious economic problems in the eastern Mediterranean basin in the 1970s, and it is still now a threat (Lapidot et al. 2014). In late summer 2000, more than 30 ha of Greek tomato greenhouses (Avgelis et al. 2001) were affected and the disease incidence by TYLCV, in 2001, in most cases, was 80–90 %, or even 100 % (Dovas et al. 2002). In the same the 1970s, *Cucumber mosaic virus* (CMV) severe outbreaks caused disruption and death of tomato plants in the Mediterranean region (Gallitelli et al. 1991). Tomato necrosis epidemic occurred in the eastern coastal area of Spain in the late 1980s and early 1990s (García-Arenal et al. 2000). During this period, in Southern Italy (Puglia, Basilicata and Campania regions), some high-quality varieties of tomato, i.e. San Marzano, were severely affected by the strong CMV epidemic (Valanzuolo et al. 1999).

Indeed, plant viruses are obligate parasites because they require living tissue for their multiplication and spread, interfering with plant metabolism and/or competing for host plant resources, and all this is translated as decreasing of plant growth and productivity. The ability of viruses to significantly interfere with physiological processes of plants is closely related to a range of symptoms caused by an abnormal growth, as stunting, galls, enations and tissue distortions. In particular, CMV is the plant virus with the largest host range of all RNA viruses; therefore, its spreading on crop plants may cause serious economic damages. It infects more than 1,200 plant species in 100 families (Edwardson and Christie 1991) and has been widely studied because it represents an interesting model from a physico-chemical point of view, as it causes a wide range of symptoms, especially yellow mottling, distortion and plant stunting (Nuzzaci et al. 2009; Whitham et al. 2006).

In such a scenario, the present work contributed to elucidate the importance in the use of sustainable agricultural practices in disease defence. In addition, here we report a case study regarding an innovative strategy to control a viral disease (CMV) in tomato cherry, based on the use of rhizosphere microorganism (*Trichoderma harzianum*, strain T-22) as an antagonist biocontrol agent (BCA).

2 Sustainable Agricultural Practices in Disease Defence

During the last decade, the studies on alternative environmental friendly technologies have received a strong impulse and have proposed a wide range of options, including agronomical, physical and biological control means. Recently, it was growing the idea that the plants have enormous self-defence potentiality, and this would allow a natural disease control with positive effects on environmental and human health safeguard (Sofo et al. 2014).

Many factors, both biotic (pathogens, insects, nematodes) and abiotic (e.g. wounds, pollutants, thermal, water and nutritional imbalances, environmental contaminants) are causes of plant stress. Plants can react to these stressors through a series of constitutive and/or inductive mechanisms which result in the elimination or the limitation of the negative effects induced by the adverse factors. The studies on these biochemical mechanisms allow to individuate control strategies against plant pathogens and parasites, based on the exploitation of the natural mechanisms of plant defence. One of this type of mechanism, already documented by Ross (1961), is known as systemic acquired resistance (SAR). It is effective against a wide range of pathogens and its action differs in relation to the inducer agent. Actually, the SAR represents a valid opportunity in plant natural protection, and, therefore, the research activities are oriented to the use of biocontrol agents as inducers of SAR in agronomically important species against some of their most severe pathogens (Sofo et al. 2014). In fact, research data accumulated in the past few years have produced a completely novel understanding of the way by which bacteria and fungi interact not only with other microbes but especially with plants and soil components. This has opened an avenue of new applications, both in agriculture and biotechnology, that exploit the ability of some microorganisms to change plant metabolism and resistance to biotic and abiotic stresses (Woo et al. 2006). Generally, as a response to diseases, plants may compensate with a broad range of cellular processes by up- or down-regulating certain genes; changing the levels of substances implicated in plant defence pathway; increasing the levels of reactive oxygen species (ROS); activating specific transcription factors, defence-regulated genes and heat shock proteins; and enhancing the transport of macromolecules, enzymes and phytohormones involved in defence signalling pathways [e.g. salicylic acid (SA); jasmonic acid (JA); ethylene (ET); auxins, such as indole-3-

acetic acid (IAA); cytokinins (CKs); abscisic acid (ABA); gibberellic acid (GA)] (Bari and Jones 2009; Vitti et al. 2013). On the other hand, all physiological process changes of plants as response to pathogens negatively affect the crops' yield with a loss of billions of euros each year not only for direct productivity decrease but also for the consequent managing of the pests. In addition, the use of traditional methods such as chemical pesticides, herbicides or fertilizer is not an eco-friendly approach, and their continued employment resulted on contamination of water, atmosphere pollution and the release of harmful residues in soils (Naher et al. 2014).

A safe method to reduce plant disease incidence without collateral damages to the environment and to human health induced by synthetic chemicals is the biological control (Tucci et al. 2011). In such a way, it is possible to manage pests by means of a sustainable approach where biocontrol agents can be used either alone or with other chemicals in an integrated practice of disease defence, according to European legislation Directives establish. The use of microorganisms for controlling plant pathogens has been shown to be very efficacious for some fungi of the genus *Glomus*, *Streptomyces*, *Trichoderma* and some species of bacteria (e.g., *Agrobacterium radiobacter* and *Bacillus subtilis*). In particular, some of these fungi interact with other fungi in a mechanism called mycoparasitism, wherein one fungus directly kills and obtains nutrients from other fungi. Mycoparasitism is one of the most important biocontrol mechanisms of *Trichoderma* spp. (Mukherjee 2011), which is considered the most versatile amongst all biocontrol agents and, for this reason, has long been used for managing plant pathogenic fungi (Vinale et al. 2009; Weindling 1934; Wells 1988). It was demonstrated that some fungal diseases can be also prevented when plants are treated with the conidial suspensions of *Trichoderma* spp. (Harman et al. 2004a). Fungi belonging to the genus *Trichoderma* are used as biocontrol agents to antagonize plant pathogens through a series of mechanisms including, in addition to mycoparasitism, competition for nutrients and space, fungistasis, antibiosis and/or modification of the rhizosphere (Benítez et al. 2004). *Trichoderma* spp. are some of the most abundant fungi found in many soil types and are able to colonise plant roots and plant debris (Harman et al. 2004a). They are agriculturally important also for their beneficial effects on plant growth and development and for their capability to induce plant defence responses against pathogens, damage provoked by insects and abiotic stress (Yedidia et al. 1999; Harman et al. 2004a; Woo and Lorito 2006). For this reason, more than 60 % of all registered products used for plant disease control are *Trichoderma*-based and they are a major source of many biofungicides and biofertilizers (Verma et al. 2007; Kaewchai et al. 2009).

In particular, the strain T-22 of *T. harzianum* (here called T22) represents the active ingredient of registered products widely employed in plant disease control. It is known that T22, by working as a deterrent, protects the roots from the assault of pathogens fungi (e.g. *Fusarium*, *Pythium*, *Rhizoctonia* and *Sclerotinia*). Establishing itself in the rhizosphere, T22 can grow on the root system, along which it establishes a barrier against pathogens. The action of T22 is not to produce something toxic to the pathogen but to induce the plant to change its physiology and metabolism to ameliorate its resistance to that disease (Harman et al. 2008). It was demonstrated that T22 improves growth in maize plants, increasing root formation (size and area of main and secondary roots) and, at the same time, rising crop yields, drought tolerance and resistance to compacted soils (Harman 2000; Harman et al. 2004b). This improvement in growth was probably due to direct effects on plants because of a better solubilization of soil nutrients or by a direct enhancing plant uptake of nutrients linked to the presence of T22 in the agroecosystems (Yedidia et al. 2001). The beneficial effects of T22 application depend on the treated plant genotype, as recently demonstrated by Tucci et al. (2011) on tomato plants.

3 The Case Study of Tomato Cherry Protected by *Trichoderma harzianum*T-22 Against CMV

In the context of plant defence by biotic stresses, understanding biochemical and molecular mechanisms deriving from the host-pathogen-*Trichoderma* interaction is without doubt essential for investigating the dynamics of infectious processes. This knowledge can be very useful for the development of new approaches for controlling phytopathogens, particularly viruses, against which chemical treatments have no effect (Vitti et al. 2015b). Thanks to recent studies, new strategies have been based on the use of peptaibols, a class of linear peptides biosynthesized by many species of *Trichoderma* (Daniel and Filho 2007). For example, it was demonstrated that trichokonins, antimicrobial peptaibols isolated from *Trichoderma pseudokoningii* SMF2, can induce tobacco systemic resistance against *Tobacco mosaic virus* (TMV) via the activation of multiple plant defence pathways based on an elicitor-like cellular response: production enhanced in tobacco plants of superoxide anion radical and peroxide; production enhanced of enzymes involved tobacco resistance, as peroxidase (POD); up-regulation of antioxidative enzyme genes, known to be associated with the ROS intermediate-mediated signalling pathway; and of SA-, ET- and JA-mediated defence pathway marker genes (Luo et al. 2010). This finding implies the antiviral potential of peptaibols, supporting the hypothesis to using them as biocontrol antiviral agents. Therefore, *Trichoderma* spp., already used as BCAs against bacterial (Segarra et al. 2009) and fungal phytopathogens (Vinale et al. 2009; Akrami et al. 2011), it was hypothesized could be advantageously used also in the control of virus diseases. *Trichoderma* spp. and/or their secondary metabolites were able to induce resistance mechanisms, similar to the hypersensitive response (HR), SAR and induced systemic resistance (ISR) in plants (Benítez et al. 2004; Harman et al. 2004a), regulated through a complex network of signal transduction pathways involving not only the abovementioned molecules, such as ROS, SA, JA and ET but also the crosstalk between them (Kunkel and Brooks 2002) and the so-called pathogenesis-related (PR) genes, a series of marker genes for the activation of SA, JA and ET signalling, involved in these defence transduction pathways (Bouchez et al. 2007). At this regard, Hermosa et al. (2012) assert that the expression of defence-related genes of the JA/ET and/or SA pathways may overlap just because of the dynamics in the *Trichoderma*-plant crosstalk.

To date, the effects of *Trichoderma* spp. in the induction of plant defence against CMV were poorly known. Only studies conducted by Elsharkawy et al. (2013) demonstrated that *Arabidopsis* plants were exploited against CMV by using *Trichoderma asperellum*SKT-1. In particular, when the researchers used barley grain inoculum, the fungus induced SAR, while ISR was elicited when *T. asperellum* was utilized as culture filtrate. On the other hand, the biochemical and molecular mechanism involved in this kind of three-way crosstalk between the plant, virus and antagonist agent has still to be well elucidated.

In such a scenario, our work represents the starting point to improve the knowledge on the possible underlying mechanisms involved in plant-pathogen-antagonist interactions and, at the same time, to develop an innovative strategy against CMV infection in tomato plants, based on the activity of a biocontrol agent (Vitti et al. 2015a).

Trichoderma harzianum strain T-22 (T22) was the antagonist microorganism used in this study. It was utilized as a granule formulation (Trianum G, Koppert, Berkel en Rodenrijs, the Netherlands). *Cucumber mosaic virus* strain Fny (CMV-Fny) was propagated in tobacco plants, purified as described by Lot et al. (1972), so that the purified CMV-Fny was used to mechanically inoculate tomato plants (*Solanum lycopersicum* var. cerasiforme).

As shown schematically in Fig. 1, tomato plants were treated with T22 and/or inoculated with CMV, according to the following six conditions: control plants untreated and healthy (PA); plants only treated with T22 (PB); plants only inoculated with CMV (PC); plants first treated with T22 and after 7 days inoculated with CMV (PD); plants simultaneously treated and inoculated with T22 and CMV (PE); and plants first inoculated with CMV and after 1 week treated with T22 (PF).

During the entire cycle of plant's life, symptom observations were monitored. Fourteen days after CMV inoculation (that is when the plants were at 1 month of age) and when the plants were 5 months old, leaves were collected and used for the following analyses: histochemical staining of O_2^- and H_2O_2 in leaf discs, in order to study the involvement of ROS and total RNA extraction from leaf tissues followed by reverse transcription polymerase chain reaction (RT-PCR) analysis, for the verification of the presence of CMV in tomato seedlings, or by real-time reverse transcription PCR (qRT-PCR), in order to analyse the transcript levels of the genes implicated in plant defence, such as genes encoding for antioxidant enzymes and for pathogenesis-related protein (Vitti et al. 2015a). In addition, here we report the yield evaluation for each experimental condition, determined since plants started to produce flowers and fruits (3 months of age) and until plants were 5 months old.

T22 showed the ability to control CMV infection on tomato cherry plants by modulating the viral symptoms during the entire life cycle of the plants and also by inhibiting the presence of CMV in 5-month-old plants. Furthermore, an involvement of ROS in plant defence against a viral disease when *Trichoderma* is applied

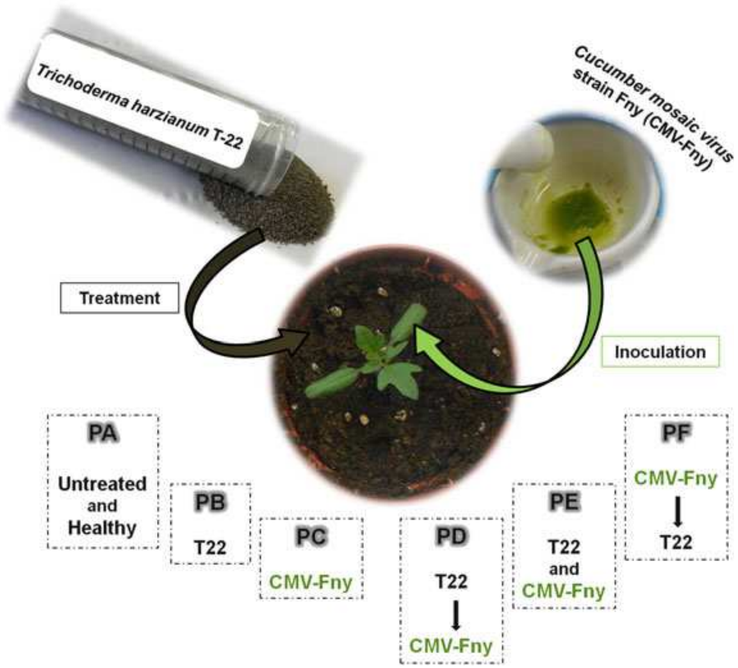

Fig. 1 Scheme of the experimental set-up. Treatments with *Trichoderma harzianum* T-22 (T22) were performed by incorporating Trianum G (Koppert, Berkel en Rodenrijs, the Netherlands) granules in the substrate used for planting (750 gm^{-3}), according to the application and dose suggested by the company. Ten micrograms of purified *Cucumber mosaic virus* strain Fny (CMV-Fny) was used to mechanically inoculate tomato cherry plants at the four-leaf stage. Plants were treated with T22 and/or inoculated with CMV in order to gain the six conditions PA, PB, PC, PD, PE and PF, as reported in the text

was demonstrated. In fact, it can be hypothesized that the interaction between CMV and tomato plants results in an oxidative burst and hence elevated ROS production, which becomes toxic for the plants. Conversely, during the CMV-tomato-T22 interaction, ROS are implicated as secondary messengers of the host's defence responses against the viral pathogen, mediated by the fungal biocontrol agent. In addition, an indication on the fact that a particular combination whereby plants first inoculated with CMV and then treated with T22 could guarantee the best control against CMV has been speculated. Finally, results obtained could also indicate an SAR-related response by the tomato plants against CMV attack, but further investigation is required to confirm these findings (Vitti et al. 2015a).

Tomato fruits were harvested from bottom branch of 3-month-old plants. As reported in Fig. 2, plants treated only with T22 (PB) showed the best size fruit and also the best root development, as expected. On the contrary, the control plants inoculated with CMV alone (PC) showed the smallest fruits, with delayed ripening, accompanied by the worst root development. Plants treated with T22 and inoculated with CMV (PD, PE and PF) were similar to the controls (PA), considering both size fruit and root development.

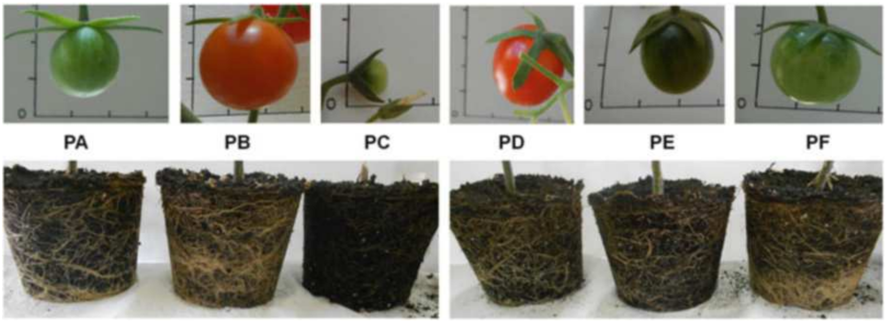

Fig. 2 Three-month-old tomato cherry plants. In each panel, a representative fruit (*above*) and roots (*below*) are shown. *PA* healthy control tomato plant; *PB* plant treated with only T22; *PC* plant inoculated with CMV; *PD* plant treated with T22 and, a week later, inoculated with CMV. *PE* plant simultaneously treated and inoculated with T22 and CMV; *PF* plant first inoculated with CMV and, a week later, treated with T22. Scale units for both abscissa and ordinate are of 1 cm

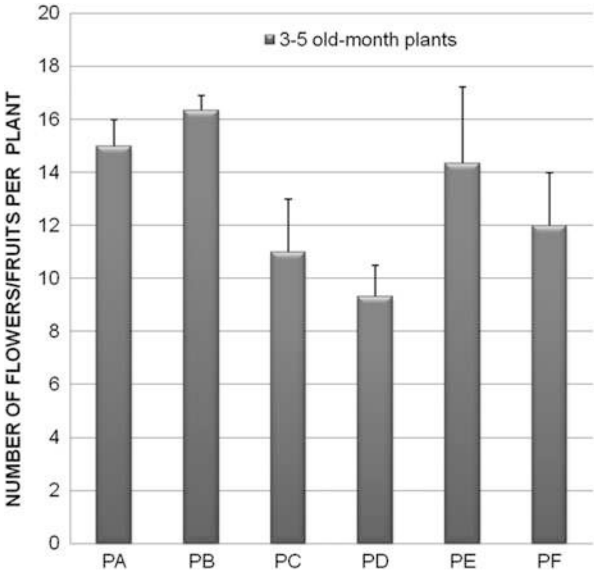

Fig. 3 Evaluation of the effect induced by T22 treatment on yield, determined as number of flowers and fruits per plant, observed from 3 to 5 months of plant's age. *PA* healthy control tomato plant; *PB* plant treated with only T22; *PC* plant inoculated with CMV; *PD* plant treated with T22 and, a week later, inoculated with CMV; *PE* plant simultaneously treated and inoculated with T22 and CMV; *PF* plant inoculated with CMV and, a week later, treated with T22. Each *bar* indicates the mean value ± SD of 16 plants observed for each condition

As clearly showed in Fig. 3, in terms of yield, considered as production of flowers and fruits in 3–5-month-old plants, those treated only with T22 (PB) showed the highest values, as expected. Conversely, plants inoculated with

CMV alone (PC) not showed the lowest yield, as we expected. This is because the number of fruits was not low, but they resulted in an important reduction in size, as Fig. 2 shows, accompanied by chlorotic/necrotic spots when they were ripe, confirming the observations previously made by Vitti et al. (2015a). Instead, as it is possible to see in Fig. 3, plants treated with T22 and also inoculated with CMV, in particular in the case of co-inoculation/treatment (PE), showed an increase in yield respect to that inoculated with only CMV (PC), except for plants first treated with T22 and then inoculated with CMV (PD).

4 Conclusion

In conclusion, data produced in the case study here reported demonstrate that *Trichoderma harzianum*T-22 stimulates the induction of defence responses against CMV-Fny in *Solanum lycopersicum* var. cerasiforme, by the clear involvement of ROS, as well as an enhancement in yields and root development. Furthermore, the knowledge on the molecular and biochemical aspects of the plant-virus-biocontrol agent interactions, in combination with the dynamics of application, has been improved. In this way, a new system based on the use of T22 as a microbial antagonist could be made available for the protection of tomato against CMV disease, which can be also extended to other plant species. Furthermore, a routine utilization of T22 in the agricultural practices in disease defence could surely bring to a reduction of the use of fertilizers and fungicides in agricultural production, with consequent benefits for the environment. Today, more than ever, this is necessary to help maintain ecosystems and to develop sustainable agriculture.

Acknowledgments This work was supported by a grant from University of Basilicata, Potenza, Italy.

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Development of Integrated Disease Control Measures for the Valorisation of Traditional Crops in Southern Italy: The Case Study of *Fagioli di Sarconi*

Pietro Lo Cantore, Annalisa Giorgio, Bruno Campion, and Nicola Sante Iacobellis

Abstract The cultivation of *Fagioli di Sarconi* (*FS*), a pool of traditional varieties protected with the mark PGI (Protected Geographical Indication) cultivated in the National Park of Agri Valley in Basilicata (southern Italy), is limited by common bacterial blight (CBB), caused by the seed-borne bacterium *Xanthomonas axonopodis* pv. *phaseoli* (*Xap*) and *X. a.* pv. *phaseoli* var. *fuscans* (*Xapf*), whose control is difficult because of the lack of safe bactericides. Hence, studies were undertaken to assess the susceptibility/tolerance of selected varieties toward the pathogens and to develop eco-compatible measures for the disease management. Five *FS* varieties showed a differential response to inoculations with virulent strains of the pathogens, and hence, two tolerant cultivars were selected for the introgression of CBB resistance characters. Among the main active components of some essential oils, eugenol determined a highly significant reduction of *Xap* density on bean seeds, though at the higher dosage, the seed germination reduction was observed. These data indicate eugenol as potentially useful for bean seed disinfection from *Xapf,* though further studies appear necessary. Among 162 bacterial isolates from bean rhizosphere, six caused a clear reduction of lesions size ranging from 30 to 66 % suggesting that induced systemic resistance may be involved in that feature.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_10

1 Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the most important legumes due to its commercial value and its high content of quality carbohydrates, proteins, minerals and vitamins. FAO data (FAO Statistics Division 2014) on bean production in Europe indicate that in 2012, Belarus, Spain and Italy were the main bean producers. In fact, bean production was 227.259 t in Belarus (only for dry beans), 175.300 t in Spain (165.400 for string and 9.900 for dry beans) and 145.933 t in Italy (134.124 for string and 11.809 for dry beans). In Italy, besides the commercial cultivars, there is an abundance of traditional varieties with unique nutritional features and for which there is a traditional market (Dinelli et al. 2006). This is the case of the *Fagioli di Sarconi* (*FS*), a pool of traditional high-value traditional varieties, selected from various landraces (Masi et al. 1999; Piergiovanni et al. 2000) and protected by the European Union (Reg. CEE No. 1263/96) with the mark PGI (Protected Geographical Indication).

FS are cultivated in the National Park of the Agri Valley in Basilicata (southern Italy) for dry seed production (Brandi et al. 1998). The germplasm, preserved on farm by the *Consorzio di Tutela dei Fagioli di Sarconi*, has been extensively characterised for its biochemical and nutriceutical traits (Piergiovanni et al. 2000; Lioi et al. 2005; Dinelli et al. 2006) but nothing is known about its response to diseases. As a matter of fact, the above varieties are plagued by the common bacterial blight (CBB), caused by *Xanthomonas axonopodis* pv. *phaseoli* (Smith) Dye (*Xap*) and *X. a.* pv. *phaseoli* var. *fuscans* (*Xapf*) (Vauterin et al. 1995), and since 2002, there have been several severe outbreaks of this disease. Bean field surveys in 2001–2002 showed that at the end of the production cycle, nearly 100 % of the plants were infected, with the consequent heavy crop loss. The disease is endemic and some evidences indicate its introduction by long time. The use of bean seed grown on farm, possibly infected and/or contaminated by the pathogens, the limited copper sprays and the use of overhead irrigation have facilitated the dissemination of the pathogen and the maintenance of a high level of the inoculum potential. Year by year, bacterial disease outbreaks have been greatly facilitated by the particular climatic conditions which, as observed in the above years, were characterised by heavy rains during the periods from July to September (Lo Cantore et al. 2004a). CBB pathogens infect all the plant organs and the disease development is favoured by warm temperature (25–35 °C) and humid conditions (Gilbertson and Maxwell 1992; Saettler 1989). CBB symptoms on foliage are water-soaked spots that enlarge forming dark brown necrotic lesions often surrounded by chlorotic zones. Infected pods exhibit circular water-soaked areas that turn to reddish-brown lesions. Pod infection often causes discoloration, shrivelling and bacterial contamination/infection of seeds though in some cases, they may appear healthy (Saettler 1989).

The causal agents of CBB, *Xap* and *Xapf*, are distinguished from each other only because *Xapf* produces a brown pigment when grown on some specific agar media (Schaad et al. 2001). Nevertheless, there is considerable genetic diversity between *Xap* and *Xapf* (Chan and Goodwin 1999; Mkandawire et al. 2004; López et al. 2006; Mahuku et al. 2006), as recent AFLP analyses have confirmed (Lo Cantore and Iacobellis 2007; Alavi et al. 2008; Lo Cantore et al. 2010b). For that, a revision of the two pathogens classification has been proposed (Schaad et al. 2005, 2006).

Dissemination in the field is mainly determined by wind-driven rain and overhead irrigation, but also by insects, field workers and contaminated equipment (Gilbertson and Maxwell 1992; Saettler 1989), which may play an important role. Common bacterial blight is the major seed-borne disease of common bean worldwide (Tarlan et al. 2001; Miklas et al. 2003), and the best way to manage CBB includes the use of pathogen-free seed (Zanatta et al. 2007). In order to control CBB, the use of bean cultivars with genetic tolerance/resistance to the disease is the most practical method (Coyne and Schuster 1974; Yoshii et al. 1978) though the availability of CBB-resistant cultivars is limited. In most of the cases, the resistance/tolerance of traditional varieties to CBB is unknown. This is the case of *FS* varieties. Furthermore, pathogen-free seed is a prerequisite for a healthy crop, but to date no efficient disinfection method is available (Lo Cantore et al. 2009). Antibiotics, in fact, are actually restricted or forbidden in the agricultural practices in many countries (McManus et al. 2002) and the use of copper compounds, because of their general toxicity and impact on the environment, is constrained in Europe (EU rule no. 473/2002). Furthermore, chemical disinfectants such as chlorine, inorganic acids, organic acids and heat treatments have been used for disinfection of potentially contaminated seeds surface or to cure infected seeds, but seed devitalisation has been reported (Claflin 2003).

The above consideration prompts the need to assess, first, the response of the selected *FS* bean varieties to CBB with the final aims to select resistant/tolerant traditional varieties and to introgress tolerance/resistance characters into the *FS* varieties of interest. Moreover, of interest was the development of alternative methods for the control of CBB to be used in integrated crop management as well as in bio-organic agriculture. Several studies have pointed out the possibility to use essential oils and/or their components in medical and plant pathology as well as in the food industry for the control of microorganisms pathogenic to consumers and/or responsible for food spoilage (Seow et al. 2014). Nevertheless, most of the studies are mainly focused on the *in vitro* assessment of the antimicrobial activity (Si et al. 2006; Terzi et al. 2007), and the exploitation of essential oils for the control of plant diseases is still in its infancy (Tinivella et al. 2009; Kotan et al. 2010). Another opportunity for plant defence towards diseases is the use of beneficial bacteria inhabiting plant rhizosphere. In several works, it was demonstrated that some bacteria belonging to *Pseudomonas* and *Bacillus* genera are able to provide different mechanisms (direct or plant mediated) for suppressing plant diseases (Saharan and Nehra 2011).

In this chapter, we report some of the results obtained in studies aimed to develop methods for integrated control of CBB.

2 Response of *Fagioli di Sarconi* Varieties to CBB

The objective of the present work was to evaluate the response to CBB of five traditional bean varieties (*Tondino bianco*, *Verdolino*, *Cannellino*, *Tabacchino* and *Ciuoto*) of the *FS* variety pool, in comparison to four available resistant bean breeding lines (VAX-4, USDK-CBB-15, ABC-Wiehing and USCR-CBB-20) (Singh et al. 2001; Miklas et al. 2006, 2011; Mutlu et al. 2008). Aliquots of bacterial suspensions of the highly virulent *Xap* and *Xapf* strains were inoculated into the first trifoliate mesophyll of bean plants (Lo Cantore et al. 2010a).

The traditional varieties *Tondino bianco*, *Cannellino*, *Verdolino*, *Ciuoto* and *Tabacchino* showed the typical CBB symptoms, and, in particular, at the inoculation sites, tiny water-soaked lesions 14 days after inoculation which then expanded and turned into necrotic spots surrounded by chlorotic halos were observed (see Fig. 1a, c). As expected, necrotic lesions of the hypersensitive reaction were observed on the CBB-resistant breeding lines (see Fig. 1b, c).

Twenty-eight days after inoculation, the *FS* varieties statistically differed in their susceptibility depending on the pathogen strain used (see Fig. 2). Indeed, while strain USB749 (ICMP14929) of *Xapf* caused on *Tondino bianco*, *Cannellino* and *Verdolino* lesions significantly larger ($P < 0.0001$; LSD.05 = 5.14 mm) than those ones on cv. *Ciuoto* and *Tabacchino* (see Fig. 2a), *Xap* USB771 (ICMP14932) caused lesions on *Tondino bianco* and *Tabacchino* significantly larger ($P < 0.001$; LSD.05 = 1.82 mm) than those on *Verdolino*, *Ciuoto* and *Cannellino* (see Fig. 2b). The lesions on *Ciuoto* and *Cannellino* did not differ significantly from the lesions

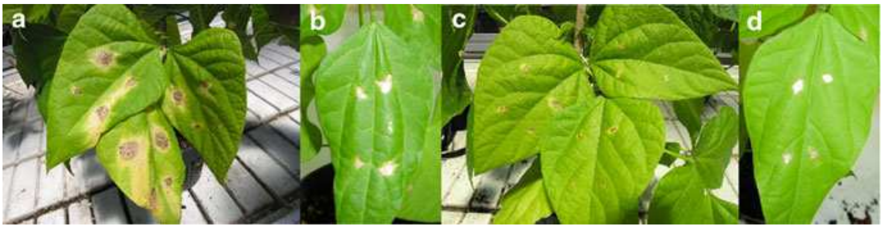

Fig. 1 Symptoms on the traditional variety *Verdolino* (**a–c**) of *Fagioli di Sarconi* and hypersensitive necrotic lesions on the CBB-resistant breeding line ABC-Wiehing (**b–d**) 21 days after syringe infiltration with 10^8 CFU ml^{-1} suspensions of the highly virulent strain USB749 (ICMP14929) of *Xanthomonas axonopodis* pv. *phaseoli* var. *fuscans* (**a–b**) and of strain USB771 (ICMP14932) of *X. a.* pv. *phaseoli* (**c–d**). Adapted with permission from Lo Cantore P, Figliuolo G, Iacobellis NS (2010) Response of traditional cultivars of *Fagioli di Sarconi* beans to artificial inoculation with common bacterial blight agents. Phytopathol Mediterr 49:89–94. Copyright 2010 Firenze University Press

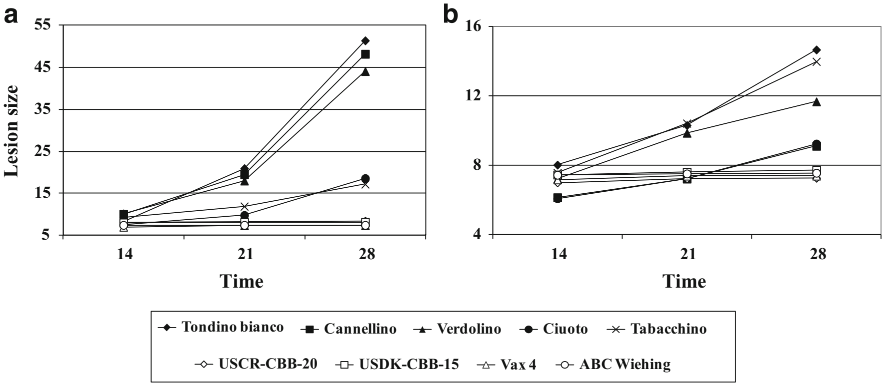

Fig. 2 Response given by the traditional bean varieties of the *Fagioli di Sarconi* and by CBB-resistant breeding lines 28 days after syringe infiltration of 10^8 CFU ml^{-1} suspensions of the highly virulent strain USB749 (ICMP14929) of *Xanthomonas axonopodis* pv. *phaseoli* var. *fuscans* (**a**) and of strain USB771 (ICMP14932) of *X. a.* pv. *phaseoli* (**b**). Adapted with permission from Lo Cantore P, Figliuolo G, Iacobellis NS (2010) Response of traditional cultivars of *Fagioli di Sarconi* beans to artificial inoculation with common bacterial blight agents. Phytopathol Mediterr 49:89–94. Copyright 2010 Firenze University Press

on the breeding lines USDK-CBB-15, ABC-Wiehing and VAX-4, but they significantly differed from those on USCR-CBB-20 (see Fig. 2b).

In conclusion, the findings that the varieties *Ciuoto*, *Tabacchino* and *Cannellino* appeared to be less susceptible or tolerant to CBB are positive since it is well established that the use of pathogen-tolerant germplasm, rather than resistant one, is advisable in order to avoid the selection of the pathogen population overcoming the resistance. The above varieties, apart from their agronomic, biochemical and nutriceutical traits, appear good candidates for the introgression of CBB resistance characters in a breeding programme.

The results further suggest that the inoculation procedure is suitable to evaluate the susceptibility/tolerance and the resistance of bean cultivars and/or breeding lines. However, the response of the traditional bean varieties to CBB pathogens inoculation needs to be further confirmed by using different plant parts (i.e. pods) since the degree of resistance/susceptibility of *Phaseolus* spp. depends on the plant organ (Aggour et al. 1989; Rodrigues et al. 1999; Marquez et al. 2007).

The development of new bean breeding lines genetically resistant to *Xapf* was another aim of this work. The selection applied to these breeding lines should tend to combine, in their genetic background, the gene of resistance and all agronomic and nutriceutical traits present in the old varieties. The bean traditional varieties *Tabacchino* and *Ciuoto*, and bean breeding lines VAX-4 and USCR-CBB-20 carrying the resistance to *Xaf* (Singh et al. 2001; Miklas et al. 2011), were used in the breeding plan.

Numerous ♀*Ciuoto* x USCR-CBB-20♂, ♀*Ciuoto* x VAX-4♂, ♀*Tabacchino* x USCR-CBB-20♂ and ♀*Tabacchino* x VAX-4♂ crosses and related reciprocals were made in greenhouse. All F_1 plants were grown in the field until the production of eight groups of F_2 seed progenies. F_3 seeds obtained from F_2 plants selected for *Xapf* resistance were sown in the field and related plants submitted to agronomic selection/evaluation. The choice of the best single plants was based on production capacity, plant hardness and health, and pod and seed quality. Only three types (groups) of crosses, out of the eight performed (♀*Ciuoto* x VAX-4♂, ♀*Tabacchino* x VAX-4♂, ♀*Tabacchino* x USCR-CBB-20♂), produced progenies with good plant and seed traits. The seed progenies are at F_4 generation level.

3 *Fagioli di Sarconi* Seed Disinfection

Our previous studies showed the antibacterial activity of coriander, caraway and cumin essential oils towards 29 bacterial pathogens of plants, including strains of *Xap* and *Xapf* (Iacobellis et al. 2005; Lo Cantore et al. 2004b). The objective of this study was to evaluate the *in vitro* antibacterial activity of the 19 main components of the above essential oils and to assess their potential use for bean seed disinfection. In disc diffusion assay (Lo Cantore et al. 2009), terpenoids and phenylpropanoids, having phenol and alcohol functionalities, showed a high bactericidal activity, inhibiting the growth of all bacterial strains used in this study, whereas a lower activity was shown by monoterpenes containing ketone, aldehyde and ester functionalities and the phenylpropanoids anethol. Monoterpenoids and sesquiterpenoid caryophyllene showed a lower activity and only on a limited number of the target bacteria. Based on the above results, eugenol was chosen in order to evaluate its disinfecting effects on the *FS* variety *Ciuoto* seeds artificially contaminated with *Xapf* (Lo Cantore et al. 2009). Eugenol seed treatments (1, 2, 4 and 8 mg ml^{-1}) caused a statistically significant reduction ($P < 0.0001$) of the bacterial population on bean seeds relative to the control sample (see Fig. 3). Assays with different bacterial densities bearing seeds and treatments with 4 mg ml^{-1} eugenol emulsions confirmed the higher efficiency of this essential oil to reduce bacterial population densities on bean seed surface when compared to the tetracycline treatments at a comparable MIQ value (100 μg ml^{-1}). However, eugenol emulsions at concentration equal or superior to 2 mg ml^{-1} caused a significant reduction of the seed germination compared to the control (see Fig. 4).

In conclusion, essential oils and/or pure components appear to be good bactericides as alternatives to antibiotics for the control of seed-borne plant pathogen bacteria.

The use of eugenol instead of complex oil mixtures may be desirable since this avoid the variability of essential oils and, furthermore, the possible toxicity of other no bactericide essential oil components. The reduction of bean seed germination after treatments with eugenol was already reported (Asplund 1968; Reynolds 1987; Oosterhaven et al. 1995), but the limited effect on bean seed germination observed at eugenol lower concentrations indicates a starting point for a possible amelioration of the disinfectant formulation and disinfection method.

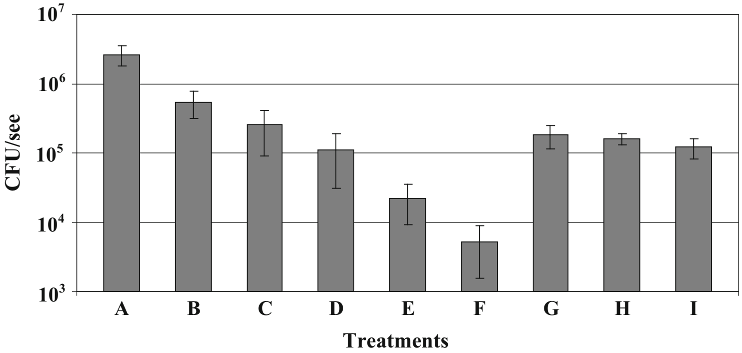

Fig. 3 Bacterial populations of the spontaneous mutant resistant to rifampicin of strain ICMP239 of *Xanthomonas campestris* pv. *phaseoli* var. *fuscans* on bean seeds bearing about 2.6×10^6 CFU per seed after different treatments (A = control, no treated seeds; B = control, seeds treated with water containing 0.01 % Tween 20; C, D, E and F = seeds treated with 1, 2, 4 and 8 mg ml^{-1} of eugenol in water emulsions containing 0.01 % Tween 20, respectively; G, H and I = seeds treated with 50, 100 and 200 μg ml^{-1} tetracycline solutions containing 0.01 % Tween 20, respectively). *Bars* on the columns correspond to the standard error of the mean. Means of bacterial populations on bean seeds after eugenol and tetracycline treatments, evaluated by the *t*-test in comparison with the means of bacterial populations on bean seeds of the controls A and B, are statistically different ($P \leq 0.002$). Adapted with permission from 'Lo Cantore P, Shanmungaiah V, Iacobellis NS (2009) Antibacterial activity of essential oil components and their potential use in seed disinfection. J Agric Food Chem 57:9454–9461'. Copyright 2009 American Chemical Society

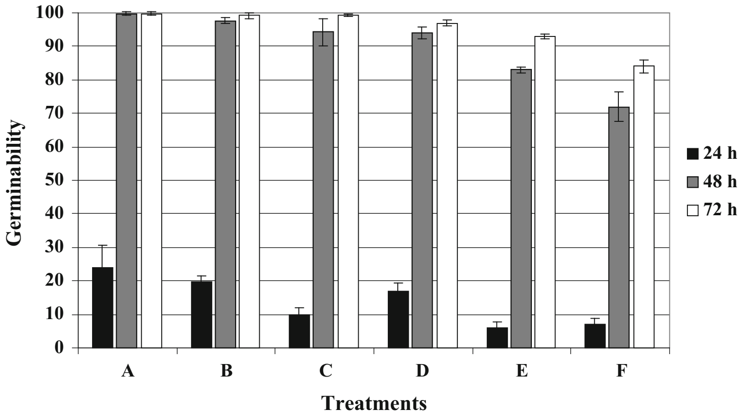

Fig. 4 Germination of bean seeds after different treatments with eugenol (A = control, no treated seeds; B = control, seeds treated with water containing 0.01 % Tween 20; C, D, E and F = seeds treated with 1, 2, 4 and 8 mg ml^{-1} of eugenol in water containing 0.01 % Tween 20, respectively). *Bars* on the columns correspond to the standard error of the mean. The *t*-test of data at 72 h showed that means of geminated seeds after eugenol treatments (8, 4 and 2 mg ml^{-1}), in comparison with the controls (A and B), are statistically different ($P < 0.0001$) and ($P < 0.02$), respectively. No statistical differences were observed in the case of treatments with 1 mg ml^{-1} eugenol emulsion. Adapted with permission from 'Lo Cantore P, Shanmungaiah V, Iacobellis NS (2009) Antibacterial activity of essential oil components and their potential use in seed disinfection. J Agric Food Chem 57:9454–9461'. Copyright 2009 American Chemical Society

4 Beneficial Rhizobacteria as Biocontrol Agents of CBB in *Fagioli di Sarconi*

Rhizobacteria are microorganisms living plant rhizosphere and some of them are able to reduce plant diseases by several direct mechanisms (i.e. niche exclusion, competition for nutrients, siderophore-mediated competition for iron, antibiosis and production of extracellular hydrolytic enzymes) (Martinez-Viveros et al. 2010) or indirectly by stimulating the basal plant defence mechanisms, phenomenon called induced systemic resistance (ISR) (Van Loon 2007).

As already discussed, CBB is difficult to manage via the conventional methods. In an integrated view of CBB control, the biological one based on the use of antagonist rhizobacteria may represent another opportunity.

The aim of this study was to evaluate the potential of selected rhizobacteria isolated from bean rhizosphere to protect plants against CBB in *in vitro* and greenhouse conditions. In total, 162 rhizobacteria were isolated from bean rhizosphere in the National Park of Agri Valley (Basilicata, southern Italy) and screened in dual-plate assays for their potential capacity to antagonise the growth of CBB pathogens. Sixty out of 162 rhizobacteria inhibited *in vitro* the growth of *Xap*, and 38 of these were also active against *Xapf*; thus, they were assayed for hydrolytic enzyme production. Subsequently, they were evaluated, when applied to seeds before sowing, for their possible effect on *Xapf*–plant interactions. The results of these assays have allowed selecting six bacterial isolates that were capable to protect, with diverse efficacy, bean plants artificially inoculated, *in vitro* and greenhouse assays, with a highly virulent strain of the mentioned pathogen. Indeed, the reduction of lesions size ranged from about 25 to 55 % *in vitro* and from about 35 to 65 % in greenhouse experiments compared to the controls (see Fig. 5). The six selected isolates were identified by partial PCR amplification of 16S rDNA as three strains of *Pseudomonas brassicacearum* subsp. *brassicacearum*, two strains of

Fig. 5 Symptoms of common bacterial blight on trifoliate leaves developed 21 days after syringe without needle inoculation with suspension (10^8 CFU ml^{-1}) of strain USB749 (ICPPM 14929) of *Xanthomonas axonopodis* pv. *phaseoli* var. *fuscans*. Comparison between bean plants obtained from not bacterised (*left*) and bacterised seeds (*right*). In (**a**) and (**b**), bean plants from seeds are treated with bacterial suspensions (10^8 CFU ml^{-1}) of *Pseudomonas brassicacearum* subsp. *brassicacearum* strains (USB2101, USB2102)

P. putida and one of *Bacillus megaterium*. The antagonist bacteria were then further characterised for phosphate solubilisation (Nautiyal 1999), nitrogen fixing activity (San Yu et al. 2011), production of indole compounds (Gordon and Weber 1951) and siderophores (Schwyn and Neilands 1987), haemolytic capacity (Lo Cantore et al. 2006) and production of ammonia (Cappuccino and Sherman 2010) and of hydrogen cyanide (Lorck 1948). Finally, bacteria were evaluated for adaptability to salinity, pH and temperature gradients (Giorgio 2014; Giorgio et al. 2013).

The mechanisms underlying bean plant protection are not completely understood so far. At the base of the pathogen control exerted by the six mentioned bacteria, some likely explanations exist. In the pathogenicity assays, the rhizobacteria and the challenging pathogen were apparently spatially separated and this may suggest that the observed effect may result from the activation in bean plants of induced systemic resistance (ISR) (Van Loon 2007). The ability to trigger ISR by some of the above rhizobacteria has been ascertained in further parallel studies in the pathosystem *Arabidopsis thaliana–X. campestris* pv. *amoriaceae* (Giorgio 2014; Giorgio et al. 2013). Molecular studies leading to determine the occurrence of ISR in bean–*Xapf* pathosystem are in progress. However, a direct effect of rhizobacteria on the pathogen at the infection site cannot be excluded since it has been reported that bacteria applied to soil or on seeds colonise rhizosphere and then may move up to the phylloplane (Nautiyal et al. 2002) or to behave as either facultative or opportunistic endophytes (Hardoim et al. 2008). Some characters shown by rhizobacteria under study may be the responsible of the possible direct antagonism exerted on the pathogens. In fact, the haemolytic activity shown by these bacteria may depend on the production of antimicrobial substances affecting biological membranes which is a quite common feature in plant-associated*Pseudomonas* spp. and *Bacillus* spp. (Ongena and Jacques 2008; Raaijmakers and Mazzola 2012). Furthermore, of great interest is the fact that strains of *P. b.* subsp. *brassicacearum* produce HCN reported as inhibitor of cytochrome C oxidase in the respiratory chain (Knowles 1976) and binding metalloenzymes (Blumer and Haas 2000) determining deleterious effect in microorganisms inhabiting the same ecological niche and nonproducers of HCN. On the other side, *P. putida* strains appeared to produce ammonia that accomplishes several biological roles and, in particular, its toxicity is well known (Weise et al. 2013). The six antagonistic rhizobacteria showed also desirable plant growth-promoting ability since they can supply inorganic phosphate to plants (Schachtman et al. 1998) via phosphatase activity which leads to the production of organic acids that decrease soil pH (Rashid et al. 2004), so that this may limit some soilborne phytopathogenic organisms, as demonstrated in the case of *P. ultimum* and *F. oxysporum* (Alhussaen 2012). Moreover, in this regard, important is the fact that the six rhizobacteria produce also indole compounds that promote bacterial environmental adaptation during stress conditions such as UV, salt and acidity (Bianco et al. 2006). Finally, their siderophore production may contribute to plant growth-promoting activity by depriving pathogens of iron accomplishing, in this way, their antagonistic activity (Kloepper et al. 1980). In conclusion, the fact that numerous mechanisms may be involved in leading to the observed effects makes worthwhile a deeper investigation on the system considered.

5 Concluding Remarks

In conclusion, the findings that the *Fagioli di Sarconi* traditional varieties *Ciuoto*, *Tabacchino* and *Cannellino* appeared to be less susceptible or tolerant to CBB are positive since it is well established that the use of pathogen-tolerant germplasm, rather than resistant one, is advisable in order to avoid the selection of the pathogen population, leading to the resistance being overcome. The introgression and stabilisation of CBB resistance characters into some of the above tolerant traditional varieties, in the breeding programme still in progress, may bring about to highly agronomic and nutriceutical values varieties with potential economic impact.

Essential oils and/or pure components such as eugenol appear to be good bactericides as alternatives to antibiotics for the sanitation of bean seeds from CBB pathogens as well as for the control of other seed-borne plant bacterial pathogens. However, studies either on formulations or on the application method of eugenol appear necessary to avoid undesirable toxic effect on seeds and plantlets.

Lastly, of highly value is the finding that strains of *Pseudomonas brassicacearum* subsp. *brassicacearum*, *P. putida* and *Bacillus megaterium*, isolated from bean rhizosphere, are capable of protecting bean plants artificially inoculated with the CBB pathogen. Also in these cases, further studies appear necessary to transfer these potential antagonists in the agriculture practices.

Acknowledgements This research was in part supported by the Ministry of Agricultural Alimentary and Forest Politics (project PROM, C.I.P.E. Resolution 17/2003). Dr. Phillip Miklas, of the Vegetable and Forage Crops Research Laboratory, USDA, WA, USA, and the *Consorzio di Tutela dei Fagioli di Sarconi* are acknowledged for the generous supply of CBB-resistant breeding lines and traditional cultivar seed lots.

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Sustainable Climate Change Adaptations in Developing Countries: A Case Study of the Turkish Cypriot Community's Adoption of Pomegranate Farming

Clare M. Finnegan and Omer Gokcekus

Abstract Climate change is a growing issue for developing countries, as they typically lack the technical and financial inputs to implement the necessary agricultural adaptations. These countries also suffer from the classic collective action problem; although they are able to identify the issue and a potential solution, their individual resources are not substantial enough to enact change. This article discusses north Cyprus' 2006 adoption of pomegranate production and its relationship to climate-related agricultural concerns. We argue that the Turkish Cypriot community would not have been able to start an effective pomegranate agribusiness without third-party financial and technical assistance. As a post-conflict developing community, they lacked the resources necessary to collectivize on their own and initiate crop switching. Thus, Turkish Cypriot farmers needed external resources in order to launch a sustainable development project. The programme was a successful example of sustainable peacebuilding as it required local ownership.

1 Introduction[1]

Climate change used to be an abstract, futuristic problem. Although there was some awareness of the need to adapt one's lifestyle to be more "environmentally friendly", the problem lacked urgency and was perceived as an issue that the coming generation would tackle. Now it seems to be an inescapable reality. Developed countries with abundant resources, like the USA, have been able to implement certain adaptations to mitigate some of the adverse effects of climate change. How have other less affluent countries adapted?

[1] Any information not directly cited is attributable to interviews and personal correspondence with Berna Berberoğlu, the deputy project manager of the Economic Development and Growth for Enterprises (EDGE) programme, and İbrahim Kahramanoğlu, the managing director of Alnar Narcılık Ltd.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_11

As what Gokcekus and Bengyak (2014) discuss in regard to corruption, climate change has the most severe ill effects on those members of society (or the world) that are least capable of preparing themselves for its impact. Often still largely agriculturally based, the economies of many developing countries are especially vulnerable to environmental changes. Limited financial resources create a collective action problem; while the individual members of a developing society may know that the adaptation or modification of existing processes can help combat climate-related issues, they lack the resources—technical and financial—to adopt these changes. The problem of adaptation is particularly acute in post-conflict regions that have been isolated from beneficial economic relationships, such as north Cyprus.

North Cyprus has been a de facto separate country since Cyprus was partitioned by the "Green Line"—a UN buffer zone—in 1974 due to conflict between Cypriots of Greek ancestry and those of Turkish (BBC 2011). Under the internationally recognized Republic of Cyprus, Greek Cypriots were able to interface with the EU and the greater international community. North Cyprus was isolated, and its economic development has lagged behind that of the Republic of Cyprus. On average, Greek Cypriots have a 61 % higher per capita income than Turkish Cypriots (Gokcekus 2008, p. 15). This paper will explore how intervention by a third party helped the Turkish Cypriot community (TCC) adapt its agricultural industry to the constraints of climate change and simultaneously overcome its collective action problem. Specifically, this paper explores USAID's 2006 agribusiness programme that assisted the TCC with starting commercial production of the nutritional superfruit pomegranate.

2 Crop Switching and Sustainable Peacebuilding

Why does climate change matter? Kurukulasuriya and Mendelsohn (2008) try to predict the impact of climate change on farms' output and revenue in 11 African countries. Under one climate change scenario—the Canadian Climate Centre (CCC) model in which the studied regions become hotter and drier—predicted revenues for the year 2100 would decline by nearly 70 % if farmers did not participate in crop switching (p. 122). In an alternative climate change scenario—the Parallel Climate Model (PCM) in which the climate of the studied regions becomes mild and wet—revenues were actually expected to significantly (82 %) increase. Which of these two models most closely predicts future conditions is currently unknown. In order to avoid a potential 70 % loss of revenue, the authors suggest crop switching; under the CCC's conditions, crop switching could reduce losses to only 6 %.

Seo and Mendelsohn (2008) also explored crop choice and its relationship to climate change, focusing on South American farms. As in Africa, crop choice in South America generally had an identifiable, significant relationship with temperature and precipitation. The one exception to this was maize, a crop with many varieties that are adaptable to most South American climates. Seo and Mendelsohn (2008) did not predict the economic impact of not crop switching, but instead assumed that farmers—making a rational economic decision—would switch.

Huda et al. (2005) suggest measures that farmers, community workers, and policy agencies can take in response to changing environmental conditions. Huda et al. were primarily concerned with the possible mismatch between crop phenology and water availability caused by climate change. Without an understanding of phenology, crop adaptation proves difficult as crops with certain phenologies only thrive in specific ecosystems. Huda et al. (2005) therefore recommend several strategies, such as changing the time of planting and adopting alternative crops, that could help mitigate mismatch between crop phenology and water resources (p. 142).

Farmers can only combat climate change by employing crop switching if "there are no barriers to the adoption of appropriate crops" (Kurukulasuriya and Mendelsohn 2008, p. 123). Seo and Mendelsohn (2008) echoed this warning, specifically mentioning that farmers may not be able to crop switch "if the adjustment requires a heavy capital investment" (p. 115). Lobell et al. (2008) argue that while "switching to an existing crop variety may moderate negative impacts, the biggest benefits will likely result from more costly measures..." (p. 607). In addition to potential financial constraints, the measures advocated by Huda et al. (2005) generally require significant technical or scientific acumen, knowledge that is often in short supply in developing nations.

These financial and technical constraints only exacerbate the collective action problem, which is particularly acute when resources are scarce. In a society with limited inputs, the participation of many actors (a group effort) is often necessary in order to secure opportunities or goods that enhance the collective benefit. As Olson (1965) details, large groups are particularly prone towards free-ridership, since members of the group believe their non-participation will be overlooked. This tendency is especially detrimental to projects in developing countries; the constrained resources of individual members in these countries often require that collective goods be provided through larger-sized groups with high levels of participation.

How can developing countries, particularly post-conflict societies like Cyprus, solve these challenges? Gokcekus et al. (2014) suggest that the solution lies with intervention by an outside actor. In their study of Turkish Cypriot beekeepers, Gokcekus et al. found that the beekeepers needed EU financial and technical assistance to overcome their collective action problem, meet the EU's health standards for commercial honey, and initiate trade across the Green Line. The EU provided the initial impetus for change; once the Turkish Cypriots beekeepers understood the standard requirements for trade and had the financial resources to meet these standards, they were able to collectivize and increase their level of economic development. In other words, although the process of updating their beekeeping practices to meet EU standards was instigated by the EU, Turkish Cypriot beekeepers accepted local ownership of the remainder of the development process.

As Donais (2009) notes, local ownership is relatively rare in post-conflict development initiatives, since the external actors tend to reserve "most key decision-making authority" (p. 4). Perhaps the interaction between the beekeepers and the EU can best be described as an example of what Donais terms "sustainable peacebuilding" (p. 14). Sustainable peacebuilding requires "negotiated hybridity" between both insiders and outsiders "in which the division of responsibilities between outsider and insider is constantly calibrated and adjusted as a means to advancing the peace process" (p. 14, 21). Like the case of the beekeepers, the decision of Turkish Cypriot farmers to commence pomegranate production is likely another example of sustainable peacebuilding.

The case of pomegranate production in north Cyprus can be approached from several perspectives. This paper concentrates on intersection of two of those: (1) the adoption of pomegranates as a form of crop switching and (2) the adoption of pomegranates as a result of overcoming a collective action problem through sustainable peacebuilding. By promoting local ownership and sharing responsibility, an external actor helped the TCC surpass the capital and technical barriers that had previously prevented the implementation of a climate change solution.

3 Climate Considerations in Cyprus

Climate change has exacerbated Cyprus' water shortages (Shoukri and Zachariadis 2012; Zachariadis 2010; EEA 2009) Cyprus has experienced extended periods of drought since the 1970s; increased demand has made the issue of water availability particularly acute (BBC 2010). In an attempt to rectify this issue, north Cyprus agreed to the construction of an underwater freshwater pipeline connected to Turkey. Referred to as Barış Su ("Peace Water"), this pipeline was expected to be completed sometime in 2014; however, it was slightly behind schedule and just over halfway completed in October of that year (Gies 2013; Sands 2014). In addition to political concerns over heightening north Cyprus' reliance on Turkey, there are also worries that the pipeline will only increase demand (Gies 2013). Water shortages have been particularly challenging for the agricultural sector. Citrus fruits, Cyprus' third most lucrative agricultural export, place considerable stress upon Cyprus' limited water resources; they originated in the tropics and have the greatest water consumption of Cyprus' irrigated crops (Sofroniou and Bishop 2014; Dworak and Berglund 2012). With Cyprus' continuing water limitations, relying on water-intensive crops like citrus fruits to drive the economy is not a sustainable development strategy.

The TCC's adoption of pomegranate farming was a response to climate change. Cyprus' competitive edge in the citrus market had been undermined by countries that do not share its climate constraints; farmers needed to implement crop switching to alleviate the growing expense and inefficiency of citrus production. By supporting the commercial pomegranate venture with financial and technical resources, an external actor helped the Turkish Cypriot realize crop switching and overcome the monetary and informational barriers to climate adaptation identified by Seo and Mendelsohn (2008) and Huda et al. (2005).

We argue that the Turkish Cypriot farmers, like the Turkish Cypriot beekeepers studied by Gokcekus et al. (2014), were constrained by the classic collective action problem. The individual farmers did not have the resource capacity to transition to an alternative crop. They lacked the necessary training and technical background to implement a successful crop-switching programme, and they also faced financial constraints. Furthermore, their resource challenges made collectivization unlikely as both technical and financial leadership were absent. Once the collective action problem was overcome, we attribute the success of the pomegranate programme to its incorporation of sustainable peacebuilding (Donais 2009). An external actor provided technical knowledge and the initial investment funds, but Turkish Cypriot farmers quickly accepted local ownership of pomegranate farming. With external assistance, the domestic actor was able to solve the collective action problem.

4 The EU and USAID

Although the EU has committed to assisting north Cyprus' economic development in the hope of the eventual reunification of north and south Cyprus, it was not the primary external actor involved in the development of north Cyprus' new pomegranate industry. Managing Cyprus' political divisions has required delicate manoeuvring by the EU. Until 2013, the EU was actually "unable to set up a delegation in the Turkish-controlled half. Instead, it had to establish a headquarters-based task force in the south with a local programme support office in the northern part of Cyprus" (Nielsen 2012). With this in mind, the EU's relatively behind-the-scenes involvement in the pomegranate initiative is understandable. Through its Economic Development and Growth for Enterprises (EDGE) programme, USAID was actually the main actor facilitating the adoption of pomegranate farming. The EU's involvement was mostly restricted to providing funding through grants.

Under EDGE, the multinational consultancy firm BearingPoint was awarded a six million dollar contract to assist the TCC with economic development. In the completion of this contract, BearingPoint released certain online reports—including a 127 page final report—detailing the development of alternative crop programmes in north Cyprus. According to the EDGE reports, "the US Government's primary policy objective in Cyprus" was fostering a "durable settlement" between the divided Greek and Turkish Cypriot communities (EDGE 2008b, p. 5). To facilitate this settlement, EDGE was commissioned "to improve banking practices, to strengthen business associations and services, and to provide firm-level assistance to promote enterprise competitiveness" (EDGE 2008a, p. 4). The programme was redefined to focus on sector-level initiatives after firm-level efforts failed to have a substantive impact on improving north Cyprus' competitiveness (EDGE 2008a, p. 6). Within the agricultural sector, EDGE focused on five alternative crop programmes: pomegranates, capers, cactus fruit, salicornia, and passion fruit. The pomegranate programme, initiated in 2006, was the first of these to be implemented.

5 Selecting Pomegranates

The decision to support the switch from citrus to pomegranate production was not so much related to the amount of water consumed by pomegranate trees as it was driven by the *type* of water they use. In fact, pomegranates trees require approximately the same amount of water as citrus trees (Sheets et al. 2013; Sauls 1998; FAO 2013). What makes pomegranates a viable solution for Cyprus' climate limitations is their ability to "endure greater water salination than citrus trees" (EDGE 2008a, p. 16). Pomegranates trees are hardier than citrus and can better process salt-contaminated water. As an island in a frequent state of drought, Cyprus' freshwater resources are limited. Additionally, Cyprus has contaminated much of its available groundwater through over-extraction. As groundwater has been over pumped, freshwater aquifers have become salinated (Anastasi 2012, p. 14). EDGE reports specifically acknowledged the "salination of the ground water," as a contributing factor in Cyprus' declining citrus market competitiveness (EDGE 2008b, p. 87). Güzelyurt (its Greek name is Morphou), a region in north Cyprus, had been particularly affected by the increased salinity levels of the groundwater as it had significant citrus orchards. EDGE officials subsequently concentrated their initial pomegranate ventures in this region.

To further heighten the resource gains of the crop switch, the pomegranate varieties chosen by EDGE's commissioned experts were ones that flourished in drier climates and required fewer water resources. EDGE invited Agro Consultant and Agricultural Engineer Shlomy Raziel to provide expertise on the pomegranate programme. After analysing Cyprus' climate constraints, Raziel suggested that the phenology of the Wonderful variety might be best suited to the project as it had proved successful in similarly dry climates, such as Israel (EDGE 2008b, p. 66). Two other pomegranate varieties—the Herskovitz and the Acco that were both developed for Israel's climate—were also selected to be planted along with the Wonderful variety.

EDGE reports cited pomegranates' "consistent[cy] with the TCC's climate, topography and *marketing* [emphasis added] potential" as the reason they were selected to be the alternative crop initiative's prototype (EDGE 2008a, p. 33). As discussed, pomegranates had climate and environmental advantages over citrus fruits. However, the programme's ultimate success was also attributable to the market advantages of switching. Heightened competition from countries without the production difficulties of Cyprus' environmental constraints meant citrus producers were experiencing declining rates of return on their investments (EDGE 2008b, p. 87). Simultaneously, demand for pomegranates increased due to the fruit's designation as a nutritional "superfruit" (Cassell 2012). Despite being a relatively new venture, market demand for the pomegranates produced through the EDGE programme has been such that participants have repeatedly sold the entirety of their yearly crop. All first quality fruits (those with traits most attractive to consumers) are consumed by the international market. The environmental gains of switching to pomegranate production were significant; the market benefits were equally important.

6 Programme Design and Implementation

Pomegranates are not a new fruit to Cyprus. During the nineteenth and early twentieth century, they were actually one of Cyprus' primary articles of export (Kahramanoglu et al. 2014; Usanmaz 2013, p. 2). The conflict that separated the island ended this trade and pomegranate orchards declined. Before the implementation of EDGE's alternative crops programme, pomegranates were either grown mostly for personal usage or "only remained around other fruit orchards as wind barriers" (Usanmaz et al. 2014, p. 62).

Prior to publicly advertising its alternative crop programmes, EDGE consultants exerted considerable effort in pre-emptively alleviating public backlash against perceived "replacement" crops (EDGE 2008b, p. 86). To protect the pomegranate programme from critics who claimed that it would subvert the livelihood of citrus growers, EDGE required that the land used by the growers be "unused, arid land" (p. 86). This stipulation meant that EDGE personnel had to devote additional resources to identifying land that fit this criteria and assisting the farmers with funding and developing drip irrigation systems to make the land productive. However, it did succeed at reducing local suspicions and had a positive long-term impact in the sense that in increased the amount of productive land available to Turkish Cypriot farmers. EDGE began publicly advertising its alternative crop programmes through various local channels in 2006. Of the five proposed projects, pomegranates received the greatest community interest. Twenty-two Turkish Cypriot farmers responded to the initial outreach efforts with 17 agreeing to EDGE's programme requirements. Farmers participating in the programme had to agree to the following:

> (a) sign a Memorandum of Understanding (MoU) that outlined their responsibilities, (b) put some of their own monetary resources into the project, which usually came in the form of purchasing the plants, and (c) allow EDGE experts access to the alternative crops fields/orchards to inspect the crops and offer advice on how to achieve the best harvest. (EDGE 2008b, p. 86)

The programme's *Phase One* focused on planting the pomegranates. EDGE arranged for Shlomy Raziel to visit the pomegranate orchards every 6–8 weeks in order to provide the farmers with on-site technical expertise (EDGE 2008b, p. 86). Prior to the actual planting of the pomegranate trees, EDGE required the farmers to attend training sessions on financial management, orchard establishment, and tree

Table 1 Timeline of pomegranate production

Year	Step
2006	EDGE develops agribusiness programmes
2006	Presented the programme to interested growers
2006	Signed MOUs with the 17 participants in phase 1
2006–2008	Training for growers
2006–2007	Establishment of the orchards
2007	Planted pomegranate trees
2007	Installed irrigation systems in orchards
2008	First harvest
2008	Establishment of Alnar Ltd
2010	Alnar awarded EU rural development grant
2011	Establishment of the Alnar processing facility
2011	First international export of pomegranates

planting. After the 17 participating farmers planted the 18,750 trees on 51 acres of formerly arid land, EDGE supplemented Mr. Raziel's assistance with additional sessions on fertilizer application, pest management, winter pruning, and flower thinning (EDGE 2008b, pp. 117–118). *Phase Two* of the programme expanded the number of participating farmers to 22, the planted acreage to 62 acres, and the number of trees to 22,450 (EDGE 2008b, p. 87).

Phase Three and *Four* of the programme were designed to develop the business side of this agribusiness programme. Under *Phase Three*, EDGE worked with the farmers to establish a fruit processing facility, while *Phase Four* focused on ensuring the sustainability of the growers' business model. Within *Phase Three*, 19 of the farmers incorporated the limited liability company Alnar Narcılık Ltd, and then using an EU grant of 150,000 €, they built a pomegranate processing and storage centre. Through Alnar, the farmers have been able to export their products to five EU countries: Sweden, England, Belgium, Germany, and the Netherlands. The collective has plans to extend their international reach beyond these countries and to expand their internationally available product line to include pomegranate juice. Table 1 provides a summary timeline of the pomegranate programme's various components.

7 Sustainable Peacebuilding

The pomegranate programme has proven to be an archetype upon which to base future sustainable agribusiness development programmes. As the farmers have become more adept at growing pomegranates, the amount of fruit produced per tree has doubled from that of the initial yield (FreshFruit 2014). Exports have grown to almost five times Alnar's preliminary offering of 49 t; in 2013 Alnar exported 232 t of fresh pomegranates (Alan 2013). The collective now produces around

30,000 L of pomegranate juice; since the producers do not use preservatives in their purely natural pomegranate juice, this is currently only consumed by the local market (FreshPlaza 2012). However, the company is exploring alternative means of bottling their juice in order to access new markets.

EDGE's pomegranate programme flourished due to elements of sustainable peacebuilding, like "negotiated hybridity" and "local ownership", that were built into the project. From the beginning, EDGE required the local actors to accept ownership of the programme through financial and organizational commitments. The monetary resources committed to the programme by the farmers were not insubstantial. Although USAID did provide some funding, its financial resources were mainly put towards training sessions and providing the farmers with technical assistance. As mentioned, the EU gave the Alnar collective a 150,000 € grant for the building of the processing plant. However, the entire project cost 450,000 €; after EDGE personnel assisted the farmers with developing a preliminary business plan, the local farmers were responsible for developing their own marketing strategy and contributing the remaining 300,000 € to the programme.

The local farmers were encouraged by the EDGE consultants to collectivize in order to foster long-term accountability among the farmers, develop local leadership, and ensure the sustainability of the programme. According to Ibrahim Kahramanoglu, managing director of Alnar, the producers collectivized in order to have ownership over the programme's business decisions. EDGE personnel suggested that Alnar apply for GLOBALGAP. certification, an independently evaluated standard designation that is often required by EU buyers. EDGE assisted Alnar with the initial application; recertifications have been handled by Alnar's personnel. After obtaining their initial certification, Alnar negotiated with the Cyprus Pomegranate Producers Union (a body of 36 pomegranate producers that has significant overlap with the producers of the Alnar collective) to handle exportation of their crops and extend Alnar's certification to cover the pomegranate products of the Union. Through Alnar, the pomegranate producers were able to develop the local leadership necessary to sustain and surpass what they achieved under the guidance of an external actor.

8 Policy Implications

Cyprus is certainly not the only country facing climate-related development challenges nor is it the only developing country with a collective action problem. Thus, the strategies that worked to foster sustainable pomegranate farming should be largely applicable elsewhere and to other agricultural products. From the case of pomegranate farming, the importance of the following factors is apparent.

When implementing crop switching, the market reputations of suggested replacement products carry considerable weight in determining whether one product is adopted over another. Both EDGE and the local farmers cited pomegranate's rapidly expanding reputation as a superfruit as an important factor in its selection.

Even with the programme's success, the director of Alnar complained that Europe lacked a "pomegranate culture" and that pomegranate products were still far from reaching optimal market recognition (FreshFruitPortal 2014). Although the Turkish Cypriot farmers did have an interest in pomegranates prior to external involvement, identifying products that are both environmentally and market friendly is potentially an area in which developing countries need assistance.

The case of north Cyprus also demonstrated that locals were more likely to view crop-switching programmes favourably if they were initially perceived as augmenting, rather than replacing, traditional crops. EDGE's approach of planting pomegranates only on unused, arid land was able to mitigate any complaints from citrus producers. However, this approach did require significant exertion on the part of the external actor to both identify the available land and then provide the technical resources to make this land arable.

Local awareness of the suggested alternative crop also impacted the programme's overall success. Of the five alternative crop programmes developed by EDGE—pomegranates, cactus, fruit, salicornia, capers, and passion fruit—the pomegranate programme has been most successful. Its success is at least partially attributable to the farmers' familiarity with pomegranates; the passion fruit programme has not inspired nearly as much interest among local actors. In interviews, the director of Alnar stressed that the pomegranate programme only succeeded (and was able to become highly successful) because of the awareness and enthusiasm of the local farmers for pomegranates. In addition to selecting crops that are both market and environmentally friendly, external actors also need to consider local preferences when designing development projects.

Local ownership is critical to achieving successful, sustainable peacebuilding through development. As is evident from the experience of the pomegranate producers, one of the simplest ways in which to inspire ownership is to require significant monetary commitments from the local participants. Overcoming the collective action problem that often characterizes developing societies does require financial input by the external actor (in order to pay for the necessary technical specialists); however, this input should be matched (within reason and considering circumstances) by local contributions. Equally important as the technical training it provided was the assistance EDGE gave the farmers in creating a business strategy. Motivated by EDGE, the producers were able to capitalize on their training and expand into exporting. Thus, in the case of Cyprus, the most important factor was not how much money was given, but how that money was used.

9 Concluding Comments

Pomegranate farming in north Cyprus might appear to be a rather niche case. However, it highlights a real problem that both developing and developed countries will soon—if they have not already—confront, namely, climate change. As the evidence from Cyprus indicates, post-conflict developing countries need financial and technical intervention from an external actor in order to implement even the simplest of climate change adaptations, such as crop switching. Additionally, post-conflict states are often hobbled by the classic collective action problem and need an outside impetus to inspire them to accept local ownership of a development programme. Sustainable development is therefore a function of external and local actor coordination; using its superior resources, the external actor helps initiate the programme, and since the local actor also makes a significant contribution, the local actor commits to ensuring the programme's success.

The sustainability of similar climate change programmes can be further enhanced by selecting crops that are at least somewhat familiar to the local community and are also desired by the external market. A crop's phenology might be ideally suited to a certain region, but the local farmers need to also support its production. Identifying suitable crops will require the combined effort of external and local actors. Ultimately, enacting successful climate change adaptations requires both parties to share leadership responsibilities (Fig. 1).

Fig. 1 A sign indicating that this is a GLOBALGAP certified pomegranate orchard, in Morphou area, Cyprus

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The Role of Women in the Sustainability of the Wine Industry: Two Case Studies in Italy

Graziella Benedetto and Gian Luigi Corinto

Abstract The chapter aims at analyzing whether female entrepreneurs have some distinctive capacities than men in managing business within the Italian wine industry and if these skills are useful for the sustainability of their farms and the whole sector. After the sketch of the women situation in the Italian agriculture and in the wine sector, we have analyzed two case studies located in two wine regions, Tuscany and Sardinia, by having meetings and interviewing two wine women. The two regions are quite different for the general condition of winemaking and for the internationally perceived image. Furthermore, the two informants have different family histories and manage different dimensioned farms. Our findings are that these two female entrepreneurs, even starting from different general conditions, have been able to use their own leading capabilities in the improvement of business and in collective regional and national initiative of wine promotion. Basing economic decisions on formal and/or contextual training, they have introduced innovations in farming, winemaking, and marketing in a specific way. We can say they have been someway slower, less hasty, and even more effective than men in involving collaborators with a charismatic heading and attracting other entrepreneurs in doing business. The role of women in farming has been too long underrated by society and the policymakers, who, on the contrary, should provide more specific attentions to the female capacity to foster the sustainability of their own farms and the wine Italian industry.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_12

1 Introduction

Even recent researches (Piacentini 2013) show persisting gender differences in labor market all over the world. Entrepreneurship is the dimension where gender differences are the most marked, and still today, business women are much less than men, and their ventures are usually small and operate with little capital. Italy is not an exception and not the Italian agriculture.

For decades the increasing presence of women in the Italian agriculture has been interpreted as a signal of loss of competitiveness since the term "feminization" has been often used in combination with the "senilization" (aging) of farmers indicating the weakening of entrepreneurial capabilities within the farmers (Bandini 1967). The traditionally underrated role of women in farming has been determined—among other causes—by the hereditary system of land property that privileged the masculine line and even more by the social role of raising children and preparing and serving food, usually performed by housewives (Mennell et al.1992; Couniham 2004). The large diffused *mezzadria*, i.e., the sharecropping land tenure, underlined the dependent role of rural housewives in the household economy, with a clear division between male and female duties, and otherwise it was also the basis for extensive socioeconomic mutations (Ciuffoletti and Contini 1994). In Central Italy, farming systems and the landscapes are strictly intertwined, and both refer to a particular organization of the agricultural habitat within, with functional relations between housing and farming, settlement and the countryside, and houses and cultivated fields being detectable (Polidori 2013). The specific objective of this kind of land tenure was to have enough foodstuffs both for the farming family and the landowner and his family. Indeed, the middle-upper class of landlords aimed at living "off one's own means," and thus, the overall land tenure was oriented to self-consumption (Jones 1980). The role of women was clearly subordinated, both in working class and in landowners.

The traditional role of rural women faced a striking change in the half of the twentieth century, when masses of rural people abandoned farming employment and rural residences (De D'Attorre and Bernardi 1994) to live in cities and work in nonagricultural industries following the general social mutation of the Italians (Corinto 2014). The agricultural and rural exodus interested both men and women, regarding younger and more skilled and willing to risk people, being agriculture clearly viewed as a poor sector for weaker entrepreneurs and workers, i.e., women and the elders (Bartoli et al.2011).

According to Barberis (1963), the feminization of agriculture, already started in the 1950s and 1960s, is to be considered as the factual emersion of the female self-employed farming, a phenomenon previously near invisible. At the end of the past century, in 1997, the European Commission (Commissione Europea 2002) showed the highest percent of female farm managers was localized in the Southern Italy (Abruzzo, Molise, Campania, Basilicata, all ranking between 28 and the 41 %). In particular, in Sardinia, the female emancipation has a long history, due to the centuries-old absence of male shepherds (the husbands) from the family house and the subsequent establishment, as a matter of fact, of a matriarchy and a female mayor propensity to training studies (Barberis 2009).

During the 1990s, feminization of agriculture "became a female sound presence in the guide and proper managing of the farm with several innovative characteristics" (Tazza 2010, p. 119). Today this "feminizing" trend continues, and women are more numerous than in the past, both among workers and farm owners and managers. Recently, a study performed by the Italian Minister of Labor enlightened some general traits of women entrepreneurs: "it emerges a model of a female entrepreneur/manager that mainly privileges a cooperative network system that includes business, community and family, fostered by the relational skills typical of women. Female entrepreneurial styles are characterized by flexible solutions in relation to the different phases of the woman's life and the difficulty of the diverse works and private/family timing of tasks, especially when women have kids. Otherwise, there are still copious facts that hinder the women/labor-market relationship, regarding women both entrepreneurs and workers" (Unioncamere 2011, p. 13).

An important point to underline is the generally stronger capacity of the female enterprises to face the current economic crisis. "At the national level, the increasing number of female enterprises […] during the crisis has more than balanced the decreasing of the male ones" (Unioncamere 2011, p. 13).

Women have different skills than men in terms of perception/sixth sense, or in organizational jargon "emotional intelligence," and in managerial jargon "multitasking" abilities due to the daily necessity to face simultaneous different responsibilities (Goleman 2001).

According to Rea (2009), a "women diversity" actually exists, stated in managerial studies and social psychology (Piccardo and Baiunco 2007; Piccardo et al.2008) that have put in light the female diversity in comparison to the male leadership. The female leadership shows "communal" features, such as cooperativeness, generosity, and empathy. The male leadership shows more "agent" features, such as self-confidence, assertiveness, and control.

A recent study (Rea 2009) realized that the distinction between "transactional and transformational leadership" (Burns 1978; Bass 1985) fits well for analyzing the female entrepreneurship. Indeed, women show a "transformational leadership" oriented to the commitment and creativity of collaborators, while men more frequently act as "transactional leaders," willing to correct/reward/punish collaborators in relation to the obtained goals (Rea 2009). The transformational leadership could be the expression of a "soft-power" (Nye 2004), while men, performing a "hard-power," actually use a top-down management. Moreover, Arlenghi (2014) reported the soft aptitudes of women are most wanted by modern companies, organized in reticular and less hierarchical schemes.

Then, our case studies aim at analyzing the role of women managers in the Italian winemaking sector, focusing in their innovation capabilities and the effects on sustainability as stated even in the Europe 2020 strategy and in particular in the Italian wine industry.

In Italy, the Italian Association *Le Donne del Vino* (The Women of Wine) was born in 1988 aiming at gathering all women committed to the realm of wine. They are female winemakers, marketers, managers of wineshops, sommeliers, restaurant owners, journalists, academicians, and researchers on the wine sector. From the origin up to today, the number of women of wine has increased from 8 to 800.

Five years ago, a dedicated study on the female perception of wine consuming behavior modifications has been performed (Rea 2009), just using the “universe” of the Women of Wine association. This study enlightened the female tendency to use the marketing leverages of communications and events organization, within the singular farm and involving the territory (Rea 2009).

We have adopted a different research perspective, more focused on the nexus between female entrepreneurship, innovation, and sustainability.

Therefore, the chapter reports results of two case studies, performed by deep face-to-face interviews to female entrepreneurs acting in the Italian wine industry. We describe and interpret the ongoing role of women in the wine sector, giving some enlightenments on economic and social reasons of the importance of women as wine entrepreneurs.

The rest of the chapter is organized as follows. Section 2 reports the overall situation of farming, winemaking, and rural tourism, even sketching the presence and role of women and female entrepreneurs. Section 3 reports background literature and research focus, questions, and method. Section 4 reports the narrative of the two case studies, the Fattoria del Colle and Tenute Olbios, respectively located in Tuscany and Sardinia, as resulted from the interviews. Section 5 is dedicated to discuss our findings and Sect. 6 gives the conclusions.

2 Background: The Overall Situation of Farming, Winemaking, and Rural Tourism in Italy

Between 2000 and 2010, years of the 5th and 6th Agricultural Italian Census (ISTAT 2002, 2010), the owned farming land tenure continued to prevail over the waged-labor-based one (Table 1), but farms have reduced by 533,000 units (−24.7 %). In particular, female holdings decreased by 107,000 units (−16.7 %), while male ones showed a stronger reducing equal to 426,000 units (−28.1 %), almost in all the geographical zones of Italy. This data proves the general tendency of women’s resistance against the crisis even in agriculture, so that the percentage of women in farming increased from 29.8 % to 33 % (Table 2) and from 28.0 to 33.2 in tourist farms (Table 3).

The latest Agricultural Census (ISTAT 2010) showed in 2010 that there were 1,630,420 agricultural holdings. The total agricultural area (TAA) was 17,277,023 ha and the utilized agricultural area (UAA) was equal to 12,885,186 ha. Agricultural holdings are mainly managed by individuals or

Table 1 Italy. Land tenure in 2000 and 2010

Land tenure	2000	2010
Owned farming	95.4	95.0
Waged labor based	4.5	4.3
Others	0.1	0.7

Sources: ISTAT (2002, 2010)

Table 2 Italy. Farm managers per gender and variations in 2000 and 2010

	Farm managers					
	Men		Women		Total	
Year	*n*	%	*n*	%	*n*	%
2000	1,512,169	70.20	641,555	29.80	2,153,724	100
2010	1,086,619	67.00	534,265	33.00	1,620,884	100
Variations (%)	−28.14		−16.72		−24.74	

Sources: ISTAT (2002, 2010)

Table 3 Tourist farm managers per gender and variations 2000–2010

	Farm managers					
	Men		Women		Total	
Year	*n*	%	*n*	%	*n*	%
2000	8,924	72.00	3,472	28.00	12,396	100
2010	12,902	66.8	6,402	33.2	19,304	100
Variations (%)	44.58		84.39		55.73	

Sources: ISTAT 2002, 2010

families (96 %), and the manager is the landowner himself/herself (95 %) or runs family lands (65.5 %).

Among the tree crops, viticulture is practiced by 383,645 companies, 23.5 % of the total, and covers 632,000 ha, equivalent to the 4.9 % of the UAA. The average size of vines is 1.6 ha, increasing by 0.7 ha in comparison to 2005.

The Italian wine sector is in very good health, as stated by Mediobanca (2014). For this research institute, the turnover in 2013 increased by 4.8 %, due more to export (+7.7 %) than the inner market reaching 24.1 % over the 2008 level. The level of employment has increased between 2008 and 2012 in countertendency to the downsizing of the beverage sector (−5.2 %) and the manufacturing industry as a whole (−6 %). In 2013, Italy is still the main wine producers in the world with a total of 44.9 million hectoliters, preceding France (44.1 million) and Spain (40.0 million). The total value is estimated to be 9.1 billion euro.

In 2013, the top three Italian companies were Cantine Riunite-GIV (534 million of turnover), the Caviro Group (327 million), and the wine division of Campari (228 million). We must underline that at the fourth position, there is the Antinori company (with 166 million euro) that has three women at the top management and strategic marketing office.

Some details about agricultural tourism and the quality productions are given. In the abovementioned decreasing number of agricultural holdings, agricultural farms showed a clear opposite tendency. Between 2003 and 2012, tourist farms increased from 13 to 20.5 thousand units (+57.3 %), and female-conducted ones increased from 4.3 to 7.3 thousand (+67.9 %) while male-conducted ones from 8.7 to 13.2 thousand (+51.9 %). In tourist farm, owning the rate of women increased from 33.2 to 35.5 %.

Data show that farm tourism is clearly increasing and the female percentage contribution is quite higher than the masculine one (Adua 2014).

In conducting farms of AOC and PGI chains, the female managers are in average less young than men and have less UAA but, on the opposite, work more in the organic farming, have a higher degree of instruction, and live more frequently in the hilly countryside (Adua 2014).

3 Background Literature and Research Focus, Questions, and Method

According to recent scholars' statements, the past vision of "feminization" as a negative attribute "is inadequate to understand the today variation of farm tenure and managing in Italy" (Sabbatini 2006, our translation). Today, "even multifunctionality and generational turnover in agriculture are fostered by women" (Sabbatini 2006, p. 20, our translation).

Rosenberg (1963) defined technological innovation as a major ingredient of long-term economic growth, characterized by a high degree of uncertainty. In this sense, innovations introduced by female rural entrepreneurs (in particular in winemaking and wine tourism) deal with technological and market uncertainty and have many ingredients of sustainability having surely a long-term vision.

In this line, the role of social capital and human capital (according to Becker 1962, 1975; Schultz 1960, 1964) and their reciprocal interrelations matter and have been tested in the Italian rural development (Benedetto 2011).

The updating of agriculture by the modification of the different forms of human, physical, and organizational capital (as stated mainly by Shultz) is an important research topic and a means for the sustainability even for wine farms.

Thus, our research focus is on the role of female entrepreneurs in using their specific capabilities and skills for the sustainability of their farms and the territories where they live and make business. Our research questions are as follows:

- Do women have a specific attitude in making business in the Italian wine industry?
- Are they able to perform feasible farming and marketing decisions in order to design a sustainable development of their business?
- Can they reconcile their family responsibilities to perform a charismatic leadership?

In order to find data useful to answer the research questions, we made two case studies following the qualitative method, gathering informations indirectly from press and the Web and directly from face-to-face interviews (Tremblay 1955; Kvale 1996; Marshall 1996; Bradburn et al. 2004) to women entrepreneurs engaged in the managing of vineyards and wine farms.

We have chosen to perform the interviews in two quite dissimilar Italian regions: Tuscany and Sardinia, which do actually represent very far wine poles in the Italian panorama. Thus, the comparison will help us in verifying the female behavior and the women perception of their own managerial "diversity" in utmost different socioeconomic environments.

4 Case Studies

The two case studies have been carried out following the abovementioned literature and aiming at focusing:

- A general picture of the wine farm and the history of the female managing
- Main issues of the winemaking and selling with a specific attention to sustainable goals
- The actual female contribution to the "organizational form" and innovation of the farm
- The interviewee's perception about the distinctive capabilities of a female managing

4.1 Fattoria del Colle, Interview to Mrs. Donatella Cinelli Colombini

The Fattoria del Colle farm is located in the municipality of Montalcino, province of Siena, and has a very long story and is linked to a famous and renowned red wine, the Brunello di Montalcino.

The first testimonies of the farm house have roots in the twelfth century. Over time, the whole real estate faced several changes and today has 336 ha lying on the hills in front of the village, where wines such as Brunello, Chianti Classico, and Nobile di Montepulciano have their historical growing place.

In 1998, Mrs. Donatella Cinelli Colombini inherited the farm house Fattoria del Colle, where she today manages 160 ha of cereals, 6 ha of olive tree yards, and 22 of vineyards, cultivating varieties of Sangiovese, Merlot, Traminer, and Foglia Tonda, which is an old vine, neglected for centuries. The Foglia Tonda variety remained in obscurity for a long time, but was rediscovered in the 1870s by Giuseppe Conti de Rovasenda, one of Italy's famous early ampelographers. It was finally admitted to Italy's Registro Nazionale delle Varietà di Vite (national register of wine grape varieties) in May 1970, still being neglected. Today, one of Foglia Tonda's strongest advocates as a blending ingredient is the Donatella Cinelli Colombini winery, whose Sangiovese-based Cenerentola wine (Orcia DOC) includes a greater portion of Foglia Tonda with each vintage that passes.

Mrs. Donatella Cinelli Colombini was born in 1953 into a family of Brunello di Montalcino's producers. Today, she manages two wineries, the Fattoria del Colle and the Casato Prime Donne, in the municipality of Trequanda and Montalcino, respectively, both in the province of Siena.

This real estate pertained to the ancestors of Mrs. Donatella yet in 1592, and in more recent year, it has been owned by her grandmother and then by her mother Francesca and in the future will be inherited by her daughter Mrs. Violante Gardini, in an evident female line.

In 1993, Donatella Cinelli Colombini, daughter of Francesca, the "Lady of Brunello," invented the first edition of Cantine aperte (Open Cellars) after the research proposed to Magda Antonioli Corigliano (1999) and the publication of the first identikit of wine tourists. Following this initiative, the Wine Tourism Movement took place in an increasing successful tendency over time. This specific feminine innovation was continued by Donatella Cinelli Colombini who started in 1998, the first Italian cellar with an entire female staff, the Casato Prime Donne, in Montalcino. In 2000, for the Christian Jubilee, Women of Wine presented "2,000 wines from Women of Wine," and the same Woman of Wine in 2001 organized the first edition of Calici di Stelle (Calices of Stars) during the first decade of August.

> "I had the duty from VIDE—Italian Excellence Vine-growers—to promote public relations, almost with no budget. I adopted a questionnaire for visitors of VIDE farms. I realized it was the very first time anyone entered such a survey. So I proposed the new event Cantine aperte (Open cellars). In 1998 I was searching for an enologist. All the male enologist graduated in Siena were employed by main producers, and there were many unemployed women. That's matched to my goal to have an entire female staff" (Donatella Cinelli Colombini).

The success of the movement and the associationism initiative has been clear, also due to the increasing interest about women's behavior in wine consuming. Today, the associated women are nearly up to 700. Young and trained women (with an academic degree in agriculture and enology) as associated members are increasing, and many women enter the world of wine not due to a family heritage but as a choice of life.

Within the family, Mrs. Donatella is the farm manager and is directly responsible for the communication. Her daughter, Mrs. Violante, is the executive sales manager for the wine.

> "My Grandfather, Giovanni Colombini, was the person that influenced me more. He taught me the value of typical products, the importance to develop the entire supply chain up to the final consumer. Form pigs to the selling of cold cuts, from sheep to cheese, from vineyards to the exportation of our bottles with our brand. He was the first who opened the cellar to public visits, even starting a farm restaurant salami, still in the 80s" (Donatella Cinelli Colombini).

The total wine production of the winery is sold abroad for the 60 %, while the 24 % in Italy and the 16 % at the cellar. All the vineyards are grown organically even if not certified, and the farm benefits from solar panels for producing about a quarter of the total energy needs.

The entrepreneurial activity of Mrs. Donatella has also evident public facets, at the national level in the life of the Movimento delle Donne del Vino and at the local level being the President of the AOC Orcia Consortium, fostering the project "Orcia, the most beautiful wine in the world." This initiative aims at transforming the million visitors of the area in the "Orcia wines" estimators and consumers.

In view of this goal, all the wineries will improve the linkages between landscaping and wine growing, building belvedere (beautiful panoramas), and hosting trekkers. The communication plan will be made by setting advertising totems in the car parkings, distributing a 100,000 of leaflets and 30,000 maps, and making a pushing Internet and social media marketing.

When Mrs. Donatella assumed the executive direction of the Fattoria del Colle, in 1998, within the village of Trequanda, there were no wineries, while today there are five. The publishing of a cooking recipes book as well as other continual initiatives of press office and public relations made the place more known and visible worldwide, inducing a tourist flux, encouraging other people to make investments and businesses.

In the area of Montalcino, the innovating action is less incisive than in that of the Orcia Valley, because the willing to innovate is less strong, probably due to the well-developed brand of the territory in comparison to the last one. Nevertheless, the Benvenuto Brunello (Welcome Brunello) event, which takes place every year in February, presenting to the press the new wines on the market since the beginning of the new year, has been welcomed by everyone.

In concluding the narrative of Mrs. Donatella Cinelli Colombini, a peculiar finding must be underscored about the idea of a "specific female organizational form" of the enterprise, as perceived by her:

> "The 'female' managing is little centralized and very flexible. There is a very high propensity to reconcile personal needs with the business. Every decision and initiative is the result of a team effort and a collective 'laboratory of ideas.' We invest in the training and external partnerships that can bring innovation."

4.2 Tenute Olbios, Interview to Mrs. Daniela Pinna

The Tenute Olbios (from the root of a Greek word meaning "felix, rich, and fertile land") is a young farm located in the municipality of Olbia, in the province of Sassari, within the zone of Gallura, the very birthplace and sole productive area of the CGDO Vermentino. The locality is named Venafiorita (due to the presence of good water) in the countryside of Olbia, just in front of the northern coast of Sardinia, yet being very close to the city of Sassari, in a particularly favorable location.

The farm has 60 ha of vineyards, managed by Mrs. Daniela, who was laureate in Agricultural Sciences at the University of Sassari. She self-provided a specialization in vine growing and wine processing, following a personal aptitude, and choosing selected specialized courses and a specific final dissertation, because the university had not yet established an autonomous Degree in Food and Wine technologies. Her specific goal was to manage the owned farm having competencies in winemaking and marketing.

The mother figure was "for better or for worse," very fundamental to the choices of Mrs. Daniela. On the one hand, her mother has been always attached to the land property, even when left alone, a widow with three children, always rejecting any favorable buying offer for the farm. "In Sardinia hardly someone sells the land" (Daniela Pinna).

On the other hand, the mother showed a strong opposition to the training of Daniela in agriculture and winemaking, emphasizing all the difficulties she could meet as a female entrepreneur.

In 2003, Mrs. Daniela became the farm manager and built together with her husband the Tenute Olbios wineries, with very few funds. The business increased, still slowly, as happens "when you have small monetary funds. This is the typical case of many historical wineries, which have a slow evolution over time, not having a sudden success, yet avoiding an equally sudden decline" (Daniela Pinna).

First, she bought secondhand machineries for pressing and refrigerating phases, performing different tests of wine production mainly with the Vermentino di Gallura grape, in order to have the first production of wine. The company profit is always reinvested in the farm.

An old industrial stazzo (a traditional one-story rural building of Gallura), already within the center of the farm and with high ceiling, has been refurbished for the wine vats settlement.

The development project was quality and environmentally oriented and the farming still follows the organic principles.

Mrs. Daniela retained all her mother's employees, because they were the memory of the farm, and allowed her to know everything that has been made within the rows of the vines, even if she perceived difficulties in their acceptance of innovative techniques. She used profitably her scientific training, albeit with prudence and diplomacy, introducing gradually all technical innovation she decided.

In 2006, Daniela introduced the bottling plant and started production with a single selection, the Vermentino di Sardegna DOC Lupus in Fabula, dedicated to her mother.

In 2007, she started to produce red wine, after replanting over time 10 ha of vineyards, choosing native red grapes and updating the winemaking techniques. After doing tests for red and rose wines, the Nessuno (Nobody), a full-bodied wine with a very intense flavor, was born. The brand name was derived from the name of Ulysses, as recent studies stated the Greek hero passed by the Northern Sardinia during his journey.

In 2008, the fourth new selection, a pure Vermentino di Gallura sparkling wine, has been produced by using the champenoise method. Its soft and velvety taste reminded her of the silk texture, so Mrs. Daniela thought of the Sardinian Bisso (a natural fiber produced by a Sardinian fan mussel) and chose that brand name for the sparkling wine.

Just during her meetings with Chiara Vigo, the last master of the marine silk, the Bisso, Mrs. Daniela has been hit by the discourse of Chiara that in Sardinia, women have provided the preservation of the female arts, from food recipes to weaving and much more.

Mrs. Daniela has always been very careful to recover the island traditions, usually combining her wines with local typical products in the farm tasting room. Moreover, she has involved many Sardinian artists in designing the wine bottle labels.

Recently, she has introduced new services, such as the possibility to book a dining at the farm, in collaboration with two Sardinian chefs she hosts in the farm kitchens. Then she organized Cooking Classes for teaching bread and pasta making, with the collaboration of a professional who was a University mate of her. The farm participates in the Tourism of Wine Movement and has organized events such as Cantine aperte (Open Cellars) and Cinema in cantina (Movies in the Cellars).

Another crucial element is the abatement of any architectural barriers to allow disabled people to visit throughout the farm.

The Tenute di Olbios sells near all the production only through the HORECA chain and frequently hosts sommeliers who visit the place of wine production, in order to be able to make a specific storytelling to final consumers. Mrs. Daniela, in the role of executive sales manager, had implemented the commercial network with agents, distributors, and importers in Italy and worldwide.

From 2010, Mrs. Daniela Pinna is the President of the CGDO Vermentino di Gallura consortium. In this role, she has contributed to an important law innovation, allowing the past prohibited use of alternative caps than corks and inducing even the modification of the Vermentino production disciplinary.

She has been the second Italian winemaker who used the glass stopper for wine bottles, considering the exclusive capabilities in maintaining the wine safety during oversea transportation and when the wine oxygenation is not necessary, and above all the overuse of preservatives should be prevented.

The next innovation Mrs. Daniela is going to introduce is in wine pricing, whether clients will undertake to turn back the bottles for recycling, in order to improve the mission of sustainability the farm has undertaken since its establishment.

Telling about the female distinctive aptitudes, Mrs. Daniela Pinna declared some clear perceptions. She asserted that women have without a doubt more refined sensibility and a manner able to introduce innovation softly and elegantly. Moreover women are very disposed to disabled persons, the diffusion of the sense of the place, the involvement of staff also during not working activities (lunches after harvest, participation in family celebrations), and concern for workers' families. Women have a greater resourcefulness and determination in making decisions. Her idea of using glass stoppers has been opposed by male entrepreneurs, who were saying, "We are in Sardinia, the homeland of cork," but results have rewarded her innovative idea.

5 Discussion

We have had the possibility of interviewing two female entrepreneurs active in two very different Italian wine regions, Sardinia and Tuscany. Only Mrs. Cinelli Colombini is the member of the Italian Women of Wine movement. They both have inherited the property of real estates and vineyards through a female line, yet in quite different farming and economic dimensions. Mrs. Donatella Cinelli Colombini belongs to a very ancient family of century-old landowners, farmers, and winemakers. Mrs. Daniela Pinna's family is someway "younger" in farming, and even her farm and winery are younger. The first lady didn't encounter the opposition of the family to undertake the farming venture, while the second one has had to deal with her mother's opposition in becoming a farmer and an entrepreneur. Nevertheless, in both cases, the start-up of the female enterprise is to be considered as factually born within the family.

Even the socioeconomic local environments they must face are quite different. They both live in wine regions, but Sardinia certainly suffers major limitations in wine traditions than Tuscany, especially about the national and international reputation of branded wines and *terroirs*, and even for the same whole image of the region. Nevertheless, they both showed a strong personal orientation to farming and marketing—and in particular to communications and public relations. Mrs. Donatella Cinelli Colombini invented some collective national level events (Open Cellars and Chalices of Stars), then followed by many of the Italian wineries over time, besides the recovery of old vines in winemaking and the continuing attention in improving the control of quality and the entire supply chain of any production, including hospitality. Today, she heads an "all-female staff" in her wineries, being a singular and atypical Italian case.

The Sardinian case study is particularly useful in reflecting the importance of the human capital (*à la* Schultz) in the performances of the business. Thus, the acquired formal training allowed the accumulation of skills which have been essential for the adoption of technical innovations, including the decision to have a farm wine processing, bottling, and distribution. This is in evident accordance with the research of Barberis (2009) on the evidence of a mayor density of graduated women in Sardinia than in the rest of Italian rural areas.

Mrs. Daniela Pinna even adopted some strong technical innovations such as the use of glass stoppers, showing courageous capacity in a cork-producing region such as Sardinia.

We can, thus, argue that their distinctive capacities in "leadership" and in "making community" led both of them to the apical role of President in CGDO wine consortiums.

We can link innovation capabilities surveyed in the case studies to sustainability. The two female entrepreneurs did "sustainability" in different manners, even though they both have adopted organic farming without requesting an official certification. The "sustainability" they try to achieve is their own farm's long-lasting future life, even by means of an evident communication program. In this sense, we cannot state that female specificity does actually exist, being evident that any competing firm must struggle against its own capital stock obsolescence (including human skills) if it wants to continue to have profits.

Moreover, a female-specific “resilience” against competition, and then for the sustainability of the firm’s long-run life, should be better found in the “soft and elegant” capacity to manage leadership, as stated in general and sectoral literature and confirmed by our informants. The two interviewed women clearly showed soft and solid capacity in involving the internal farm staff and even in managing social relations to improve the role of winemakers, not only women, in the policy of the sector. They focused not only on improving winemaking techniques, or introducing farm hospitality, but even on branding, labeling, wine naming and showing the willingness to care about the necessity of laborers and families, as in the case of the Tenute Olbios.

To be considered as having a broader validity, our findings should be compared in a larger-scale survey, performing and comparing more than two case studies. Nevertheless, the particular choice of the informants, which have different histories but both having been able to reach leading roles in the realm of the Italian wine industry, gives sense to our findings, especially for future deepening on the same topic.

6 Conclusion

Our case studies do confirm the modified role and mayor persistence of women than men in the Italian wine industry. Even when starting from a weaker or “marginal” position, in terms of capital endowment and initial minor technical skills, women seems to be perfectly able to improve their training and to introduce innovations in managing their farms in order to ensure a long-run perspective to their businesses. We can say that, at least in the two reported cases, women show some distinctive capabilities. These are retrievable in the capacity to perform leadership in soft and elegant manners, preferring a “transformational” to a “transactional” leadership in order to achieve a charismatic heading.

Both the cases are a testimony on the importance of formal and informal and contextual training in increasing skills and competencies of female entrepreneurs, as either the family or the university can be a source of entrepreneurial capacity improvement.

The multitasking aptitudes of women have been confirmed, as well as their capacity in performing public relations with high-level goals, maintaining the family cohesion as an important and not a secondary target.

Policymakers have not always shown a dedicated attention to the female capacity to make business, and the agricultural sector is even the most effective example. Our study can help policymakers in paying more attention to women’s capacity to give a specific form of resilience to the entire sector of agriculture.

Acknowledgments The authors are indebted to Mrs. Donatella Cinelli Colombini and Mrs. Daniela Pinna for their valuable contribution during the interviews, subtracting time to their activities. Their field experience has been not substitutable for our research aims, and helped us in improving our knowledge on the research topic we wanted to investigate.

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Part II
Natural Resource Systems and Environment

The Effects of Climate Change on the Multifunctional Role of Basilicata's Forests: The Effects Induced on Yield and CO_2 Absorption

Severino Romano, Luigi Fanelli, Mauro Viccaro, Francesco Di Napoli, and Mario Cozzi

Abstract The first studies on the possible impact of climate change on European forests and the development of adaptation and mitigation strategies began in the 1990s and resulted in the identification of risk assessment models and forest management tools. The prediction of climate change impacts on forests has been based using *the evidence theory* or *Dempster-Shafer* (DS)'s *theory*, appropriately spatialised. The implemented evidence lines refer to the concepts of vulnerability and resilience. The results of the DS model, applied to the Basilicata region, were utilised to assess the loss in biomass production capacity and CO_2 absorption ability of different forest-derived biomasses. The loss in stumpage value and in the estimated CO_2 absorption shows a reduction over time of forest system's economic value that is basically higher in 2050 than in 2100. The applied methodological approach has shown that the high degree of spatial and information detail may be helpful to produce good predictions to envisage environmental policy strategies for the monitoring and mitigation of the damages caused by the climate change, with a view to ensuring the ecosystems' capacity to produce positive externalities, including air carbon sequestration capacity.

1 Introduction

Following the last report of the Intergovernmental Panel on Climate Change (IPCC), the rise in greenhouse gases (GHGs) has increased over the last 10 years more rapidly than over the three previous decades; projections actually indicate a 3.7–4.8 °C rise in the average temperature by the end of the century, in the absence of real mitigation strategies (IPCC 2014). The main climatic parameters, including

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_13

the increase in average temperature (Donat et al. 2013), describe worrying scenarios both for humans and for natural systems. The large-scale extreme events (Hanley and Caballero 2012), which have increased over the last few years, are all undeniable signs of climate abnormalities.

The climate components, i.e. rainfall, temperature and winds, are the major elements influencing animal and plant species, by regulating their distribution and density in space and over time (Maron et al. 2014) and by interfering, in general, with the physiology and the behaviour, the life cycle, the geographical distribution and the composition and interaction of complex systems. This also applies to forest systems, where the effects are more substantial as compared to multifunctionality levels (Nijnik and Miller 2013). Woods are actually the major carbon absorption sink and the principal means to contrast climate change (Fu et al. 2014). Therefore, it is essential to avail of appropriate tools to understand the effects on forests and develop the adaptation and mitigation strategies required. Simulation models are the main tool for investigating the climate. These mathematical models can predict the climate pattern by simulating the main physical processes of the earth system and testing their functioning based on the simulations of the past climate compared against recent data. Simulations are run for the possible variations of input parameters that in turn depend on other variables (Nakićenović et al. 2000). However, the quality and quantity of the interactions involved in the climate system vary a lot, so that the results of simulation models are affected by inaccuracies and uncertainties.

This work has produced a dynamic and statistical local climate simulation model based on the combination of *downscaling* techniques. These methods enable the transfer of results to a more detailed scale (Giorgi and Lionello 2008; Rojas et al. 2013; Jacobeit et al. 2014) and, more specifically, to the territory of Basilicata region, Italy. As a matter of fact, the Mediterranean region, which includes Basilicata, has long been identified, among the various world areas, as one of the major climate change *hotspots*, i.e. one of the biogeographical regions most sensitive and vulnerable to its effects. The implemented simulation model, projected to 2050 and 2100 based on the SRES A1B scenario of the IPCC (IPCC 2007), has enabled the assessment of the mean status and the possible climate variations on the local scale.

Based on the results obtained using the applied climatic model, the research was directed to assessing the effects induced on forest ecosystems. The loss in forest system multifunctionality attributable to the climate change has been extensively studied over the last few years (Seppälä et al. 2009). In this framework, the evidence theory has been applied to forestry for assessing new adaptive management forms (Ducey 2001; Yousefpour et al. 2013), integrated with the fuzzy approach (Deng et al. 2011), and for the economic quantification of damages (Bernetti et al. 2010; Roberts 2008). For the latter aspect, it is necessary to know the physical impact of climate change and set an economic value to this impact. This is difficult to apply, since in many cases there is no monetary value for all physical damages caused by climate change (Carraro et al. 2007). Forests actually produce different environmental externalities (CO_2 absorption, protection from erosion, surface runoff control, tourism, biodiversity, etc.) that do not have a market, so they cannot be monetarised. For this reason, starting from the vulnerability and resilience notions, this work has estimated the economic damage resulting from the loss in biomass yield and the reduced CO_2 absorption by Basilicata's forests. The estimates have concerned three time frames, 2100, 2050 and 2012, as reference years.

2 Materials and Methods

Forests and natural systems, in particular, play an important role in rebalancing and absorbing the effects caused by external disturbances, provided their resilience is kept constant. Unluckily, the multifunctional essence of forests is not constant over time, partly due to the climate change. The effects are visible in the variation of growth and yield rates, the changes in the composition of existing species and *shift* in altitude and latitude, with the subsequent change in the biodiversity level and CO_2 absorption function.

The ability to predict events by using climate simulation models can be very helpful to identify action strategies and management techniques aimed at improving the climate change adaptation capacity. The applied methodology, summarised in Fig. 1, basically analyses the concepts of vulnerability and resilience of forest stands, using DS theory.

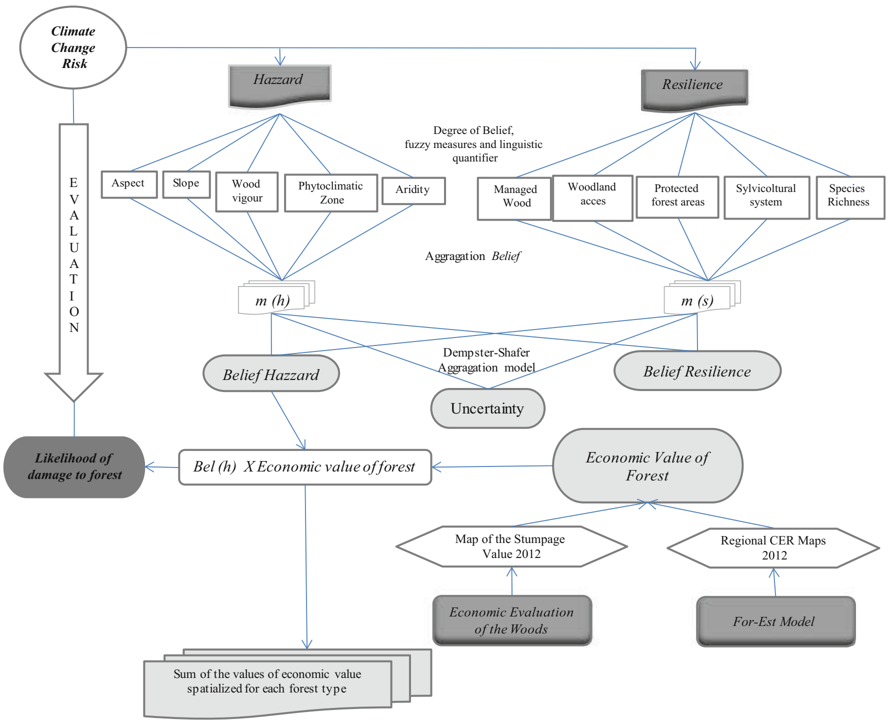

Fig. 1 Model of environmental impact assessment

Vulnerability is defined as “the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes” (IPCC 1997), although in the case of forestry, the main factors are the ecological characteristics of species and the morphological traits of the area (Bernetti et al. 2010). Resilience instead has been meant as the capacity of the systems to react to external environmental variations keeping the same structure and the same basic functioning mode (IPCC 1997). Applying the notion of resilience to forests, this may be defined as their capacity to cope with external environmental variations, maintaining some ecological stability, both for the specific composition and the maintenance of the structure, depending on the growth stage of forest (Bernetti et al. 2010). The first step of the work involved the standardisation of the variables that contribute to the resilience and resistance of forest areas, using the *Fuzzy Logic* (Zadeh 1987). The variables used for the definition of vulnerability and resilience (Fig. 1) have been previously standardised and then grouped, using the DS theory, into three probability indicators:

1. *Belief* of vulnerability [Bel(h)]
2. *Belief* of resilience [Bel(s)]
3. Uncertainty (U; h, s)

The DS theory makes it possible to strengthen knowledge by integrating different kinds of information and distinguishing uncertainty, in order to understand any possible risk associated with decision-making.

The assessment of indicators enabled the estimate of the loss in biomass and in the subsequent stumpage value of Basilicata’s forests, by correlating the vulnerability of forest stands with the loss in wood increment. The wood biomass reduction was also assessed and expressed in terms of damage caused by the avoided CO_2 fixation by 2050 and 2100, taking 2012 as reference.

2.1 The Concept of Plausibility According to Dempster-Shafer’s Theory

P*lausibility* is a common concept in many situations, ranging from the scientific world to everyday life; it also meets the need to manage and reduce uncertainty. Plausibility can make explicit and formalise given models of appropriate behaviour and reasoning via other conceptual models, such as, for example, the evidence theory.

Coping with uncertainty being the principal objective of plausibility, the DS theory is explicitly targeted at overcoming the limitations of Bayes’ conception: as a matter of fact, believing in localization h does not imply necessarily believing in its denial s to the extent of the remaining belief. The DS theory assumes the theoretical possibility to make use of two distinct opposite values to express both belief h and belief s. Therefore, taking into account the DS notion of plausibility, we can state that, while the Bel(h) represents the degree of concrete evidence in support of an assumption h, the plausibility indicates the degree to which the conditions seem to be adequate for this assumption, although an evidence line in support of it is lacking or difficult to attribute. Hence for any assumption, the Bel(h) is the lower limit of our commitment, and the *plausibility* PLS(h) is the upper limit. The range between the two is the degree of uncertainty to establish either the presence or absence of this assumption.

The assessment of assumptions is based on three key concepts: *basic probability assignment* (BPA), *belief* and *plausibility*. Through the BPA, the DS theory distinguishes clearly the notion of belief from that of plausibility, but it provides an explicit representation in terms of probabilistic functions. The BPA is the contribution of a factor (a_i) to support a specific assumption (e.g. the resilience). In this case, the assessment of the BPA [Eq. (1)] is based on the combination of the fuzzy functions of environmental and socioeconomic variables, weighted via the *analytical hierarchy process* technique (AHP) (Saaty 1988; Malczewski 2004):

$$\mathrm{BPA}(a_i x) = \mu_{\mathrm{AHP}}(a_i)^* \mu_{ai}(x_{ai}) \tag{1}$$

where $\mu_{\mathrm{AHP}}(a_i)$ is the assessment via AHP of the belief of the effect concerning damages to forest stands in the hypothetical scenario of climate change with the variable (a_i) and $\mu_{ai}(x_{ai})$ is the assessment of the hypothetical environmental effects of the a_i variable in the space x. The aggregation for the assumption of vulnerability and resilience to climate changes may be made for pairs of tests, based on their joint probabilities (Shafer 1976). All factors are progressively aggregated by pairs so as to calculate the amount of vulnerable probable mass $m(h)$ and the amount of resilient mass $m(s)$. Once the single BPAs are quantified, the DS technique ratifies the evidence combination procedure (Shafer 1976), updating the belief in the light of the new evidence thanks to the rule of the "orthogonal sum":

$$\mathrm{Bel}(h) = \frac{m(h) \cdot (1 - m(s))}{1 - m(h) \cdot m(s)} \tag{2}$$

$$\mathrm{Bel}(s) = \frac{m(s) \cdot (1 - m(h))}{1 - m(h) \cdot m(s)} \tag{3}$$

The mix of sources results in a forecast that strengthens the belief (Shafer 1976) of Bel(h) [Eq. (2)] and Bel(s) [Eq. (3)], already expressed by $m(h)$ and $m(s)$, assuming both sources are equally reliable.

The model aggregates the two evidences Bel(h) and Bel(s), which are in conflict with each other, standardises their joint nonconflicting probabilities and determines the uncertainty U intrinsic to the assessment. $U(h, s)$ shows the point where the analysis requires further investigations to clarify the uncertainty.

2.2 Estimating the Stumpage Value of Basilicata's Forests

The *stumpage value* (SV) is the most likely transformation value of the forest stand. The estimate of the stumpage value is theoretically related to the contributions provided by Serpieri (1917), Cantiani (1957), Patrone (1947), Merlo (1991) and, more recently, Bernetti and Romano (2007). It is the result of an estimate procedure based on some theoretical-methodological assumptions specific to appraisal, and it is targeted at the monetary estimate of the asset. For the determination of the SV, we can focus on two economic appraisal aspects:

- The most likely market value
- The most likely transformation value

The former is determined by direct comparison with the market prices recognised to forest stands that are similar to the one under question, in terms of intrinsic and extrinsic properties (e.g. species, size, site-specific characteristics, etc.), and results directly in the formulation of the value judgement. The latter is based, instead, on an indirect comparison, because the judgement is obtained from simple market data that do not pertain to the asset but to its formation process, so that by subsequent analyses, they enable an estimate judgement. Regardless of the economic appraisal, the applicable procedures may be categorised as:

- *Synthetic*: visual, comparative and by typical values
- *Econometric*: the estimate for unit values and by multivariate models
- *Analytical*: based on the drafting of partial or global business balances

The SV was determined by building the analytical balance of the logging process of standing woody mass till its transformation in assortments. It is based on the drafting of the partial balance, including the market value of production in the assets and the amount of costs required for woody mass transformation till the allocation of products at the landing in the liabilities. The determination of the SV [Eq. (4)] is based on the building of the partial balance of the transformation cycle, in which there are *revenues* (R) and *costs* (C):

$$\mathrm{SV} = \sum R - \sum C \tag{4}$$

More specifically, the financial flows that are supposed to occur in the period from the owner's decision to utilise the stand to its conclusion with the inspection of the work performed are all included.

The determination of the balance assets R [Eq. (5)] is derived from the *gross marketable production* (GMP) and the *market price at landing* (MPL) for different assortments. For assessing the assets of the stumpage value, bibliographic data (INEA 2012) have been integrated with the prices recorded at landing across the regional area for various assortments. Formally there is:

$$R = [\mathrm{GMP} \cdot \mathrm{MPL}] = \sum_{i=1}^{n} \mathrm{PMI}_i \cdot Q_i \tag{5}$$

where Q is the volume in m^3, obtained directly (dendrometric data) and/or indirectly (scaling tables), and n the types of assortment.

The liabilities of the balance have been obtained by distinguishing the costs [Eq. (6)] of the *forest holding* (FH) from those of the logging company (LC—thus splitting the transformation process into operational steps) and obtaining the total transformation cost. For the assessment of balance liabilities, bibliographic data (Cozzi et al. 2013) have been integrated with data found out among the forest holdings operating in the region:

$$Kt = \left(\sum_{i=1}^{4} K\_\mathrm{FH}_i\right) + \left(\sum_{i=1}^{4} K\_\mathrm{LC}_i\right) \tag{6}$$

where Kt are the total costs of the transformation cycle, K_FH the costs charged to the forest holding, K_LC the costs charged to the logging company and $i = 1, \ldots, 4$ the steps of the transformation cycle. The costs charged to the owner include all the costs incurred since the decision to cut is taken till the conclusion of cut; they include the costs concerning the administrative procedures (remuneration of forest technicians).

The costs paid by the LC are instead mostly concentrated in the implementing phase. They are traditionally grouped as direct costs (running costs), concerning the remuneration of labour and of the other production factors directly used, and indirect costs (overheads).

Direct costs depend on the organisation of the logging system, the type of expected product, the site-specific characteristics, the distance from the landing/loading area and the applied extraction technique (short wood system, length wood system and full tree system). In general the items of direct costs are the cost of labour and the running cost/rent of machines.

Overheads include, instead, the costs for management and surveillance; they are often implicit costs, calculated (in per cent) in relation to the other cost items.

Once the assets and liabilities of the balance are identified, a spatialised map of the stumpage value may be obtained for 2012, chosen as reference year. Afterwards, based on forest stand vulnerability values, the SV has been projected to 2050 and 2100, and the loss in biomass income attributable to the climate change has been economically quantified. The stumpage value for future scenarios [Eqs. (7) and (8)] has been calculated in relation to the present stumpage value (SV_{2012}), appropriately weighted according to the degree of vulnerability, and assessed for each land unit considered (pixel) using the following equations:

$$\mathrm{SV}_{2050} = \mathrm{SV}_{2012} \cdot (1 - \mathrm{Hazard}_{2050}) \tag{7}$$

$$SV_{2100} = SV_{2012} \cdot (1 - \text{Hazard}_{2100}) \tag{8}$$

The SV_{2012} has been calculated from the average increases deduced from the scaling tables available for each forest type considered; the increment, which is, in silvicultural terms, an expression of growth of a particular forest system, represents, in economic terms, the increase in value of forest over time. In probabilistic terms, in a scenario of local climate change and subsequent increase in the degree of vulnerability of forests, increments would decline together with the biomass with unfavourable consequences on CO_2 absorption.

2.3 The Economic Evaluation of the Sink Function of Basilicata's Forests

In Kyoto's Protocol forest, ecosystems are given an important role in the fight against climate change, as they are able to absorb and store carbon and act as a sink of CO_2. However, the forest capacity to act as carbon sink is not unlimited: ageing, tree death, natural disasters, etc. result in the release of the previously stored CO_2. Among the multiple variables that influence the forest systems' capacity to absorb carbon, climate variations are the major cause. As a matter of fact, the variations of climate act on the biosphere and, in this specific case, on forest systems, both directly and indirectly. Starting from the climate simulation model and the regional forests' vulnerability and resilience values, the variation in CO_2 absorption was assessed at three time instants, i.e. 2012, 2050 and 2100, so as to point out the future influence of climate changes on the *sink* function of regional forests.

Carbon absorption in different forest sinks was estimated by the Forest model (Vitullo et al. 2007; Federici et al. 2008) taking into account the following components (pool) identified by the Good Practice Guidance for land use, land-use change and forestry (IPCC 2003):

- *Living biomass* including both epigeal and hypogeal parts
- *Dead organic matter* including the dead matter and litter
- *Soils* meant as soil organic matter

The forest model enables the quantification of growth in the carbon stored in forests and its subsequent year-to-year variation. CO_2 storage was estimated using the regional forest map, drawn by the *National Institute of Agricultural Economics* (INEA), from the average increases deduced from scaling tables for different species available for Basilicata region. At present the carbon credits generated by the *land use, land-use change and forestry* (LULUCF) activities have not been incorporated in the *European Union Emissions Trading System* (EU-ETS), which is the largest cap-and-trade scheme (of carbon credits) in the world (Bonomi et al. 2009; Hamilton et al. 2011). This exclusion means that *Removal Units* (RMUs) cannot be converted into European Union Allowance (EUA). Due to the impossibility of conversion, trading these credits is also inhibited. At the national level, the situation is even more complex because the carbon stored by most Italian forests (both public and private) has been converted by the National Register of agroforest carbon sinks in the corresponding RMUs used by the national government to comply with the obligation of reducing emissions, without providing any remuneration to forest owners, thus confining the sink function to a mere externality of forestry production cycle (Alisciani et al. 2011). The accounting of RMUs prevents forest owners from accessing voluntary markets[1] as a result of double accounting. At the national level, however, some initiatives, recognised by the National Government, have been undertaken that enable the trading of credits generated by forest activities.[2] Based on these initiatives, the *Certified Emission Reductions* (CERs) produced by regional forests and the tradable share in a hypothetical voluntary market have been calculated. The CERs at 2012 were obtained using the following formula:

$$C_{\mathrm{CO2},i} = \left[(0.85^{*}\mathrm{Im}_i)^{*}(1 - d_{\mathrm{f}}) - U\right] \times 0.5 \times \frac{44}{12} \tag{9}$$

where Im_i is the annual average increase for each forest type (m^3/ha*year); d_{f} is the reduction coefficient that takes into account the occurrence of any disturbance related to local-scale fires ($d = 0.33$);[3] U is the annual allowable cut, assessed according to the regional regulations and equal to 60 % of the Im for forest trees and 90 % of Im for coppice; 0.5 is the dimensionless conversion factor used to convert dry biomass into carbon (IPCC 2006); and 44/12 is the stoichiometric ratio to convert C into CO_2. CO_2 absorption at 2050 and 2100 was calculated from the values observed for 2012 deducting the fire hazard and based on the possible effects caused by the climate change:

$$C_{\mathrm{CO2},i} = \left[(0.85^{*}\mathrm{Im}_i)^{*}\left(1 - d_{\mathrm{f,Bel}(h)}\right) - U\right] \times 0.5 \times \frac{44}{12} \tag{10}$$

where $d_{f,\mathrm{Bel}(h)}$ includes both the risk associated with fires and the estimated vulnerability for forest stands [Bel(h)].

For the economic estimate of the damage caused by the sink function of regional forests, it has been necessary to analyse the financial markets pertaining to the trading of carbon credits. The diversity of projects, the size and geographical location and the trading market result in wide price variability. The uncertainty associated with the selling price of credits generated by regional forests could be

[1] Voluntary markets are widespread in parallel to the regulated market for nonprofit enterprises, associations, public administrations, etc., in order to reduce the GHG emissions of their activities.

[2] Carbomark Project. Available at: http://www.carbomark.org/

[3] The reduction coefficient d_{f} has been calculated considering the forest areas affected by fires from 2008 to 2013 and the national Law n. 353 of 21 November 2000 “Legge quadro in materia di incendi boschivi” (Framework law on forest fires).

stabilised through the setting up of a regional voluntary market of carbon credits that might fetch a higher price compared to the other trading platforms. This economic mechanism could develop optimally in Basilicata region due to the presence of both market actors. In particular the demand side could be represented by the existing oil-drilling companies that could buy the credits generated by regional forests and partly compensate for the impacts caused by the extraction of fossil fuels. The supply side would be represented by public and private landowners and holders of forest areas through forms of sustainable and certifiable management. This would generate benefits to both market actors: the benefits for demand would involve a greater social acceptance and the possibility of developing a real green marketing strategy, whereas for the supply side, the benefits could be summarised in the increased income-producing activity of forest holdings, the recovery of marginal lands and, last but not least, the improvement in territorial and soil defence (Romano et al. 2013). Based on the above, the selling price of CERs was assumed equal to 45 €.

3 Results

The vulnerability maps (Bel(h), Figs. 2 and 3) show the projections obtained for all the region's forest areas. The statistical analysis has pointed out a low risk probability associated with the climate change, 0.09 at 2050 against 0.10 of 2100, with a time interval between the first and third quartile of 0.10 for 2050 and 0.11 for 2100. Despite the low risk probability, some regional areas show vulnerability values above 0.5.

In particular, the forest areas most susceptible to climate change effects are located in the province of Matera, in an area where the increasing levels of aridity

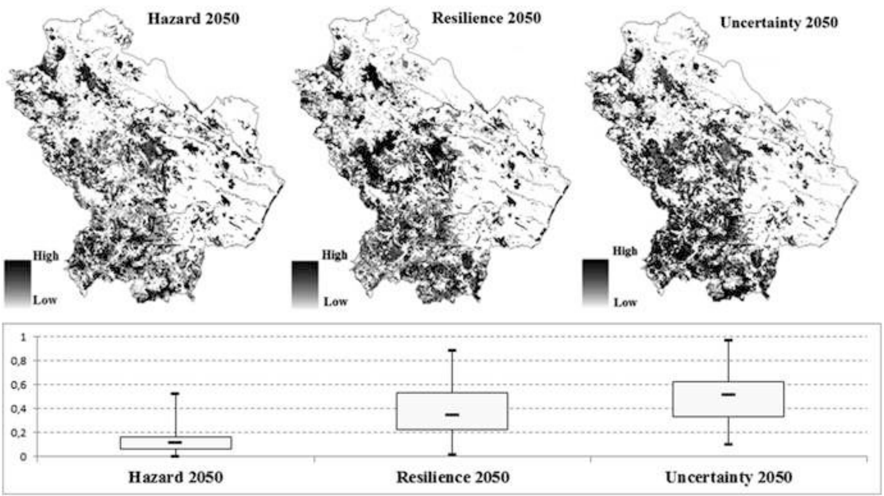

Fig. 2 Vulnerability, resilience and uncertainty maps at 2050

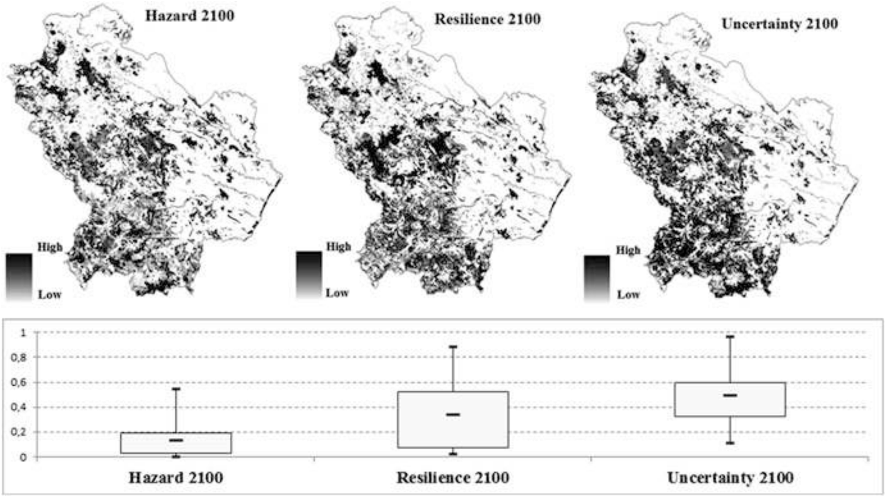

Fig. 3 Vulnerability, resilience and uncertainty maps at 2100

estimated for 2050 and 2100 are the limiting factors to forest vegetation growth. Other susceptible areas are found in the north-west, north-east and south-west parts of the regional territory. For the latter, the problems are mostly related to the poor management of forest resources.

As to the species, higher probability risks will occur in Mediterranean pine-woods, with average values of 0.20 and 0.22, respectively for 2050 and 2100. They are followed by spruce groves (Pollino Mountain, spruce plantation of Laurenzana and Ruoti), with an average probability of 0.12 at 2050 and 0.18 at 2100, and chestnut groves with values ranged between 0.15 of 2050 and 0.16 of 2100. For all other forest types, the average values are below 0.14 for both reference years. As for the silvicultural system, probability values range between 0.12 at 2050 for coppice of mesophilic-thermophilic broad-leaved trees and 0.22 for chestnut coppice at 2100. For high forest, instead, values fluctuate between 0.08 for beech groves at 2050 and 0.23 for holm oak groves at 2100.

Depending on the degree of vulnerability observed for different forest-derived types, the SV declines by 15.1 % and 17.6 %, respectively, for 2050 and 2100 as referred to 2012. In economic terms, the loss in income and the subsequent damage attributable to the climate change is about 6 million euros for 2050 and 7 million euros for 2100 (Table 1). As for the forest-derived types, the largest variations are found for mesophilic and mesothermophilic oak groves, contrary to the plantations and reforestations that show the lowest variations. The size of damages is of course largely influenced by the extent of areas and the stumpage price of assortments.

The exclusion of forest owners from the carbon market induces to consider the sink function of forest areas as an externality, rather than a forest product, tradable on the market like wood. The problem associated with credit trading and the high price volatility could be solved by the creation of a regional voluntary market. The results regarding the function of CO_2 absorption by Basilicata's forest resources

Table 1 Stumpage value and economic damages

		2012	2050			2100		
	Surface SV	Total SV	Total SV	Δ 2012–2050	Δ 2012–2050	Total SV	Δ 2012–2050	Δ 2012–2050
Species	ha*1,000	€*1,000	€*1,000	€*1,000	€/ha	€*1,000	€*1,000	€/ha
MTO (cop)	108.71	30,736.24	26,346.68	4,389.57	40.38	25,849.44	4,886.81	44.95
MTO (hf)	53.64	8,210.13	7,544.85	665.28	12.40	7,384.28	825.85	15.40
BF (cop)	15.14	2,588.15	2,200.49	387.66	25.60	2,109.41	478.75	31.62
BF (hf)	1.35	1,520.94	1,406.43	114.51	84.61	1,366.58	154.36	114.05
HF	1.39	1,491.13	1,310.58	180.54	129.59	1,288.18	202.94	145.66
WP&REP	2.21	269.09	230.17	38.92	17.64	225.00	44.09	19.99
mP	19.38	2,239.66	1,799.35	440.32	22.72	1,751.19	488.47	25.21
MP	5.70	632.34	574.68	57.66	10.12	555.21	77.13	13.54
Total	207.52	47,687.67	41,413.22	6,274.45	–	40,529.29	7,158.39	–

MTO mesophilic and thermophilic oak forests, *BF* beech forests, *HF* hygrophilous forests, *WP&REP* wood plantations and reforestations using exotic plants, *mP* Mediterranean pine forests, *MP* mountain pine forests, *cop* coppice, *hf* high forest

Table 2 CO_2 absorption for different examined scenarios

Species	Absorption CO_2 2012 tonne*1,000	Absorption CO_2 2050 tonne*1,000	Δ 2050–2012 tonne*1,000	Absorption CO_2 2100 tonne*1,000	Δ 2100–2012 tonne*1,000
BF (high forest)	147.35	136.06	11.29	132.17	15.19
BF (coppice)	242.77	208.11	34.66	199.75	43.02
TO (high forest)	476.16	438.27	37.89	428.55	47.61
TO (coppice)	1,449.30	1,264.26	185.03	1,242.36	206.93
MTO (high forest)	143.21	130.46	12.75	127.92	15.29
MTO (coppice)	1,684.71	1,435.08	249.62	1,405.43	279.27
CF (high forest)	0.31	0.28	0.03	0.28	0.03
CF (coppice)	388.01	310.97	77.04	304.39	83.62
HO (high forest)	27.72	24.58	3.14	24.32	3.41
HO (coppice)	154.40	134.27	20.13	132.45	21.95
MTD (high forest)	50.79	46.80	3.99	46.48	4.31
MTD (coppice)	256.20	226.09	30.10	223.09	33.11
MP	73.70	66.84	6.85	64.37	9.32
mP	496.20	393.79	102.41	382.60	113.60
HF	197.61	171.31	26.29	168.09	29.52
WD	15.52	13.15	2.36	12.84	2.67
SF	2.54	2.29	0.31	0.312	0.46
Total	5,806.50	5,002.58	803.92	4,895.42	909.32

TO turkey oak, CF chestnut forests, *HO* holm oak forests, *MTD* mesophilic and thermophilic deciduous forests, *SF* silver fir forests

show a total absorption of about 5.8 million tons at 2012, 5 million for 2050 and 4.8 million at 2100 with a 16 % reduction compared to 2050 and 18.6 % decline in relation to 2100 (Table 2).

In economic terms, this reduction results in a damage amounting to 3.6 and 4.1 million euros, respectively, for 2050 and 2100. In fact the trading of CERs in a hypothetical regional market would produce a benefit of 27.4 million at 2012, 23.7 million at 2050 and 23.2 million at 2100[4] (Table 3).

[4] The values shown concerning the SV, the stock of C and CERs refer to the years 2012, 2050 and 2100 and do not represent stored values.

Table 3 CERs generated by the sink activity of regional forests and related variations

Species	CERs 2012 €*1,000	CERs 2050 €*1,000	CERs 2100 €*1,000	CERs Δ 2012–2050 €*1,000	CERs Δ 2012–2100 €*1,000
BF (high forest)	1,510.52	1,394.80	1,354.85	115.72	155.67
BF (coppice)	622.16	533.33	511.92	88.83	110.24
TO (high forest)	4,881.09	4,492.72	4,393.07	388.37	488.02
TO (coppice)	3,714.19	3,239.99	3,183.86	474.20	530.32
MTO (high forest)	1,468.06	1,337.33	1,311.34	130.74	156.72
MTO (coppice)	4,317.48	3,677.76	3,601.78	639.72	715.70
CF (high forest)	3.22	2.85	2.83	0.36	0.39
CF (coppice)	994.38	796.94	780.07	197.44	214.31
HO (high forest)	284.20	252.02	249.29	32.18	34.92
HO (coppice)	395.69	344.10	339.44	51.59	56.24
MTD (high forest)	520.68	479.74	476.47	40.94	44.21
MTD (coppice)	656.57	579.41	571.72	77.15	84.85
MP	755.43	685.21	659.88	70.23	95.55
mP	5,086.54	4,036.74	3,922.06	1,049.80	1,164.48
HF	2,025.68	1,756.13	1,723.90	269.55	302.59
WP	159.07	134.83	131.65	24.23	27.42
SF	26.05	22.85	21.33	3.21	4.72
Total	27,421.02	23,766.77	23,234.65	3,654.25	4,186.37

4 Conclusions

The high degree of variability and uncertainty of climate changes has induced the European Union, through the 2009 White Paper, to ask the member states to develop mitigation and adaptation strategies, with special reference to forestry and agriculture. In particular, for forestry, mitigation strategies should take into account appropriate adaptation measures to reduce the vulnerability of forest ecosystems in relation to the climate change, while emphasising the role of forests in local economies. The methodology applied in this work has shown that a high degree of spatial and information detail can actually be a good starting point for future environmental policies on the monitoring and mitigation of damages caused by climate change. In fact, the use of methodologies associated with the use of fuzzy approach of the evidence theory are effective tools for data integration, forecasts and assessment of the impacts caused by climate change. The applied approach provides a forecast of forest vulnerability, as well as the economic quantification of the impacts induced by a decline in productivity and, as a consequence, in the sink function.

It results that the mountain and sub-mountain areas of the region show the highest vulnerability values, in particular for the species definitely mesophilic, especially coppiced chestnut groves, mesophilic and thermophilic oak forests and Turkey oak plantations. Higher vulnerability has also been found in monospecific Mediterranean pine forests along the Ionian coastal areas. Lower vulnerability levels are found for the formations falling within the protected areas and reforested pinewoods. The greater vulnerability observed for some forest formations leads to a reduction of the forest economic value. In fact, the analysis on stumpage value and carbon absorption shows an overall damage—attributable to the climate change—equal to 9,928,705.94 € for 2050 and 11,344,760.80 € for 2100 as compared to 2012.

To prevent, reduce and/or contrast the problems affecting forest resources, a preventive approach would be recommended involving an active human action, aimed at enhancing and strengthening the adaptation capacity of environmental systems and minimising the adverse effects. For low-resilience populations, specific silvicultural actions could be envisaged that might contribute to improve the ecological-functional levels of forests. To this end, it would be advisable to apply treatments aimed at increasing interspecific diversification, increase appropriately the amounts of biomass by extending the turnover and favour the conversion of monospecific non-native species into native species in the typical systems of local vegetation forms.

The major limitation encountered is associated with the components of the economic value that is looked for. Actually it is largely known that the forest, meant as mixed asset, accomplishes other tasks that are not directly measurable within the market. In this framework, it is hoped that the research will be extended to explore the values associated with further services provided by forest areas, with a view to identifying the overall impacts and proposing new planning tools.

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Wildlife Agriculture Interactions, Spatial Analysis and Trade-Off Between Environmental Sustainability and Risk of Economic Damage

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Abstract Over the last few years, wildlife damages to the agricultural sector have shown an increasing trend at the global scale. Fragile rural areas are more likely to suffer because marginal lands, which have little potential for profit, are being increasingly abandoned. Moreover, public administrations have difficulties to meet the growing requests for crop damage compensations. There is therefore a need to identify appropriate measures to control this growing trend. The specific aim of this research is to understand this phenomenon and define specific and effective action tools. In particular, the proposed research involves different steps that start from the historic analysis of damages and result in the mapping of risk levels using different tests (ANOVA, PCA and spatial correlation) and spatial models (MCE-OWA). The subsequent possibility to cluster risk results ensures greater effectiveness of public actions. The results obtained and the statistical consistency of applied parameters ensure the strength of the analysis and of cost-effectiveness parameters.

1 Introduction

Dealing with problems related to the damages caused by wildlife to the agricultural sector involves environmental and socioeconomic sustainability issues associated with the management of natural resources.

If, on one hand, farmers are suffering due to the damages caused to crops, on the other, hunters push towards the growth of wild fauna populations for having greater hunting opportunities. This has led to conflicting interests in many European (Wenum et al. 2003; Calenge et al. 2004; Geisser and Reyer 2004; Herrero

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_14

et al. 2008; Thurfjell et al. 2009) and Italian areas (Brangi and Meriggi 2003; Amici et al. 2012; Serrani 2012).

Under the current agricultural-forestry conditions, the pressure exerted on agricultural crops by wild animal populations, in particular ungulates, is a major problem for the development of rural policies, as it creates a conflict between wild animals and farmers, resulting in growing costs for public administration to compensate for damages.

From an economic point of view, the damages caused to crops, especially by ungulates, are dramatically and seriously growing. Unluckily, the national bibliography does not report recent data of this phenomenon. The unique national data date back to 2004 when, according to the estimates provided by the Ungulate National Database (Carnevali et al. 2009), the total indemnified compensations amounted to about 8.9 %[1] for damages caused by ungulates. When analysing the impact of each single species, it results that, at the national level, 90 % of damages are attributable to the wild boar (*Sus scrofa* L.).

In Basilicata region, the observed trends in relation to the economic size of damages confirm the above data. As a matter of fact, in the 6-year period from 2007 to 2012, the damaged area doubled, shifting from about 2,800 to 5,850 ha; as a result of this increase, the estimated compensations have more than doubled, shifting from over 550,000 € till 1,134 M€. The same proportion does not unluckily apply to the compensations actually paid to private citizens that shifted from 64.7 to 39.5 % of estimated compensations. At the regional level as well, there is a high incidence of wild boar that is the major damaging species, with 98 % of damages caused to crops.

The conflict of interest associated with the presence of the wild boar on land, together with some objective technical difficulties (related to the quantitative estimate of populations), makes the management of this species particularly critical. Special attention is to be attached to the areas in which the use of land for agriculture or animal production is particularly important, with a great impact on crops.

As for the possible actions to undertake in order to control the expansion of wild animal populations, the literature confirms that hunting is not actually a solution. In fact, it has been found that the populations subject to strong hunting pressure increase their prolificacy (Herrero et al. 2008; Servanty et al. 2009) by bringing forward the sexual maturity of females and by increasing to two deliveries per year. Some authors (Massei and Toso 1993; Boitani et al. 1995) state that wild boar is a very adaptable species following the “r-selection” strategy (many offspring and relatively low parental care). Due to this kind of reproduction, the expansion of European wild boar populations cannot be controlled using the traditional hunting methods.

[1] This amount accounts for 85.56 % of the ascertained damage. It results that the overall amount ascertained for damages caused by ungulates in 2004 would not be less than about 10.3 %.

This is true for traditional hunting but not for the selective culling of the species. In fact, population control strategies can involve both selective hunting techniques (shooting from fixed positions, using dog teams that chase wild boars towards hunters (*cerca* technique), or the so-called girata, where a single bloodhound is used as “finder”) applied by appropriately trained operators and “in vivo” catches, through self-opening fences (closed fencing), where animals are attracted by a feed bait. Closed fences are highly selective within the social groups of the population and are used to catch mostly the population of red, striped and adult females (in a decreasing order), whereas males are caught much less frequently. The selective action of traps is matching with the objective of the control, since immature and female boars are the target social groups to control the population dynamics (Toso and Pedrotti 2001).

Positive effects in the reduction of damage to agriculture have also been obtained by permanent and mobile electric fences. For the latter type, different analyses carried out in France by the ONC (*Office National de la Chasse*, National Hunting Service) in the 1977–1980 period have shown the technical and economic effectiveness of this practice as an active protection of crops from wild boar-caused damages, provided that some rules for installation and monitoring are complied with.

Electric fencing may be basically installed by two operational procedures: (a) as a specific protection along the boundary of the individual holding and (b) as a linear protection in boundary areas between large woodlands and typical farmlands, for separating cultivated from natural lands. If the first type might be a good solution for private landowners, the second could be particularly suitable for public administrations with an eye to long-term planning.

Among the methods reported in the literature, chemical and noise disturbances have shown significant failure, and this is due to the fact that the species adapts rapidly to these disturbances. The research is designed to (a) set up a historical geo-referenced database of the damages caused by wild animals in the area under study and (b) identify the areas at high risk of damage, on which to focus the attention and the appropriate actions.

2 Methodology

2.1 ANOVA Test

The analysis has been conducted starting from the inventory of damages recorded at the regional level in the period from 2007 to 2012. To check on the size of damages caused by ungulates, the ANOVA (*analysis of variance*) test was applied to the variable “total estimated compensation”, taking the annualised costs of damage as source of variation.

The analysis of variance (ANOVA) is a set of statistical techniques, related to inferential statistics, used to analyse the differences between two or more groups of data by comparing the variability within and among the groups. The ANOVA test provides a *final balance* (C), given by the ratio of the sum of squares of intergroup means to the sum of squares of intragroup means, compared with the resulting value of Fisher's F with $p-1$, $nt-p$ degrees of freedom, among the different annuities being compared.

In this study the one-way ANOVA test has been used to assess the differences between the amounts of compensations in the 6 years under study, both at the regional level and by reference area.

The test is used to test whether the differences between the means of compensations from 2007 to 2012 are significant. In other words, the test enables to understand whether the dynamics connected with the damages caused by wildlife are due to unpredictable extraordinary events or to an existing trend.

Moreover, if conducted for different local areas, the ANOVA test enables the differentiation based on randomness and/or trends. This specific step has entailed the choice of the target area.

2.2 Study Area

The area relating the *Parco Nazionale del Pollino* is shared by three provinces and two regions, Potenza and Matera in Basilicata and Cosenza in Calabria. The total area covers nearly 193,000 ha, of which 88,650 in the Basilicata hillside. Basilicata's 24 municipalities fall within the boundaries of the *Parco's* territory. The peculiarity that makes this protected area a unique environment is the sudden change from the coast to the mountain that creates a very rapid sequence of environments generating as many habitats and environments suitable for number of animal and plant species.

The Basilicata's portion includes the Sinni basin and encompasses large forests, pastures and farmland areas.

Settlement areas are closely related to farming activities that identify a landscape featured by rural areas and scattered or grouped houses forming small nuclei, with a mean population density of 40 inhab./km^2 (ISTAT 2010). The areas destined for primary production have been progressively abandoned: through the last 30 years, over one third of farmland (37 %) has not been cultivated any longer, and this surface has further reduced by 13 % over the last decade only. Cultivated crops include mostly cereals, followed, to a much lower extent, by forage, vegetables, grapevine and fruit trees. Most crops are not highly remunerative, although there is a high agricultural biodiversity, made of traditional native species and varieties, among which annuals and vineyard are at high risk.

This diversification of environments forming real mosaics of structural and morphological components of the landscape combined with the protection levels ensured "ope legis" to the animal and plant species living in the protected area and creates a strong concentration of some wild animal species, thus generating severe damages to the existing agricultural systems.

2.3 Analysis of Damages

In the *Parco Nazionale del Pollino*, about 700 compensation requests for damages were submitted from 2007 to 2012. Ninety-nine percent of them were caused by wild boars. The economic incidence is significant with mean values of about 600,000 € every year.[2]

The requests written by the landowners concerned were computerised in an electronic spreadsheet. Collected information concerned the cadastral location, the damaged area and crop, the year, the percentage of damage, the market price of the agricultural product and the estimated and indemnified compensations. Overall the database consists of 8,600 requests, each describing 19 variables. For entering the data drawn from requests in a Territorial Information System, the database was further broken down so that each record corresponded to a land parcel. Twenty-four thousand records were thus obtained. A part of them (2,720 *records*) were lost when they were transferred into the GIS that enabled the geographical location of the damage, once crossed with the regional cadastral database.

2.4 Parametrisation of Damages

Some studies conducted in Europe have shown a correlation between the size of damages in single geographical areas and the density of wildlife population (Keuling et al. 2008; Apollonio et al. 2010); however, this does not always follow proportionality criteria (Bleier et al. 2012).

Based on that, the assumption is directed towards checking whether also in the Italian areas there is a correlation between the size of damages (intensity, perpetuity and related costs) and the physical and/or structural parameters specific to the reference area (Romano and Cozzi 2008). Table 1 shows the applied parameters.

The selected parameters result from a more general evaluation, which has been validated via the statistical correlation with respect to the spatial distribution of damages.

2.4.1 Principal Component Analysis

To understand the dependence between the identified variables, the multivariate statistical analysis was applied using the PCA (Principal Component Analysis) (Sanguansat 2012; Bleier et al. 2012).

The PCA transforms data from a multidimensional space to a smaller space. The PCA per se does not reduce the size of the set of data. It rotates only the axes of data

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[2] The trend is definitely rising. The requests increased from nearly 600 in 2007 till about 900 in 2009 and the estimated compensations from 458 to 829,000 € from 2007 to 2011.

Table 1 Parameters applied for damage evaluation

Physical parameters	Structural parameters
Distance from the main road	Contrast-weighted edge density (CWED)
Distance from the hydrographic network	Contagion index (CONTAG)
Distance from wooded areas	Percentage of like adjacencies (PLADJ)
Distance from continuous urban fabric	Aggregation index (AI)
Distance from urban discontinuous	Simpson diversity index (SIDI)
Type agrarian soil	

in the space along lines of maximum variance. The axis of the greater variance is said the first principal component. Another axis orthogonal to the previous and positioned to represent the subsequent greater variance is called the second principal component and so forth. The reduction in size is performed only using the first principal components as basic set for the new space, usually the components that provide an explained cumulative variance between 70 and 90 %. Therefore, this subspace tends to be small and may be eliminated with a minimum loss of information. If the problem is well set, the first two to three eigenvalues will be able to explain about 70 % of the data variance. Input data representing different units and/or orders of magnitude should be previously standardised.

In particular, the T-mode PCA has been applied in our study. This means that each input image may be considered as a variable and what we obtain as result is not only the images of the principal components, but also the components of eigenvalues and the synthesis of eigenvectors (the list of eigenvectors associated to each eigenvalue in a column) and the percentage of explained variance.

The output is the matrix of correlation between variables, a square matrix in which the rows are the variables and columns stand for the eigenvectors of the correlation matrix. If multiplying these squared values by the associated eigenvectors, you have the matrix of *loadings* ([L]):

$$L = \begin{bmatrix} L_{11} & L_{1n} \\ \vdots & \vdots \\ L_{n1} & L_{nn} \end{bmatrix} \tag{1}$$

where the actual coordinates of descriptors are represented on the new axes formed by the principal components identified. The value of the eigenvector (in absolute terms) indicates the weight of each variable, i.e., the importance of each original variable in that specific eigenvector, based on which it is possible to choose the variables to reject.

2.5 Aggregation of Criteria

The analysis of wildlife damage hazard has been conducted by the joint use of MCE techniques and Geographical Information System (GIS). The integration of MCE techniques-GIS may be useful to solve conflicting situations in spatial contexts (Janssen and Rietveld 1990; Malczewski 2004) and constitutes an effective approach in the analysis of land use suitability/risk (hazard) (Yager 1988; Carver 1991; Eastman 1997; Malczewski 2004; Thill 1999; Romano and Cozzi 2006; Romano et al. 2013; Cozzi et al. 2014). This integration may be conceived as a process that combines and transforms spatial and nonspatial data (input) into a decision (output), defining a relation between input maps and the output map obtained from geographical data and decision preferences, handled according to specified decision rules (Malczewski 2004).

Among the MCE techniques, the ordered weighted averaging (OWA) was applied in this work with relative linguistic quantifiers (as proposed in Romano et al. 2013).

There are three principal components in GIS-OWA procedures: (1) criterion maps (and standardisation procedures associated to them), (2) criterion weights (and the associated procedures to define the weights of relative importance between criteria) and (3) order weights (and the procedures associated to the identification of OWA parameters) (Romano et al. 2013; Cozzi et al. 2014; Malczewski and Liu 2014). In this study, the choice of linguistic quantifiers for the definition of OWA parameters depends on whether they can best represent the decision maker's qualitative information with respect to his/her perception of the relationship between different assessment criteria. Thus, choosing the appropriate linguistic quantifiers and defining an adequate system of weights result in a wide range of risk maps (Table 2).

3 Results

The ANOVA test provides a *Final Balance* (C) of 6.70 against a quantile of $F_{[5;5344]} = 3.02$; $p < 0.05$ between the different annuities being compared. Therefore, there is a highly significant difference between the group means, i.e., between the total estimated compensations produced by wild boars in the period from 2007 to 2012 on the regional scale.

Table 2 Linguistic quantifiers

Quantifiers (Q)	α	Calculating weights order
All	$\alpha \to \infty$	$v_j = \left(\sum_{k=1}^{j} u_k\right)^{\alpha} - \left(\sum_{k=1}^{j-1} u_k\right)^{\alpha}$
Almost all	$\alpha = 10$	
Most	$\alpha = 2$	
Half	$\alpha = 1$	
A few	$\alpha = 0.5$	
At least a few	$\alpha = 0.1$	
At least one	$\alpha \to 0$	

v_j is the weight order, u_k is the weight criterion ordered and α is the parameter related to the linguistic quantifier

Table 3 ANOVA test results

Land areas	Fisher F
ATC 1	$C = 2.84 > F_{[5;149]} = 2.27$
ATC 2	$C = 2.04 < F_{[5;334]} = 2.24$
ATC 3	$C = 1.48 < F_{[5;566]} = 2.23$
Gallipoli Cognato Piccole Dolomiti Lucane Park	$C = 1.45 < F_{[5;246]} = 2.25$
Province of Matera	$C = 3.14 > F_{[5;1060]} = 3.03$
Oases	$C = 1.27 < F_{[5;8]} = 3.69$
Murgia Materana Park	$C = 0.33 < F_{[5;33]} = 2.50$
Pollino National Park	$C = 13.24 > F_{[5;2661]} = 2.22$
Appennino Lucano Val d'Agri-Lagonegrese National Park	$C = 5.01 > F_{[5;79]} = 2.33$
General	$C = 6.60 > F_{[5;5344]} = 2.22$

C: final balance

The results of the one-way ANOVA test applied to land areas (ATC, oases, parks and provinces) show highly significant differences between different annuities for the *Pollino National Park* and the *Appennino Lucano Val d'Agri Lagonegrese* National Park that fall within no-hunting zones (Table 3). This information led the authors to focus on the Pollino National Park.

Results show that the trends of damages in Basilicata are uprising, on average, as shown in this case by the economic size of this phenomenon.

Within the Pollino National Park, out of a total damaged area of about 7,500 ha, the estimated compensation was 2.2 M€ over the 6 years. This accounted for 43 % of the regional estimated compensation, of which about 1.5 million (68 % of the ascertained damage) has been paid. Cereals are the most common crops, in terms of cropped area, and are the most affected ones, followed, to a lower extent, by protein crops, vegetables, grapevine and olive, in addition to some limited cases of woody crops. Another interesting element concerns the damage frequency on the same plot. In fact, it has been noted that a particle out of three is involved more than once by the damage over the 6 years considered. This induces the authors to consider that there is a systematic approach, a species custom to return to the same plot. This is maybe due to the fact that the plot shows cropping and localisation conditions that are favourable to the damage.

This originates the assumption that it is possible to trace back the setting up of an appropriate logical model, aimed at identifying the areas with a greater propensity to the damage.

To this end, 15 explanatory parameters have been identified, including 6 physical and 9 structural parameters, on which a correlation has been made with respect to the damages occurred. It results that only 11 are appropriately correlated, as shown in Table 4.

The correlation equations reported in Table 4 have been utilised to standardise the variables.

The assessment of the dependence/overlapping between the variables performed by the PCA has shown that 78 % of cumulative variance is obtained in the first

Table 4 Physical and structural parameters correlated to the damage

No.	Parameters	Description	Correlation function
1	Distance from the main road	The presence of infrastructures reflects a greater presence of cultivated fields for accessibility	$y = -5.96E - 10x^3 + 2.56E - 06x^2 - 3.54E - 03x + 1.58$ $R^2 = 0.991$
2	Distance from the main channel	Flow channels offer a path to the wild boar from the wooded areas to cultivated lands and are a water source for drinking and splashing (Cai et al. 2008; Amici et al. 2012)	$y = -0.0013x + 1.0949$ $R^2 = 0.996$
3	Distance from wooded areas	The wild boar uses more frequently the first 50–100 m from the boundary of the wood (Wilson 2004; Calenge et al. 2004; Thurfjell et al. 2009)	$y = 2E - 06x^2 - 0.0037x + 1.5052$ $R^2 = 0.832$
4	Distance from the discontinuous urban fabrics	The discontinuous urbanised fabrics are represented by rural houses located close to agricultural soils	$y = 4E - 08x^2 - 0.0005 + 1.4216$ $R^2 = 0.999$
5	Distance from the continuous urban fabrics	The continuous urbanised fabrics reflect the siting of agricultural soils	$y = 2E - 09x^2 - 0.0001x + 1.2929$ $R^2 = 0.958$
6	Cropping classes of agricultural soil use	Three risk classes have been determined based on the codes of the CLC (Corine Land Cover) Class 1: 222, 241, 243 Class 2: 231 Class 3: 211, 242	$y = 0.3858x^2 - 1.0811x + 0.7707$ $R^2 = 1.000$
7	Contrast-weighted edge density (CWED)	The index assesses the weighted edge density (m/Ha). It quantifies the edge effect from a functional point of view	$y = 2E - 05x^2 + 0.0014x + 0.8271$ $R^2 = 0.811$
8	Contagion index (CONTAG)	It expresses the concept of dispersion and interspersion and is based on the probability of finding a pixel of type I next to a pixel of type J (Li and Reynold 1993)	$y = 0.0003x^2 - 0.0445 + 1.6083$ $R^2 = 0.988$
9	Percentage of like adjacencies (PLADJ)	This is a metrics calculated from the matrix of pixel adjacencies and equals the sum of the matrix diagonal elements, namely, the adjacencies per class, divided by the total number of adjacencies	$y = -0.0005x^2 + 0 - 0.0672x - 1.6884$ $R^2 = 0.790$
10	Aggregation index (AI)	AI is the ratio of the number of adjacencies observed to the maximum number of possible adjacencies (in percent)	$y = 0.0002x^2 - 0.0099x + 0.0417$ $R^2 = 0.958$
11	Simpson evenness index (SIEI)	It expresses a uniform distribution so that the area of different types of patch achieves the maximum uniformity	$y = 3.0367x^2 - 2.7021x + 0.6151$ $R^2 = 0.937$

component and up to 87 % may be achieved if considering the second component. The values obtained show that the variables used are not correlated to each other and, therefore, basically applicable as criteria for the multicriteria analysis. In particular, based on the first two components, the matrix of *loadings* has been calculated, and a single evaluation criterion has been eliminated (*crop classes of agricultural land use*).

The next step was to attribute to the ten remaining criteria the weights of relative importance via the Analytical Hierarchy Process, AHP (Saaty 1977, 1980; Malczewski 2004). More specifically, in the attribution of weights to different criteria, it was considered to take into account the R^2 derived from standardisation functions: the greater correlation of the criterion to the damage hazard is given a greater weight and vice versa. It is obvious that since all criteria have not a high R^2 ($R^2 \rightarrow 1$) so that the aggregation model gives back a reliable result, it is advisable that all or most criteria are satisfied. Based on that, the linguistic quantifiers *All*, *Almost all* and *Most* have been chosen for calculating order weights and implementing the OWA aggregation model (Fig. 1). When comparing the risk maps obtained by the actual damage data, it is expected that high-risk values (close to 1) are obtained: based on this consideration, the map connected with the *Most* quantifier has been chosen as the final one, since 75 % of higher hazard values correspond to actual damages.

Reclassifying this map using Chen's method (Chen and Hwang 1992) (Fig. 2), areas may be grouped as areas at no hazard (0–0.25), low hazard (0.25–0.56), medium hazard (0.56–0.92) and high hazard (>0.92).

It is important to restate that the area under analysis is only the portion of the parkland sited in Basilicata, but the analysis carried out is intended to be a general predictive model of the damage hazard.

Based on the guidelines for wild boar management in protected areas, set out by the INFS (National Institute for Wildlife) for the Ministry of the Environment and Protection of Land and Sea, the envisaged wild boar management might be

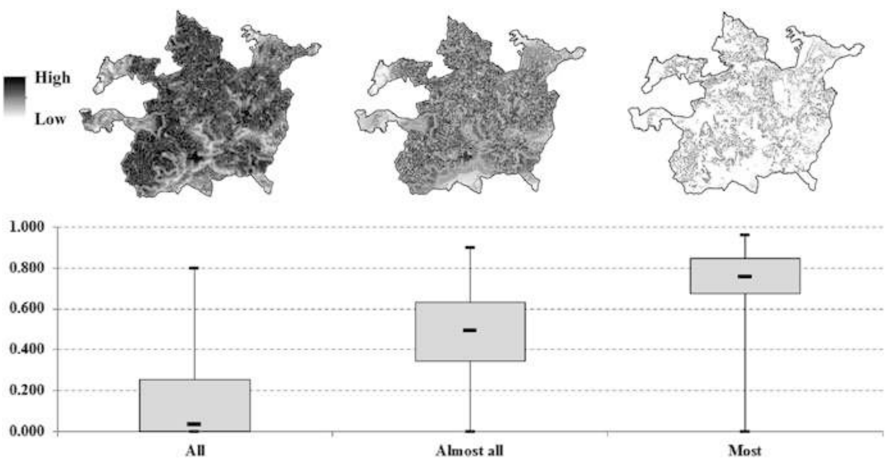

Fig. 1 MCE-OWA maps and *Box Plot*

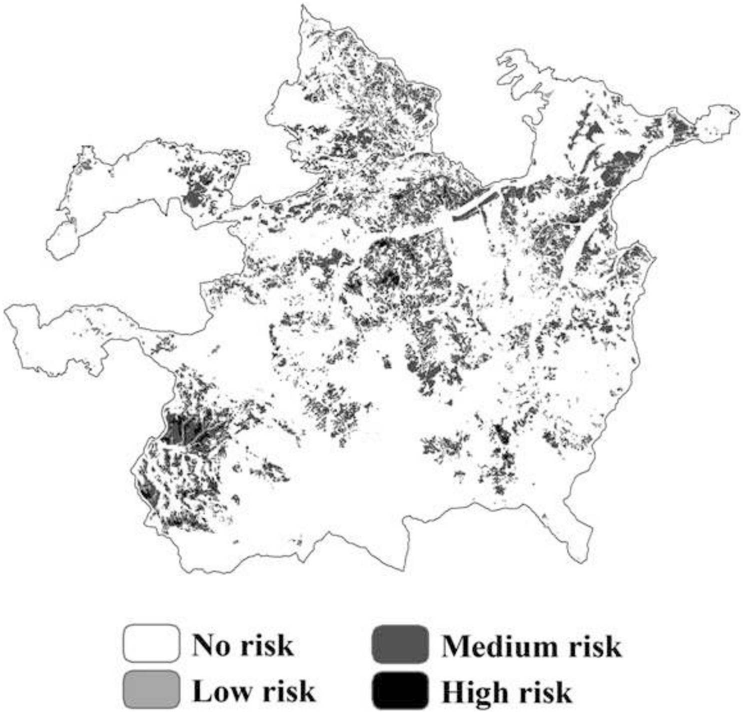

Fig. 2 Hazard risk reclassified

implemented by diversified actions, and methods somehow integrated with each other.

Therefore, based on the hazard map and considering only the high-risk class, seven larger areas were identified (Fig. 3) and tested for approximate damages against the costs required to develop an appropriate preventive system to hamper the transit of wild animals, for which, as previously mentioned, the most reliable system is represented by artificial separators, such as fences or electric obstacles. From the hazard map, the area and perimeter of these systems were extrapolated, and their semi-perimeters were taken into account, since the area does not require to be wholly enclosed. The costs have been obtained on the basis of wholesome (and for large amounts) estimates requested to national tradesmen. The resulting values are ranged between 500 and 1,500 €/km. This size has been confirmed by the recent tests carried out within the 2007–2013[3] Emilia Romagna Rural Development Plan that indicates values fluctuating between 765 and 890 €/km, depending on whether it is connected or not to the power network.

It results that the total costs, calculated from the seven higher risk areas, where the total surface covers 155 ha and the semi-perimeter 28 km, range from 21,615 to 24,618 €. To these values it is necessary to add the cost for the installation and

[3] www.agenter.it/pdf/fuorilafauna.pdf

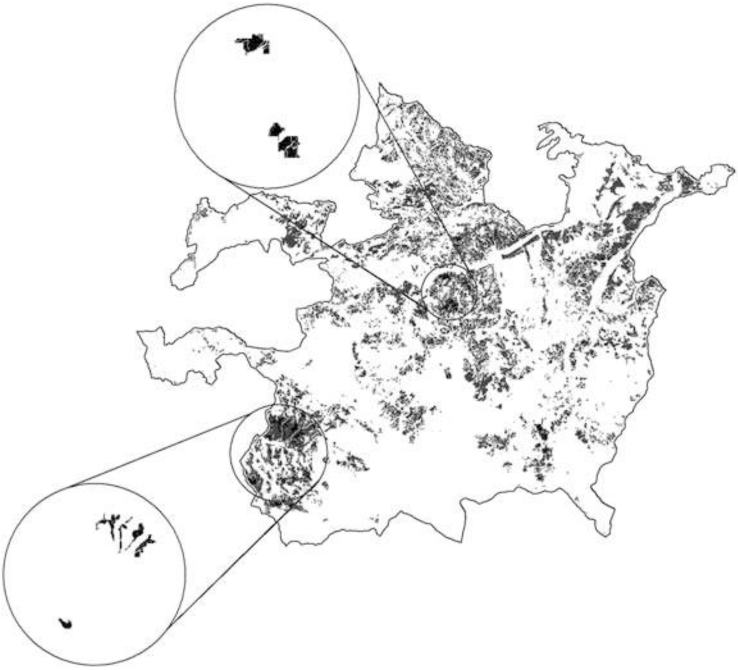

Fig. 3 Cluster areas

maintenance of fences (brush cutting, periodical restoration, repair of any breaks) that would certainly involve higher costs, if fully outsourced. For comparative purposes, the equivalent cost incurred by the public administration for compensation was calculated and resulted to be 32,500 € on average for about 155 ha, concerning the surface of considered clusters.

Moreover, for the numerical control of wild boars, a comprehensive action plan involves a species-selective culling scheme; from the hazard map it is possible to plan the distribution of selective hunters across the area[4] based on the high-risk zones proportioned to municipal areas, so as to optimise the actions and resources made available by the public administration (Table 5 and Fig. 4).

4 Conclusions

Based on the historical data of wildlife damages to crops, it results that the occurrence of this phenomenon is generally raising. The damaged area between 2007 and 2012 has more than doubled, shifting from about 2,800 to 5,850 ha.

[4] The number of selective hunters has been drawn from the "Regulation for wild boar control" N° 30 of 29/04/2011 that involves the recruitment of 370 selective hunters across the whole area of *Pollino National Park*.

Table 5 Distribution of selective hunters across the region

	Municipality	*N*		Municipality	*N*
1	Calvera	12	13	Lauria	0
2	Carbone	5	14	Noepoli	4
3	Castelluccio Inferiore	0	15	Rotonda	20
4	Castelluccio Superiore	0	16	San Costantino Albanese	3
5	Castelsaraceno	0	17	San Paolo Albanese	3
6	Castronuovo di Sant'Andrea	11	18	San Severino Lucano	5
7	Cersosimo	3	19	Senise	0
8	Chiaromonte	16	20	Teana	15
9	Episcopia	15	21	Terranova di Pollino	3
10	Fardella	5	22	Viggianello	13
11	Francavilla in Sinni	17	23	San Giorgio Lucano	1
12	Latronico	0	24	Valsinni	0
	Total				152

N Numbers of hunters

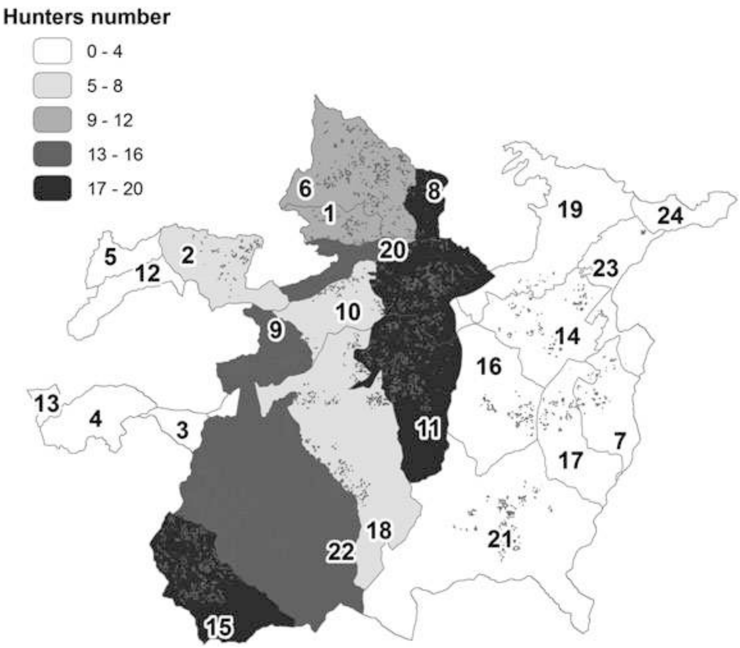

Fig. 4 Distribution of selective hunters by municipality

Besides a growing discontent among farmers, compensation costs have generally increased for public administrations that, in the case of Basilicata region, amounted to 1,134 M€ in 2012.

It is urgent to take actions to prevent and even control this phenomenon. This can be done on the basis of a careful analysis of the context area and of the prevailing trends. In this framework it may be useful to apply spatialised analysis models, aimed at facilitating land planning and governance choices, so as to optimise the existing planned actions to mitigate damages to farms.

This study has shown that from the identification of land parameters connected with wildlife damages, it is possible to build a map representing the areas at high damage hazard, where actions should be targeted.

On the other hand, we need to carry out direct field surveys to check the actual effectiveness of what is proposed by the applied methodology.

The analysis, conducted on the *Pollino National Park*, has resulted in the spatial identification of the agricultural areas most sensitive to wildlife damages.

The results obtained show that targeted actions might be taken to downsize the effects of crop damages in the long-term perspective. The effectiveness of actions depends, however, on other factors as well that need to be controlled. For example, no fence or obstacle could be overcome if there is not sufficient feed supply in natural environments. Therefore these control actions may be successful only if they are integrated by other simultaneous or alternative actions throughout the year (fodder in periods of feed deficit, selective hunting).

Over the last 15 years, despite the actions undertaken by the managing body for the solution of the problem,[5] it seems that the applied approach has been directed towards an “individualist” solution through compensations and/or incentives for prevention systems addressed to single farmers. No linear protection fencing systems have been used in the bordering areas between forests and agricultural zones nor other “community” systems based on long-term planning have been implemented to know and understand the phenomenon and obtain a detailed picture of the distribution, the size and the evolutionary trends of the species across the region (no data are available so far on these parameters). This would be useful to identify the target densities and the withdrawal densities compatible with economic damages. In this sense, there are no absolute indications of optimal density and size, and each environmental site necessitates its own solution, which is to be sought by trial and error (adaptive management).

Today’s objective is to achieve a kind of “agroecological” balance that means a sustainable balance between the amount of social and economic costs of crop damage—in terms of refund and prevention—and a sufficient population size for maintaining the ecological role of the species in the protected ecosystem (Mattioli et al. 1995).

In conclusion, managing a wild boar population means adapting its size and structure to the capacity of the environment while minimising the associated economic and environmental damages and the subsequent social conflicts.

[5] “Regulation for the granting of financial aid on the protection of wild boar-caused damages” N° 122 of 15/10/1998 and “Wild boar management plan” N° 23 of 27/10/2006, N° 941 of 06/11/2012 for the granting of financial aid aimed at setting up fencing for preventing damages to crops caused by wild boars and deers in the *Pollino National Park.*

Future developments of the applied model will involve defining cost-effectiveness indices to demonstrate the monetary and social effectiveness of both analyses and proposed actions.

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The Sustainability of Non-renewable Resources Use at Regional Level: A Case Study on Allocation of Oil Royalties

Mauro Viccaro, Benedetto Rocchi, Mario Cozzi, and Severino Romano

Abstract The aim of this work was to assess the socioeconomic impact derived from the oil royalty allocation on regional development, using a multi-sector model based on a Social Accounting Matrix (SAM), appropriately implemented for Basilicata region (Italy), the typical case of a region lagging behind in a developed economy. Our focus was on how political decisions have influenced the economic development of the region and how a different set of choices can be more effective in transforming public receipts into long-term benefits. Results show clearly that in the past the allocation of oil royalties to the regional Government (as a whole 990 million euros) generated a much lower impact than expected, in terms of economic growth and employment. Given the structure of the regional economy, much of the impact of investments and running expenses financed by royalties has maybe been lost outside the regional boundaries. A greater effect on income and employment will not be possible unless resources are redirected towards greater competitiveness of the regional economic system. Better balancing the use of royalties between social expenditure and production investments would probably be the first step towards a strategy of sustainable development of the regional economy.

1 Introduction

The countries and regions that use a new natural resource, such as an oil deposit, usually see an increase in their financial resources due to the benefits (both direct and indirect) deriving from oil drilling. Their ability in managing these additional resources in a sustainable way influences the future of their entire economy. According to the *big push* theory (Rosenstein-Rodan 1943; Hirschman 1958), the new source of income should lead to increase public investments, promote growth

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_15

and result in long-term economic development. However, empirical evidence reveals a negative correlation between the abundance of resources and economic growth, known as *natural resource curse* (Sachs and Warner 2001). Different studies, concerning not only economic but also political and social aspects, have provided different possible explanations of this phenomenon (Larsen 2006; Torvik 2009; Van der Ploeg 2011). A preliminary economic interpretation of the negative relation between the dependence on the exploitation of natural resources and economic growth is known as the *Dutch disease* (Torvik 2009; Van der Ploeg 2011). This expression refers to the decline of production activities observed in the Netherlands after a large natural gas deposit was discovered at the end of the 1950s. According to this model, the big inflows of foreign capitals resulting from the export of resources overvalue the actual exchange rate, thus reducing capital and labour for agricultural and manufacturing activities. As a consequence, production costs increase, while the competitiveness and exports of the sectors unrelated to the resource decrease, with a depressing effect on the growth of the whole economy. Two more aspects seem to be the cause of the *natural resource curse*: (1) the implementation of non-sustainable macroeconomic policies by Governments, due to the abundance of resources (Atkinsons and Hamilton 2003), and (2) the intrinsic volatility of the international market of non-renewable resources (Van der Ploeg 2011).

The planning and implementation of effective policies to contrast this process is a challenge for Governments, not an easy one, especially in developing countries; typical examples are Chad and Brazil where, despite the huge financial resources derived from oil royalties, the living standard of populations has not improved accordingly (Keenan 2005; Pegg 2005; Caselli and Michaels 2013).

Different studies suggest that the appropriate policy to prevent the *curse* in developing countries is based on the allocation of the financial resources derived from oil-related activities towards policies aimed at promoting productivity, competitiveness and well-being improvement (Levy 2006; Breisenger et al. 2010; Rocchi et al. 2015).

It is worth noting that developing countries are not the unique countries involved by this *curse*, which may also influence, to a different extent, the regions lagging behind in developed economies that start to exploit a new natural resource, such as oil fields (Rocchi et al. 2015). The negative impact in these cases seems to be mostly due to the following: (1) the opening of the regional economy would result in the *loss* of most effects derived from the expenditure of royalties out of the regional boundaries; (2) the sudden increase in the *export base* may conceal the lack of competitiveness of the regional non-oil exporting sectors in relation to the rest of the country, reducing the investments required to improve their competitiveness; (3) part of oil royalties are used in short-term local redistribution policies aimed at reducing the negative effect of the regional economic gap (including unemployment and poverty), but are ineffective in improving the competitiveness of the regional system in the long run. Lastly, if the allocation of these financial resources is not implemented with due appropriateness and transparency, the entailed risks are bribery or rent-seeking behaviours.

To prevent these adverse effects and favour the highest possible outfalls on the areas involved by financial investments based on the use of royalties, the priority for decision-makers is to better focus on the strategic objectives to promote long-term sustainable socioeconomic development, while compensating for the deployment in environmental assets resulting from the exploitation of a non-renewable resource.

The possibility of setting out regional policies, assessing the impact on the main socioeconomic indicators at the local level and monitoring the effectiveness over time is largely dependent on the availability of an adequate territorial information system that should be complete, relevant and coherent both internally and with the national framework (Carbonaro et al. 2001). Different authors (Stone 1961; Seers 1970, 1972) maintain that the most suitable statistical tool, in terms of information bases and economic model, is the Social Accounting Matrix (SAM). As a matter of fact, it has a regional dimension enabling to analyse different economic and fiscal policies within the same country, notably when large internal differences coexist (Thorbecke 1985).

The aim of this work is to assess the socioeconomic impact derived from the allocation of oil royalties on the regional development, using a multi-sector model based on a two-region SAM, specially tailored to Basilicata region, a typical example of a region lagging behind in a developed economy. After describing—via different macroeconomic indicators—the regional economic system (see Sect. 2.1) and the methodology applied to perform the impact analysis based on SAM multipliers (see Sect. 2.2), the allocation of oil royalties is examined from 1997 to 2013, making it possible to implement the model (see Sect. 2.2.1). Results are shown in Sect. 3, and conclusive remarks (see Sect. 4) close the paper.

2 Materials and Methods

2.1 Case Study: Basilicata Region

The Basilicata region is the typical case of a region lagging behind the rest of the national economy.

Despite the presence—in its territory—of the largest onshore oil field in Europe, Basilicata's economy shows strong difficulties compared with the rest of the country, with a poverty index more than double the national average (Fig. 1) (Istat 2014).

When oilfields were discovered in the Agri valley (in the southwestern part of the region) in the early 1990s, they were considered as an important opportunity for the regional economy. The oil regional industry currently produces about 16,137 tons/day of crude oil: in 2013, the production was about 5.48 million tons, i.e. 9.3 % of the gross national domestic consumption and about 71.7 % of Italy's total crude oil production (Ministero dello Sviluppo Economico 2014). There are indeed good

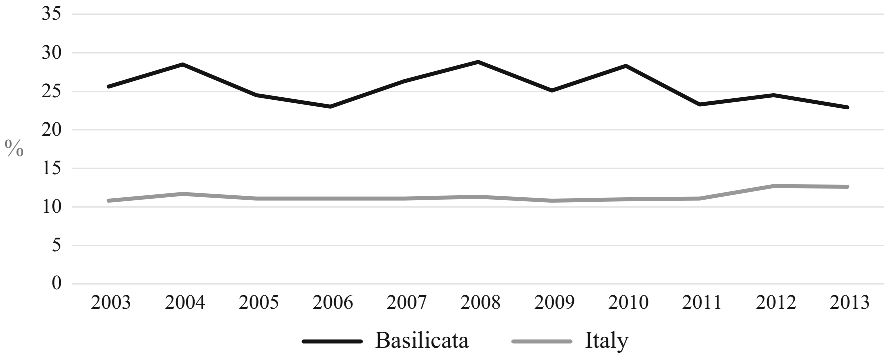

Fig. 1 Relative poverty index

opportunities for the regional economic development (in addition to the direct impact on employment) in the form of royalties. Under the agreement between the State and oil drilling companies, above a given output threshold, the companies must give 7 % of their earnings to the regions in the form of royalties and an additional 3 % for safety and environmental monitoring (Ministero dello Sviluppo Economico 2014). This has meant that between the start of drilling in 1997 and the end of 2013, the regional balance has matured over 990 million euros earnings from oil.

Moreover, a recent national regulation (N° 99/2009) allocates an additional 3 % of earnings to the households living in Basilicata as *vouchers* to purchase fuel (fuel card).

Surprisingly, oil earnings have not had a great impact on the local economy, despite the huge quantity of additional financial resources channelled into regional development policies. Figure 2 shows that the regional GDP grew quite steadily till 2008, when it experienced a decline—partly due to the overall economic recession—resulting in a decrease of employment to 195,000 labour units recorded in 2012. In accordance with the national trend, the unemployment rate has increased starting from 2007 till 16 % in 2013 (Istat 2014).

This results in a loss of competitiveness, in terms of labour productivity (Fig. 3).

While the average productivity of the other southern Italy regions has slightly decreased, between 1995 and 2009, the Basilicata region has seen a considerable decline: although the regional employment till 2003 has grown more rapidly than in the neighbouring regions, this has not resulted in a substantial increase in terms of productivity.

It is evident that oil exploitation has not generated the expected benefits according to the *big push* theory, due maybe to all of the causes that contribute to explain the so-called natural resource curse (Van der Ploeg 2011).

It is thus crucial to understand how resources are allocated and to assess their impact on the socioeconomic system for trying to provide an explanation of the current situation.

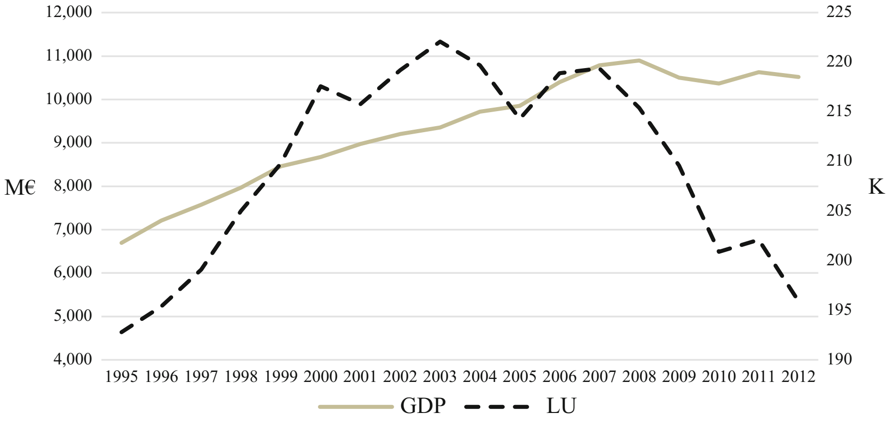

Fig. 2 GDP (M€) and labour unit (K)

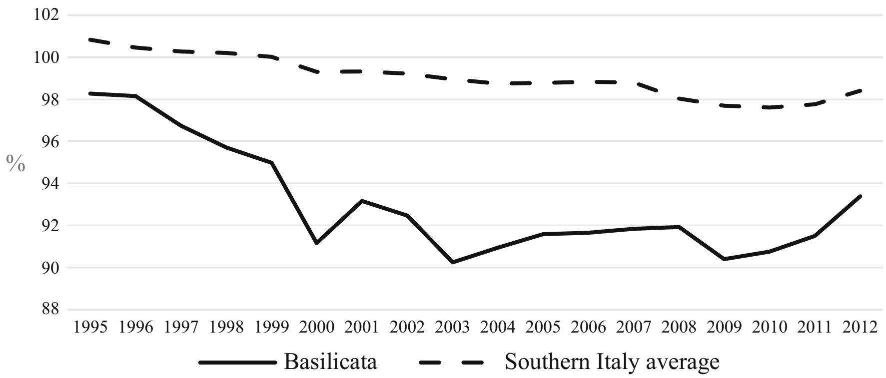

Fig. 3 GDP per labour unit—ratio between different areas

2.2 SAM: A Two-Region Model

A model based on SAM has been used to assess the impact of the allocation of the oil royalties earned by Basilicata region since the start of drilling till now. The SAM (Pyatt 1991a, b, 1994a, b, 1999; Pyatt and Round 1977, 1985) is a two-entry matrix that records the flows occurring between all actors of an economic system, in a given place and for a given time period (usually 1 year). Each raw/column pair represents, respectively, the inflows and outflows of a given account, so that by definition the matrix is balanced (the row totals equal the column totals). It may be considered as an expansion or a generalisation of Leontief's input–output table (1936). While in the latter emphasis is laid on the production system, in the SAM the perspective is larger. The simultaneous representation of the accounts of production activities, production factors, institutions (households, businesses and public administration), capital formation and exchanges with the rest of the world makes it possible to follow the formation of value added and its distribution and redistribution in the form of income to the institutions.

The utilisation of SAMs in the analysis of development is by now a well-established branch of the economic literature (Stone 1961; Pyatt and Round 1977, 1985; Pyatt 1991a, b, 1994a, b, 1999; Round 2003; Miller and Blair 2009). Applications refer both to developed and developing economies, because it is not only an important tool to improve the consistency of national accounting estimates (United Nations et al. 1993) but also the first step for the calibration of impact simulation multi-sector models, both linear and computable general equilibrium ones (Pyatt 1988). Through the implementation of a linear model based on the calculation of multipliers (Miller and Blair 2009), it is possible to calculate the impact that variables have on the economic system; endogenous accounts normally include the institutional sectors of households and firms; the unique accounts that are considered, either alternatively or simultaneously, exogenous to the model are those of Government, of the rest of the world and of the capital account. Deciding which and how many of these three accounts are exogenous means establishing the "closing rule" of the model based on the SAM (Miller and Blair 2009).

The SAM used in this study is a two-region matrix, referred to 2010, in which the existing flows between Basilicata region and the rest of Italy are represented with a high level of detail. The structure of the matrix includes 301 accounts, subdivided into 37 production activities, 54 production factors and 3 institutions (households, businesses and Government). The household sector is subdivided by income deciles into ten groups, whereas the Government is distinguished as local and central. There are of course also the accounts entitled to the capital formation and to the rest of the world.

The advantage of a two-region model lies in the possibility of considering the rest of Italy as being endogenous to the model; this makes it possible to break down impacts and estimate not only the total but also the intraregional and interregional ones (spillovers and feedbacks).

In the present study, for the analysis of the impacts derived from the use of oil royalties considered as exogenous shocks to the regional economy, a static analysis has been carried out, considering a closure of the model with respect to the *Government*, *capital formation* and *rest of the world*: the estimated multipliers take thus the value of Leontevian–Keynesian multipliers.

The structure of the matrix of accounting coefficients of the two-region model is shown below (Miller and Blair 2009):

$$A = \begin{bmatrix} A^{\mathrm{rr}} & A^{\mathrm{rs}} \\ A^{\mathrm{sr}} & A^{\mathrm{ss}} \end{bmatrix} \quad (1)$$

where r = Basilicata region and s = rest of Italy.

By solving the linear system $x = Ax + f$ (where x is the vector of totals of endogenous accounts and f is the vector of exogenous account flows) for x, you have

$$x = (I - A)^{-1} f \tag{2}$$

where $M = (I - A)^{-1}$ is the matrix of SAM multipliers.

Each coefficient m_{ij} quantifies the total increase for each account i derived from a unit exogenous shock on the account j.

If the matrix of multipliers M enables the estimate of the total impact, the breakdown of the matrix of accounting coefficients A into intraregional $\begin{bmatrix} A^{\mathrm{rr}} & 0 \\ 0 & A^{\mathrm{ss}} \end{bmatrix}$ and interregional elements $\begin{bmatrix} 0 & A^{\mathrm{rs}} \\ A^{\mathrm{sr}} & 0 \end{bmatrix}$ enables to estimate (Round 1985, 2001; Dietzenbacher 2002; Miller and Blair 2009) the following:

$$Intraregional\ \ effects : M_1 = \left(I - \tilde{A}\right)^{-1} \tag{3}$$

where $\widetilde{A} = \begin{bmatrix} A^{\mathrm{rr}} & 0 \\ 0 & A^{\mathrm{ss}} \end{bmatrix}$.

$$Interregional\ \ spillover\ \ effects : M_2 = I + A^* \tag{4}$$

where $A^* = \left(I - \tilde{A}\right)^{-1}\left(A - \tilde{A}\right)$.

$$Interregional\ \ feedback\ \ effects : M_3 = [I - (A^*)^2]^{-1} \tag{5}$$

Let us consider the intraregional submatrix A^{rr} and the blocks constituting it:

$$A^{\mathrm{rr}} = \begin{bmatrix} B & 0 & C \\ V & 0 & 0 \\ 0 & Y & H \end{bmatrix} \tag{6}$$

where B is the matrix of interindustry technical coefficients, C is the matrix of endogenous final expenditure coefficients, V is the matrix of endogenous value added factor shares, Y is the matrix of endogenous coefficients distributing income to institutions and H is the matrix of endogenous coefficients for income redistribution among institutions. The intraregional effect of impacts may in turn be broken down as follows (Miller and Blair 2009):

$$Regional\ \ direct\ \ effect : M_1^{\mathrm{rr}} = (I - Q)^{-1} \tag{7}$$

where $Q = \begin{bmatrix} B & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & H \end{bmatrix}$.

$$Regional\ \ indirect\ \ effect : M_2^{\mathrm{rr}} = I + T \tag{8}$$

where $T = (I - Q)^{-1}R$, $R = \begin{bmatrix} 0 & 0 & C \\ V & 0 & 0 \\ 0 & Y & 0 \end{bmatrix}$.

$$Regional\ \ feedback\ \ effect : M_3^{\mathrm{rr}} = \left(I - T^2\right)^{-1} \tag{9}$$

Once the multipliers required for the analysis are calculated and the vector of shocks *df* defined, it will be possible to define the vector of impacts *dx* as follows:

$$dx = Mdf \tag{10}$$

In the present study, the vector of shocks is made up of the current and capital expenditures of the oil royalties according to different scenarios.

2.2.1 The Vectors of Exogenous Shocks: Allocation of Oil Royalties

The available information on the allocation (or distribution) of royalty earnings among different uses is summarised in Table 1, where the total amount is disaggregated by year and action.

For most receipts, it has been impossible to allocate expenses by specific political actions. About three quarters of total expenditure (over 723 million euros) has been just used to fund running expenses of Basilicata region (itemised as *other actions*).

The remainder has been shared among various initiatives mostly designed towards the mitigation and compensation of adverse effects derived from the oil mining industry. The environmental issues involved in the exploitation of the major inshore oil source in Europe are obviously very important. The location of oil fields influences high nature value areas, which have a considerable potential for the development of tourism and agricultural activities. Moreover, the mining plants and the distribution pipelines of the existing processing plants on the coast concern an area that stores the major water resource for southern Italy. For this reason, the regional Government has decided to mitigate the possible negative impacts by setting up a system for the monitoring and compensation of the areas directly affected by oil drilling operations.

One of the most important actions funded by royalties is the *Piano Operativo Val d'Agri* (POV), an expenditure operating plan aimed at promoting economic development and the improvement of life quality in the area neighbouring the oil fields. The POV is structured into four pillars related to the enhancement of local resources, the improvement of infrastructures, the improvement of life quality and the improvement of the local production supporting systems. The POV includes both current expenditures and investments.

Table 1 Allocation of royalties by action (M€)

Year	POV	Other actions	Natural gas distribution network	Environmental monitoring	Environmental compensation	Total
1997	0	0.43	0	0	0	0.43
1998	0	2.25	0	0	0	2.25
1999	0	1.24	0	0	0	1.24
2000	0	3.17	0	5.01	11.02	19.20
2001	0	8.04	1.03	0	5.58	14.65
2002	0	10.04	0	0	0	10.04
2003	0	24.05	0	0	5.60	29.65
2004	4.89	30.31	7.00	0	5.61	47.81
2005	6.23	32.80	0	0	5.62	44.63
2006	17.26	61.84	0	0	5.68	84.78
2007	23.98	72.57	17.79	0	5.67	120.02
2008	31.39	71.30	0	0	0	102.69
2009	22.10	79.47	0	0	3.10	104.67
2010	26.10	28.15	0	0	0	54.25
2011	25.88	59.21	0	0	0	85.09
2012	12.04	111.58	0	0	0	123.62
2013	17.82	127.49	0	0	0	145.31
Total	187.67	723.94	25.82	5.01	47.88	990.31

POV Piano Operativo Val d'Agri

To calculate the total impact of the use of royalties in the time period under study, all these expenditure flows have been considered as an exogenous shock directed towards the regional economy and reclassified based on the disaggregation of accounts in the SAM. While in the case of allocation towards specific actions there have been no problems in identifying the accounts on which they are directed, the expenses concerning *other actions*, in the basic simulation, have been considered as an exogenous increase of the local public administration expenditure and have been distributed as inputs towards the endogenous accounts, based on the current expenditure coefficients of the regional administration included in the SAM.

Moreover, the analysis also takes into account the shares for the *fuel card* supplied so far.[1] These shares have been considered as an exogenous increase in income of the households living in the region, according to a distribution based on what is declared by the Ministry of Economic Development (2014) (Table 2).

Since the envisaged uses refer to different years, the values have been converted into 2013 Euros (Istat 2014).

[1] The shares concerning the *fuel card* have been supplied starting from 2011; till now the two first supplies concern the shares allocated for 2009 and 2010.

Table 2 Amounts concerning the supply of the *fuel card*

Year	Amounts (M€)	N° beneficiaries
2009	32.22	320,000
2010	44.88	320,000

Two ex post analyses of the impacts derived from the use of royalties were conducted:

1. Impact of the expenditure relating the use of royalties allocated in 2010, the reference year in the SAM construction (counterfactual analysis); this analysis also estimates the potential impact that could be generated from the granting of fuel vouchers for 2010.
2. Total impact derived from the total expenditure of royalties till now, based on their actual use.

Moreover, to provide helpful indications on the possible effects of an alternative use of the financial resources derived from mining, the four following simulations have been made that assume a different use of the shares allocated to *other actions*:

1. Increase in current consumption for public administration (scenario I)
2. Increase in the current consumption of public administration and in transfers to households (scenario II)
3. Funding of current activities of private enterprises (scenario III)
4. Funding of investments of private enterprises (scenario IV)

3 Results

On the basis of the counterfactual analysis for 2010 (Table 3), it resulted that part of the effect derived from the use of royalties occurs outside the regional boundaries: only about 50 % of what has been utilised has entailed a direct impact in the region. The remaining uses have resulted in the growth of output, value added and income of households through moderate feedbacks from the rest of Italy.

As compared to the baseline scenario, the impact of royalties on the regional economy involves a 0.3 % increase of output and value added and 0.2 % rise in households' gross income (actual use). The lower impact observed on the income depends on the fact that the expenditure of royalties is mostly concentrated on the accounts allocated to the production and purchase of goods and services. If fuel vouchers had been supplied in 2010 (hypothetical use), this would have resulted in an additional 0.49 % increase of households' income, with outfalls on the whole economy, leading to an additional 0.2 % increase of the output and value added. This is due to a higher availability of households' income for the purchase of goods and services, especially outside the regional boundaries: above 70 % of the output and value added generated in the region benefits the rest of Italy.

Through an analysis of the breakdown of impacts on the regional economy in 2010 (Table 4), it seems clear that a targeted programme like the POV results in a

Table 3 Counterfactual analysis—impact of the use of royalties in 2010 (M€)

			Actual use (royalties)		Hypothetical use (fuel card)	
	Baseline	SAM totals	Impact	Impact (%)	Impact	Impact (%)
Royalty			54		45	
Basilicata				Impact/baseline		Impact/baseline
Output	21,203	21,268	66	0.31	45	0.21
Value added	12,245	12,281	36	0.30	29	0.23
Households' income	12,544	12,574	30	0.24	62	0.49
Italy				Italy/Basilicata		Italy/Basilicata
Output	3,041,624	3,041,659	35	52.92	35	77.17
Value added	1,742,931	1,742,952	20	56.58	20	71.75
Households' income	1,697,044	1,697,058	14	47.18	14	22.19

SAM Social Accounting Matrix

Table 4 Breakdown of impacts by allocation of 2010 royalties (M€)

	Output	Value added	Households' income
Direct impact			
POV	23.80	0.00	0.00
Other actions	0.00	0.01	8.31
Indirect impact			
POV	16.42	0.00	0.00
Other actions	0.81	0.06	0.21
Induced impact			
POV	9.96	26.38	15.17
Other actions	14.62	9.71	5.88
Regional total impact	65.61	36.16	29.57
Interregional feedback			
POV	0.07	0.04	0.03
Other actions	0.03	0.02	0.01
Total impacts	65.70	36.22	29.60

higher direct and indirect impact (through the production system) on the output, as compared to that related to the expenses incurred by *other actions* aimed to support the public administration expenditure. This expenditure has actually a direct impact on households' income leading to an induced impact on output and value added (multiplier effect) only through the increase in consumption.

If considering the total impact derived from the use of royalties since the beginning of drillings till now (Table 5), it results clearly—in this case as well—that the POV seems much better in promoting growth and employment. Overall, royalties have generated an extra output of about 1 billion euros, 593 million euros of gross households' income and 10,258 total annual full-time labour units.

Table 5 shows that the ratio of generated output to the expenditure allocated to the POV is more than three times the one recorded for the *other actions* (1.82 € vs. 0.55 € of additional output for each additional € of expenditure). The POV has generated almost the same labour units using only 25 % of the budget available for the *other actions*. These higher impacts are mainly due to the fact that a considerable portion of the POV expenditure is directed towards *construction activities* (both to improve infrastructures and to preserve the cultural heritage), a sector mainly based on local businesses.

As resulting from Fig. 4, the sectors that most bear on the output and employment include constructions, trade and private and public services. As for agriculture and fishery, despite their low multiplying effect on output (Table 6), their capacity to generate more employment on the produced output is double compared to the other sectors.

In general, however, most effects derived from the use of royalties have been lost by the regional economy. The typical opening of a regional economy is expressed by the ratio of the generated output to the total value of spent royalties: on average, only 0.88 € of additional output has been produced at the regional level for each €

Table 5 Impact of royalty uses by allocation type—2013 Euro (M€)

	Allocation type		
	Total	Other actions	POV
Royalties receipts	1,166	786	203
Total impacts:			
Output	1,027	432	370
Value added	593	274	194
Households' income	668	402	111
Labour unit (n)	10,258	4,422	3,634
Average impacts:			
Output	0.88	0.55	1.82
Value added	0.51	0.35	0.95
Households' income	0.57	0.51	0.55
Labour unit (*n*)	9	6	18

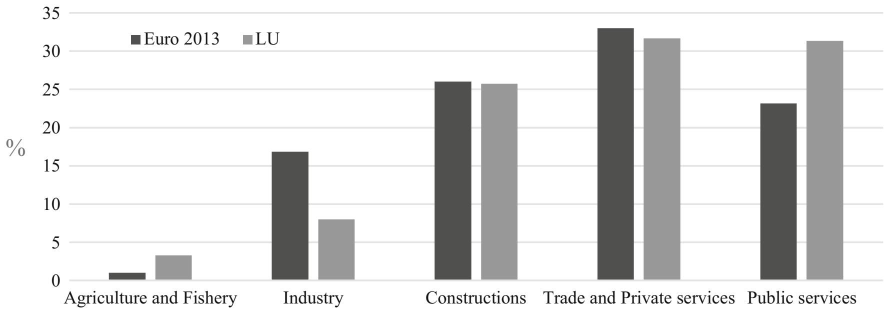

Fig. 4 Percent distribution of impacts on output and employment

Table 6 Sectoral output multipliers

Sector	Output multipliers
Agriculture and fishery	1.56
Industry	1.78
Constructions	2.04
Trade	1.82
Public services	1.84

spent. The mean incidence on the income is even smaller, with only 51 % of expenditure converted into actual income earned by the households living in the region. The overall impact is thus moderate compared to the absolute value of the available budget, which has stabilised around 100 million euros/year (about 3 % of the annual expenditure of public administration in Basilicata region). These results may only partly be assessed by static simulations. The use of supplemental financial resources derived from royalties has maybe played a fundamental role to tackle the regional economic decline. However, the allocation of these additional financial resources could be significantly improved also in the short run.

Table 7 Simulations on the alternative use of royalties allocated to *other actions* (M€)

	Allocation type				
	Current use	Scenario I	Scenario II	Scenario III	Scenario IV
Royalties receipts	786				
Total impacts:					
Output	432	1,072	869	792	1,049
Value added	274	704	559	395	521
Households' income	402	469	849	225	292
Labour unit (*n*)	4,422	11,012	8,982	7,344	9,454
Average impacts:					
Output	0.55	1.36	1.11	1.01	1.34
Value added	0.35	0.90	0.71	0.50	0.66
Households' income	0.51	0.60	1.08	0.29	0.37
Labour unit (*n*)	6	14	11	9	12

We can deduce that a specific programme like the POV is a better solution in promoting economic growth in the short run; moreover, since this is a programme supporting investments in production activities, it has greater probabilities to improve the competitiveness of the regional economic system. An alternative use of the resources, allocated so far to the public administration expenditure, might further contribute to development.

Based on the simulations run (Table 7), it would seem that the uses of royalties directed to support only the public administration consumptions (scenario I), or the latter and the households' income (scenario II), are those that would generate greater impacts, in terms of output, value added, income and employment. These results are however controversial: the uses of part of oil royalties in supporting Government expenditure and in local redistribution policies are ineffective in improving the regional system competitiveness in the long run. This would have short-term effects mostly aimed to reduce the negative impact of the regional economic gap (such as unemployment and poverty).

An alternative solution would be provided by scenario IV, in which royalties are entirely spent to support the investments of private enterprises operating on the local scale, for the purpose of enhancing the competitiveness of the regional production system. The impact on the output and employment is comparable to that of scenario I. Although it presents, among the scenarios, one of the lowest impacts on the income in the short run (0.37 € of income generated per € of royalty spent), the strengthening of the regional production system competitiveness might lay the bases for sustainable economic development of the entire region in the long run. A strategy that is in line with the notion of sustainability of natural resources and involves a progressive replacement of the deployed natural assets (oil in this case) with the produced capital (Hamilton and Atkinson 2006).

4 Conclusion

In this work, a multi-sector model based on a two-region SAM has been used to study the socioeconomic impact of the use of oil royalties on the economic system of Basilicata region.

To this purpose, it was necessary to carry out a counterfactual analysis to test the impact that the expenditure of royalties had in 2010 and an ex post analysis of royalty allocation since the beginning of drillings till now. Some simulations were performed to estimate the effect that might have been generated by a different use of the royalties actually utilised in funding the Government expenditure.

Results clearly show that in the past the allocation of oil royalties granted to the regional Government (as a whole 990 million euros) generated a much lower impact than expected, in terms of economic growth and employment. Given the structure of the regional economy, a large part of the impacts of investments and current expenses funded by royalties have been probably lost outside the regional boundaries. As a whole, the use of part of the royalties to support the regional Government expenditure has been less effective in promoting the regional economic growth compared to a targeted programme like the POV, aimed at supporting the areas where oil fields are found.

These results, together with the macroeconomic indicators that describe the economic system of the region (see Sect. 2.1), show clearly that Basilicata's economy is at risk for the *natural resource curse*. The same opacity in the distribution of royalties is a symptom of a potentially distorted policy and of the ineffective use of a considerable amount of additional financial resources. Detailed information about the use of royalties was actually available only for a quarter of the earnings received by Basilicata region between 1997 and 2013.

The additional financial resources derived from the exploitation of oil fields over the last few years have undoubtedly played a role to mitigate the impacts of the overall macroeconomic crisis. This use is understandable in a region, like Basilicata, that has an economic gap. However, the absence of a clear strategy targeted to increase the regional economic system competitiveness might, paradoxically, result in a deterioration of the relative position of Basilicata within the national economy. The exploitation of non-renewable natural resources could also crowd out the other production activities. Simulations show that even expenditure programmes directed to implement investments could favour economic growth in the short run, without jeopardising the regional system competitiveness prospects. Better balancing in the allocation of royalties between social expenditure and production investments would probably constitute the first step towards a sustainable development strategy of the regional economy.

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Land Use Sector Involvement in Mitigation Policies Across Carbon Markets

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Abstract Different local and international experiences show that the agroforestry sector can be fully included in the global warming mitigation strategies and in the market mechanisms that may have environmental and socioeconomic benefits. At present, however, the primary sector plays only a minor role in mitigation policies within the UNFCCC and under Kyoto's Protocol, due to problems and difficulties related to emission/absorption accounting models and monitoring and standardisation systems. If, on one hand, the progress in science has enabled to overcome accounting-related problems, on the other, there are no adequate mechanisms to encourage and remunerate the primary sector's efforts. More specifically, if the primary sector is considered as a source of emissions, it should also be recognised that it has beneficial impacts, notably in economic terms, as carbon sink. Therefore, the definition of clear and internationally shared rules might increase the carbon friendly initiatives and help reduce greenhouse gas emissions. This article is focused on the international experiences that have concerned the primary sector and is intended to supply researchers and policymakers with suggestions and recommendations for implementing local market practices related to carbon credits.

1 Introduction

The inclusion of the agricultural and forestry sector in the global warming mitigation strategies has not been clearly and definitely implemented yet. As a matter of fact, if the primary sector accounts for over 30 % of greenhouse gas emissions (FAO 2003), on the other hand, it has a great potential absorptive capacity (Galik et al. 2009; Gorte and Ramseur 2010). Agricultural and forestry activities actually play a twofold role in climate changes, since they suffer from their effects, while still contributing, either positively or negatively, to emissions (Pettenella et al. 2006).

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_16

Recent studies have highlighted that forests have the highest absorption capacity of greenhouse gases (GHGs; Beer et al. 2010; Canadell et al 2007). The primary sector's capacity to act as carbon sink is limited in the space and over time and might be strengthened by specific management measures aimed at increasing the carbon sink potential and reducing the release of GHGs (Houghton 2003; Pacala and Socolow 2004; Ciccarese and Pettenella 2005; Canadell and Raupach 2008; Sohngen 2009). The main measures aimed at increasing the absorption capacity include:

1. Forestation and reforestation practices and the reduction of deforestation
2. Reducing forest degradation by improving forest stand quality
3. The sustainable use of fertilisers and other chemicals in agricultural practices
4. Maintaining carbon stocks within ecosystems through the implementation of sustainable forest management (SFM techniques)
5. The use of biomasses and wood material as substitutes for fossil fuel-derived products

The need to introduce appropriate procedures in climate change mitigation strategies has actually been debated in recent years. In the new Common Agricultural Policy (CAP), the struggle against climate changes and the primary sector's contribution to a low carbon economy have actually been included among the European objectives. Despite the efforts made, in the 2008–2012 Kyoto's Protocol (KP) first planning phase, the carbon credits generated by LULUCF (Land Use, Land Use Change and Forestry) activities were not included in the EU Emissions Trading System (EU-ETS), which is the largest regional market of carbon credits currently working at the world level (Hamilton et al. 2011; Bonomi et al. 2009). This exclusion means that the Removal Units (RMUs) cannot be converted into European Union Allowances (EUAs) so they are not tradeable in the European market. With this in mind, this work is intended to review the role of the primary sector in the struggle against climate changes based on the analysis of the main markets involved and of the currently available accounting methods, so as to highlight their strengths and weaknesses. Some suggestions and reflections are then proposed to implement an appropriate model of local compensation voluntary market that can promote local development and generate economic and environmental benefits to the actors concerned, in terms of mitigation/reduction of climate altering gas emissions.

2 The Primary Sector in the International Negotiation

The United Nations Framework Convention on Climate Change (UNFCCC), the first legal international tool to contrast climate changes, ratified the need to initiate a global complex action in favour of the environment and sustainable development. In fact, in compliance with the three main pillars mentioned in the Convention, *equity between generations*, *common but differentiated responsibility* and *precaution*, the UNFCCC invited the member States to monitor the national GHG flows grouped by sectors and to communicate regularly their inventories and the planned reduction measures. Based on the classification drawn up by the Organisation for Economic Co-operation and Development (OECD), the member States were subdivided into three groups: Annex I countries should take the lead in modifying the trends in greenhouse gas emissions, Annex 2 countries are required to assist financially nondeveloped countries and non-Annex I countries have no reduction obligation. The proposals developed during the Heart Summit of 1992 were implemented only in 1997 during Kyoto's 3rd Conference of parties (COP-3). During the COP-third session, most national governments from all world regions decided to approve "Kyoto's Protocol" (signed by 176 countries, 38 of which have binding targets), to enforce compliance with the commitments made at Rio. The protocol is the implementation tool of the Framework Convention on Climate Change and defines legally binding limits for greenhouse gas emissions in industrialised countries. The treaty imposed on Annex I countries to account their GHG flows by sector and to reduce pollutant emissions by at least 8 % compared to 1990, which was selected as baseline year. As to the accounting methodology, the applied mechanisms include the *gross–net accounting*,[1] adopted for some activities, such as forest management, and the *net–net accounting*[2] for reforestation and the management of cultivated fields and pastures.

3 Overview of Carbon Credit Markets

KP provides some actions to be taken by industrialised countries for the reduction of their emissions. These actions are categorised as domestic or national actions and international actions or flexible mechanism. The former are targeted towards the reduction of energy consumption in all economic sectors, whereas the second group includes actions to be implemented through cooperation among developed countries and between them and developing countries. Among flexible mechanisms, a major role is played by Emission Trading (ET), which has enabled the setting up of the so-called carbon credit markets, which may be either regulated or voluntary (Torres et al. 2015; Linacre et al. 2011; Pirard 2012).

The differences encountered in the two markets are quite significant; regulated (or mandatory) markets are actually identified by their regular functioning, based on rules established by institutional bodies that ensure transparency requirements and the obligation to provide information on prices and the traded volumes. This type of

[1] The gross–net accounting includes only the carbon stock variations due to the differences between emissions and removals in the commitment period, without comparison to the stock variations in the reference year (baseline).

[2] The net–net accounting measures the carbon flux variations—observed in the commitment period—compared to the reference year (baseline).

market is accessible—upon specific request—to the big industrial groups, submitted to regulatory emission limits and obliged to comply with the trading system. At the international level, there are 15 regulated markets based on the Emission Trading System (ETS) and characterised by a *cap and trade*[3] (IETA 2014) accounting system. Voluntary markets instead are not based on a system of consistent rules defined by authoritative bodies; this makes possible non standardized contracts both for the amounts and the deadlines. These markets are based on a system of *offsets*[4] that can link directly both market actors, i.e. the parties interested to implement GHG mitigation projects that represent the supply side and the parties intended to compensate for part of their emissions that instead represent the demand side.

4 Analysis of the Main International Markets and the Inclusion of the Agroforestry Sector

4.1 International Voluntary Markets: The Verified Carbon Standard

The Verified Carbon Standard (VCS) is one of the leading programmes to reduce GHGs in the voluntary market, and with regard to Agriculture, Forestry and Other Land Use (AFOLU), it is used to check and certify the credits generated by land use improvement projects. Over the last few years, many accounting models, often differentiated by geographical areas, have been proposed within the VCS to take into account the local and/or sectoral peculiarities.

In dimensional terms, the VCS does not set any limitation, in terms of project size, while classifying projects in three main categories:

1. Micro projects with an absorption potential below 5,000 t CO_2/year
2. Projects with an absorption potential ranging between 5,000 and 1 million t CO_2/year
3. Macroprojects with an absorption potential above 1 million t CO_2/year

In operational terms, the VCS system involves different information about the project for the purpose of monitoring and understanding its positive and negative impacts, in terms of potential production of CO_2, competition with other chains related to the primary sector, economic sustainability, scope (whether public or private), causes of failure, etc. As to the criterion of additionality, meant as

[3] The *cap and trade* system involves defining a maximum limit (cap) of emissions, subdivided into a given number of licences that are distributed among participants, with reference to a limited time period. Permits may be freely traded among the participants in the trade market, but at the deadline of the reference period, each should return as many permits as those corresponding to its actual emissions.

[4] Mechanism involving the purchase of carbon credits to offset an emission made elsewhere.

reduction of any extra emission produced in the absence of the certified project activity, the standard refers to what is provided for in the Clean Development Mechanism (CDM) (Montini 2008), with the additional possibility to carry out three types of test: the project test, the performance test and the technology test. The determination of the baseline is based on the methodologies approved for the CDM, whereas the leakage factor, meant as the increase in the emissions in areas beyond the project boundaries, is calculated in advance by analysing carefully the area at risk and indicating a default value that ranges, depending on the risk, between 10 and 70 %.

To ensure effective GHG absorption rates, the VCS-certified projects are submitted to an initial checking and a periodical control every 5 years based on ISO 14064-2:2006 principles.

The VCS has been the main market platform, in terms of credits traded at purchase prices of 7 $/t CO_2. Most projects have concerned the mechanism of reducing emissions from deforestation and forest degradation (REDD) followed by afforestation/reforestation (A/R) and sustainable forest management.

4.2 The American Carbon Registry Standard (ACR)

The ACR was founded in 1996 as the first voluntary GHG registry in the world. In relation to the LULUCF sector, the ACR includes methodologies related to A/R, REDD and Improvement of Forest Management (IFM). The innovations of the ACR consist in the introduction of a methodology to restore wetlands, a REDD methodology and a methodology for N2O in agriculture, contained in the ACR guidelines enacted in 2012. The ACR standard sets limits on the initial date of projects that should not have started before November 1, 1997. For the projects complying with the ACR, it is necessary to provide an accurate certification of the right of ownership of the estates concerned in compliance with the local existing regulations.

As for the criterion of *additionality*, the ACR requires for each project a performance testing or alternatively the fulfilment of three types of additionality criteria:

1. Regulatory/legal requirements
2. Innovative requirements of the common project practices
3. Institutional, financial and technical requirements

The ACR platform provides, the same as the VCS, periodical checking every 5 years in order to test GHG absorptions and all risks connected with the project. The crediting period, provided for by the ACR standard, is 20 years for A/R activities and 10 years for REDD and IFM projects.

Due to its stringent procedures, this year the ACR has allowed higher credit prices than the other voluntary platforms with values ranging between 8 and 9 $/t CO_2 especially for A/R projects.

4.3 *Regional Carbon Market*

4.3.1 The European Trading Systems (EU-ETS)

The ETS was introduced in 2005 by the EC Directive 2003/87 amended by the EC Directive Linking 2009/29 and includes both *cap and trade* and *offsetting* systems that allow parties to buy and sell EUA emission permits and carbon reduction credits (offsets) in order to comply with the pre-established reduction objectives. As a matter of fact, the EU-ETS obliges some sectors to limit their emissions of GHG[5] and creates a real credit market in which the supply is represented by those who can reduce their emissions above the established limits, thus generating credits, whereas the demand side is represented by those who do not comply with the reduction constraints and are obliged to address to the market for fulfilling their obligations.

The COP-17, held in Durban in 2011, has boosted the agreements designed to contrast climate changes; the new accounting rules resulting from the international meeting have actually driven the European Parliament and Council to develop a proposal concerning the action plans on the greenhouse gas emission and absorption associated with the LULUCF activities. Besides some actions provided for in the project monitoring phase, the following was proposed—the voluntary supervision of emissions and absorption due to revegetation activities, drainage and rewetting of wetlands and the obligation, since January 1, 2013 to December 31, 2020, to report the emissions and absorption due to man-made activities of afforestation, reforestation and deforestation:

- Forest management
- Management of cultivated lands and pastures

Following on the European Parliament and Council's approval, the decision was enforced on July 8, 2013 (Decision 529/2013/EU of the European Parliament and of the Council) and constrained the member States—starting from 2014—to collect and communicate all information on the LULUCF implemented policies, including the historical trends and implemented actions to increase carbon sinks and reduce the emissions produced by the activities connected with the primary sector. Although no reduction target was established for single member States, the Decision 529/2013 has marked a new step for the inclusion of the LULUCF sector in the mechanisms targeted to contrast climate changes at the European level.

[5] The system concerns carbon dioxide (CO_2) emissions for thermoelectric and industrial plants in the field of energy and manufacturing production (energy activities, metal production and processing, concrete, ceramic and bricks, glass, paper) and air operators; since 2012 the system has also been enlarged to the operators of the air sector and, since 2013 it has been further extended to the activities for the production of aluminium, quicklime, nitric acid, hydrogen, sodium carbonate and bicarbonate and to the plants involved in CO_2 capture, transportation and storage.

4.3.2 The Chicago Climate Exchange

The Chicago Climate Exchange (CCX) is an exchange platform created in 2003 by private citizens. To ensure the full transparency of operations and the compliance with rules, an independent inspection authority, the Financial Industry Regulatory Authority (FINRA), was established. The main tasks of the FINRA were the spread of information and guidelines relating the operation of the market, the development and updating of the baselines and the activity of checking and annual certification of the offsets programme. Because it does not operate for public purposes but according to merely private objectives, such as the adoption of simple and cost-effective measures for the calculation of the baselines and for the estimate of GHG emissions, the system has lost, over time, its transparency, thus discouraging those interested to join the CCX that has officially ceased to exist in 2011 but has still operated in the markets over the counter[6] (OTC).

The objective of the CCX was to regulate the trade of GHG emission quotas indicated by the Intergovernmental Panel on Climate Change (IPCC 2006) as extremely dangerous to the environment. Public and private operators could join this market, on a voluntary basis, through a legally constraining agreement between the same operators. The CCX provided for a *cap and trade* system associated with an *offsetting* mechanism that assessed the production of credits derived from the activities related to the management of agricultural, forest and pasture areas, based on the compliance with the principles and constraints imposed by the specifically created standard. In fact, the estimates were based on the applied practices rather than on the actually measured effects induced by the project.

As to the type of project, the CCX did not indicate any limitations in terms of eligibility or project size; the actual unique constraint was the project start date that should not have been before January 1, 1999 (1990 for forestry). The duration of the investment was 15 years for forest management projects.

Moreover, the CCX required two types of test, related to regulation and common practices, to satisfy the additionality criteria, and a storage quota, not below 20 % of the total credits generated by the project to satisfy the permanence criteria.

4.4 The National Carbon Markets

A voluntary national market often requires the involvement of the central government in bearing the start up and running costs and ensuring the initial quantity of demand. The participation and involvement of national institutions in a voluntary market also facilitates the access to funding and aids and also increases the economic and collaboration opportunities with research bodies, enabling the development of a local standard system more consistent with the real conditions of the

[6] The OTC markets are over the counter.

reference area. One of the advantages of this type of market is the possibility to set the prices on a local basis, i.e. based on the local demand and supply levels. The peculiarity of the local voluntary market is actually the existing proximity between the seller, the buyer and the mediator. These three categories, appropriately inter-related within an environmental, social and economic approach, may originate a transparent, functional and sustainable system. At the local level, it is also easier to include the primary sector in the market mechanisms, thanks to the possibility to elaborate ad hoc methodologies closely related to local dynamics. Lastly, by restricting the scope of the market, there are greater aggregation possibilities in terms of project proposals. This enables the reduction of transaction costs as well as the development of more coordinated and sustainable strategies, preventing sporadic and isolated actions.

Another important element of voluntary markets is the possibility of setting up an actual registry of credits where to record all the credits generated by voluntary actions and prevent the problem of double accounting.

4.4.1 The *Carbomark* Project and the Carbon Monitoring Group

In Italy, the difficulties related to the methods for the recognition and accounting of the credits derived from the forestry sector are particularly accentuated as compared to other countries, due to the impossibility for forest owners to have access to the carbon market. As a matter of fact, the carbon stored by all Italian woods (both public and private) has been converted into the corresponding RMU credits by the National Registry of Agroforestry Carbon Sinks (INFC), which are utilised by the national government to fulfil its obligations to reduce emissions, without paying any compensation to forest owners, thus confining the sink function to a mere externality of the forestry production cycle (Alisciani et al. 2011). For Italy, the accounting of RMUs prevents forest owners from having access even to voluntary markets, due to the double accounting, contrary to other European countries, such as France, for instance, where the State has taken well-defined regulatory measures to distinguish the two markets: in fact, in France, the State has allocated part of its stocks of Assigned Amount Units (AAU) to emit Emission Reduction Units (ERUs) to the developers of GHG reduction projects, thus producing an economic return derived from the sale of credits. Despite the difficulties pointed out for forestry, some initiatives have been developed in Italy within the voluntary market to promote actions aimed at reducing GHGs. From a scientific point of view, the Carbon Monitoring Group[7] has worked out a Forest Carbon Code with a view to stimulating low carbon economy, by facilitating private and public investments in

[7] The Carbon Monitoring Group stems from the need to strengthen and make more transparent the national voluntary market of carbon credits. It was established by the *Osservatorio Forestale dell'Istituto Nazionale di Economia Agraria* in collaboration with the *Dipartimento TeSAF* of Padua University, the *Dipartimento DiBAF* of Tuscia University and the *Compagnia delle Foreste*.

forest and farmland management, the afforestation of new areas and the improvement of green systems in agricultural and urban systems in Italy. In line with the existing experiences in Europe, the Code actually intends to provide landowners (either public or private) with guidelines for the sustainable management of green areas that can generate carbon credits to be included in the national and international voluntary market.

From a practical and merely local point of view, the *Carbomark* project was implemented some years ago in order to promote a voluntary local market of carbon credits operating on a wide range of agroforestry activities, such as forest management, wood products, urban forestation and biochar. The *Carbomark* project is based on the matching of demand from the private sector and supply, represented by forest owners and public or private local bodies that sometimes take measures directed to carbon sequestration. As for the double accounting, considering the specific legal condition existing in Italy, it has been established that the forest inventories defined under Kyoto's Protocol should be considered *business as usual*. Therefore, the additional quota obtained by the forest owners who adopt sustainable and certified management systems for a given time period (usually 20 years) is not accounted at the national level and is thus tradeable within a voluntary market.

The *Carbomark* market was enforced some years ago and has recorded credit selling prices between 4 and 80 €. The observed price range is influenced by the type of implemented projects.

5 The Inclusion of Agroforestry in Mitigation Policies: Some Remarks

The major role of the primary sector in the fight against climate changes was known since the implementation of KP. This is demonstrated by the fact that PK provided for different activities specifically mentioned in arts 3.3 and 3.4 concerning the LULUCF activities. Despite this, it is only recently that the EU has invited the member States to monitor very carefully the GHG flows related to the primary sector and to identify all the activities aimed at increasing the role of carbon sinks of agricultural and forest lands.

The primary sector may influence significantly the absorption and storage capacity of large amounts of carbon. To that effect, it is worthy underlining that the LULUCF sector is considered in the European policies to contrast climate changes just because it is the unique natural sector that can actually store significant amounts of CO_2. Besides being directly one of the main carbon sinks, the primary sector includes different associated subsectors, like that of agroforestry biomasses, and contributes indirectly to the reduction and absorption of GHGs through the production of clean energy produced from renewable sources.

The main reason for including the LULUCF sector in the strategies to contrast climate change is the possibility to measure and monitor more accurately, as compared to the past, the emissions and absorption of GHGs. The science achievements in this area enable, under the existing conditions, to assess more accurately the magnitude of emissions/absorption with significant future repercussions both at the European and international level. To this end, the methodology for calculating the baselines, the tests aimed at ensuring the criterion of additionality and the monitoring and checking systems, combined with the strategies implemented to limit the inefficiencies resulting from temporary absorption, have made the VCS and ACR the most largely used basic models for the implementation of new market mechanisms on the international scale.

Among the various types of offset projects, afforestation, reforestation, the sustainable forest management and the reduction of forest degradation (as for the forest sector), pasture and farmland management (for the agricultural sector) are by now well-established techniques that may be included in any market mechanism.

Besides Kyoto's principles and the *cap and trade* system that does not promote agroforestry credits, Italy faces a quite complicated legal situation. Despite this, the huge resources linked to the national land area have induced to elaborate the Carbon Code to encourage landowners to take soil management measures and increase GHG absorption, thus reducing the emissions into the atmosphere. The experiences implemented across the national area, such as the *Carbomark* project, have yielded good results and outlined new strategies to contrast climate changes. This confirms the importance of woody products in carbon storage, in line with the principle of absorption permanence, in addition to the identification of innovative mechanisms for the solution of the problems concerning double accounting. Other experiences conducted at the international level, such as in New Zealand, have demonstrated that forest owners' participation in the carbon credit market ensures better results, in terms of reduction of carbon emissions, and generates new income resources that could be reinvested in the agricultural-forest sector, besides many positive externalities associated with the forestation of new areas and the management of the existing ones (employment, tourism, bioenergy, etc.).

From an economic point of view, the prices observed in the examined markets show heterogeneous levels due to internal and external market variables that differ according to the type of project, geographical reference area, actors involved, etc. The mean prices observed in the examined markets actually point out the need for measures and actions to be taken by public bodies to ensure both the market transparency and the stability and increase in prices with a view to including the primary sector in climate change mitigation policies.

6 Conclusions

This article is intended to provide some suggestions for the implementation of a voluntary local market model through the involvement of the agricultural and forestry sectors. Over the last few years, the scientific community has introduced new accounting methodologies and upgrade old standards to improve the procedures for calculating the GHG absorption related to the primary sector. As a matter of fact, despite the sink role of the primary sector, notably of forestry, this is not yet recognised as being eligible as the main tool to contrast climate change.

The full awareness of the general public on this problem and the increasingly targeted experiments are showing the positive effects obtained through the win–win collaboration between the public–private sector and the world of research. One of them is the cut of transaction costs through the development of transparent and accurate standardised models.

The new market experiences should be based on what has been actually achieved, showing at the same time great adaptation and flexibility capacity, with a view to minimising the risks and errors made so far. With this in mind, the implementation of a local voluntary market of carbon credits could contribute to reduce the associated risks, by testing new methodologies and improving the governance and the awareness of all actors involved. New offset mechanisms shall ensure increasing certainty on the GHG stored by the primary sector. The economic benefits to the private and public sectors should not be considered as being independent and exclusive but quite exhaustive and comprehensive. The environmental benefits, the reduction of degradation of natural resources and the development of an environmental awareness in the community should be viewed as primary mitigation elements both for developed and developing countries, with a view to putting a stop to climate change.

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Evaluating the Role of Soil Variability on Potential Groundwater Pollution and Recharge in a Mediterranean Agricultural Watershed

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Abstract Regional-scale studies on groundwater vulnerability assessment of non-point source agrochemical contamination suffer either from no evaluation of uncertainty in data output, in that of qualitative modelling, or from prohibitively costly computational efforts, in that of deterministic modelling. By contrast, a methodology is presented here which integrates a solute transport model based on transfer function (TF) and a geographic information system (GIS). The methodology (1) is capable of solute concentration estimation at a depth of interest within a known error confidence class, (2) uses available soil survey and climatic and irrigation information and requires minimal computational cost for application and (3) can dynamically support decision-making through thematic mapping. Raw data (coming from different sources) include: i) water table depth, ii) soil texture properties, iii) land use, and iv) climatic information with reference to a study area located in southern Italy. Such information has been then manipulated in order to generate data required for the subsequent hydrological modelling. Simulated breakthrough curves were generated for each soil textural class. They are texture-based travel time probability density functions (TF_{tb}), describing the leaching behaviour of soil profiles with similar soil hydrological properties. The latter, in turn, were estimated by indirect estimation techniques such as pedotransfer

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_17

functions (PTFs) to overcome the trouble of intensive in situ and/or laboratory determinations of soil hydraulic and hydrodispersive properties, which are generally lacking for regional-scale studies. Results showed large differences in the magnitude of the different travel times and related uncertainties among different profiles. The lower or higher vulnerability was found to be mainly related to the average silt content of the soil profiles.

1 Introduction

Non-point source (NPS) pollution in the vadose zone (simply defined as the layer of soil extending from the soil surface to the groundwater table) is a global environmental problem. The knowledge and information required to address the problem cross several technological and sub-disciplinary lines: spatial statistics, geographic information systems (GIS), hydrology, soil science and remote sensing (Corwin 1996; Corwin et al. 1997; Coppola et al. 2014).

As discussed by Stewart and Loague (2003), the main issues encountered in NPS groundwater vulnerability assessment are the large spatial scales, the complex processes that govern fluid flow and solute transport in the unsaturated zone (Comegna et al. 2010; Coppola et al. 2011), the absence of unsaturated zone measurements of diffuse pesticide concentrations in 3D regional-scale space (as these are difficult, time-consuming and prohibitively costly) and the computational effort required for solving the nonlinear equations for physically based modelling in heterogeneous media at regional scale (Coppola et al. 2014). This results in significant simplifying assumption in NPS contaminant leaching models.

Currently, existing regional-scale leaching models can be grouped into four main categories, ranging from qualitative models that rely on index and overlay techniques, over simple drainage algorithms, to stream tube models coupled to process-based numerical simulations (Stewart and Loague 2003; Coppola et al. 2014). The large datasets of physical factors involved in the leaching process required for regional-scale studies limit the use of deterministic methods that would result in more realistic estimates of solute concentration. Besides, the use of overlay models encounters less computational and data lacking issues, though resulting in relative output information in terms of risk factor.

As a compromise solution, an approach is presented here which is based on coupling of texture-based transfer function (TF_{tb}) and GIS modelling. TF_{tb} are texture-based travel time probability density functions describing a characteristic leaching behaviour for soil profiles with similar soil hydraulic properties. They actually represent the result of an upscaling procedure applied to Jury's transfer function model (TFM) (Jury and Roth 1990).

GIS represents a spatially enabled database management system (DBMS) that is able to depict real-world geographic features of relevance to the leaching process, serving both as a baseline data depot for hydraulic modelling and a final gateway for output representation and interactive delivery.

With these premises, the main objective of this study was developing a regional-scale simulation methodology for vadose zone leaching that is capable of overcoming the limits of both fully deterministic and fully qualitative models in that it relies on easily available and accessible data and on affordable computational efforts and finally offers quantitative answers to groundwater vulnerability to agrochemical leaching at regional scale within a defined confidence interval.

This result was pursued through (1) the design and building of a spatial database containing environmental and physical information regarding the study area, (2) the development of the TF_{tb} for layered soils and (3) the final representation of results through digital mapping.

One side GIS modelled environmental data in order to characterise, at regional scale, soil profile texture and depth, land use, climatic data, water table depth and potential evapotranspiration. On the other side, such information was implemented in the development of a set of TF_{tb}, each describing the leaching behaviour of soil profiles with specific hydraulic properties. The latter, in turn, were estimated by area-specific pedotransfer functions developed on our own texture–hydraulic properties datasets coming from several sites in the investigated area. A wide area (about 12,000 ha) in the Metaponto plain in southern Basilicata, Italy, was completely characterised by a pedological point of view by digging several soil profiles. The textural properties of soil horizons of each soil profile were converted to the corresponding hydraulic properties by using a PTF specifically calibrated for the soils of the area (mainly silty loam, silty and silty clay). The solute travel times to water table for specific soil profiles were then imported back into GIS, and finally estimation of groundwater vulnerability for each soil unit was represented into a map.

2 Materials and Methods

2.1 Study Area

For this study, the area of interest was subbasin of Metaponto agricultural site, located in southern Basilicata, Italy, across the municipalities of Policoro, Scanzano Jonico, Montalbano Jonico and Pisticci, approximately 11,698 ha in size and crossed by two main rivers, Sinni and Agri, and from many secondary water bodies. Figure 1 shows the location of the study area.

Topographically, the area is characterised by fairly distinct variations in elevation in the western part of the basin, away from the coast, and extremely flat terrain in the nearshore portions of the basin, to the south and east. The main soils in the area are the "soils of the alluvial plains" and the "soils of the Ionian coastal plain". The soils of the alluvial plains are those formed along the fluvial channels of the

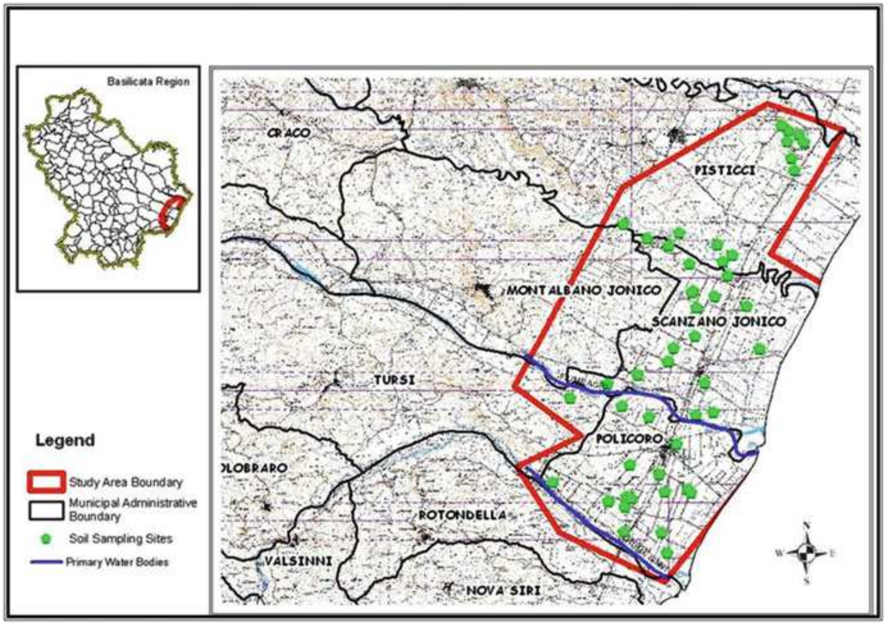

Fig. 1 Study area overview (*circles* indicate soil profile sites)

rivers crossing the area. Therefore, they are soils on alluvial and lake deposits, with variable grain size from clayey to stony. The soils of the Ionian coastal plain consist of marine deposits of different ages, from Pleistocene to Holocene, and of alluvial deposits of variable grain size. The soils of the internal areas, less extensive than those described above, are those that formed on a substrate of sandstones with alternations of marl and clay.

Much of the basin is used for agricultural purposes. Major crops and land uses receiving applications of nutrients and chemicals include cereals, vegetables and fruit orchards. Soils that support these land uses range from the loam to clay loam, in the northern portions of the basin, to the fine silty loams in the southern basin.

2.2 Geo Database Implementation

A spatial digital database for the study area was established through the assembly of various publicly available physiographic data sets (land use, soils, climate, depth to groundwater, elevation).

Such datasets characterised features considered to be directly or indirectly involved in the leaching process, thus characterising boundary conditions. Data was structured into feature datasets and raster datasets, in that both discrete and continuous data types were implemented in this study (Table 1).

Table 1 Summary of the GIS datasets

Feature	Data format	Spatial resolution	Data source
Land use	Vector	Digitised form 1:10,000 scale	INEA-Progetto SIGRIA
Soil texture	Vector	Cell size 20 m	Basilicata region Senise
Soil profile depth	Vector	Cell size 20 m	Basilicata region Senise
Precipitation (years)	Raster	Cell size 20 m	AdB
Temperature (year mean)	Raster	Cell size 20 m	AdB
Elevation	Raster	Cell size 20 m	SAFE-Univ. Basilicata
Freatimetry	Raster	Cell size 20 m	AdB

Table 2 Land use classes from the original map are summarised into 10 main categories

Land use	Number	Hectares
Non-vegetated area	1505	17.705
Forest	10	0.524
Cereal	445	10.794
Fruit tree	1689	50.564
Leguminous	39	0.624
Olive orchard	456	4.206
Vegetable	1003	10.959
Grass land and pasture	16	0.660
Ploughed areas	1083	17.816
Grape orchard	229	3.131

Data manipulation and spatial analysis were performed to finally produce output datasets as described in the previous table.

2.2.1 Land Use

Land use dataset, published within *Progetto Sigria, INEA 2000*, was used to describe cropped species at parcel level and furthermore to define the spatial extent of the whole GIS project in this work. Table 2 shows cropped surfaces in hectares summarised by aggregated land use classes.

Fruit orchards land use dataset, published within *Progetto Sigria, INEA 2000*, was used to describe cropped species at parcel level and furthermore to define the spatial extent of the whole GIS project in this work. Fruit orchards cover almost 44 % of total study area, followed by ploughed areas covering 15 %, vegetables 10 % and cereals 10 %. Non-vegetated areas, such as urban or water bodies, make up for 15 %.

Soil data were originally acquired from regional geology agency in tabular format for 52 soil profiles sampled across the study area (see circles in Fig. 1. For each profile, a fictitious soil system was adopted, assuming the soil to be composed of only two layers, A and B, the first being superficial and 40 cm thick (this was the average depth of the first horizon for all the soil profiles and the latter reaching the water table). A fictitious soil profile was obtained for each real soil profile by averaging textural data with a weighted procedure using horizon depths as weights.

Data were then imported into GIS and spatial structure of sand, clay and silt contents, and depth measures were analysed with Exploratory Spatial Data Analysis (ESDA) tools, by means of classic statistical and geostatistical analyses. After interpolation, continuous surfaces for sand, clay, silt and soil profile depth were produced in raster format for both A and B soil layers (maps not shown).

Sand, silt and clay raster datasets were concurrently queried with a map calculator using a set of SQL statements, each defining a texture constraint for each soil class according to USDA classification system, in order to produce two final texture maps (Fig. 2), one for each fictitious soil layer.

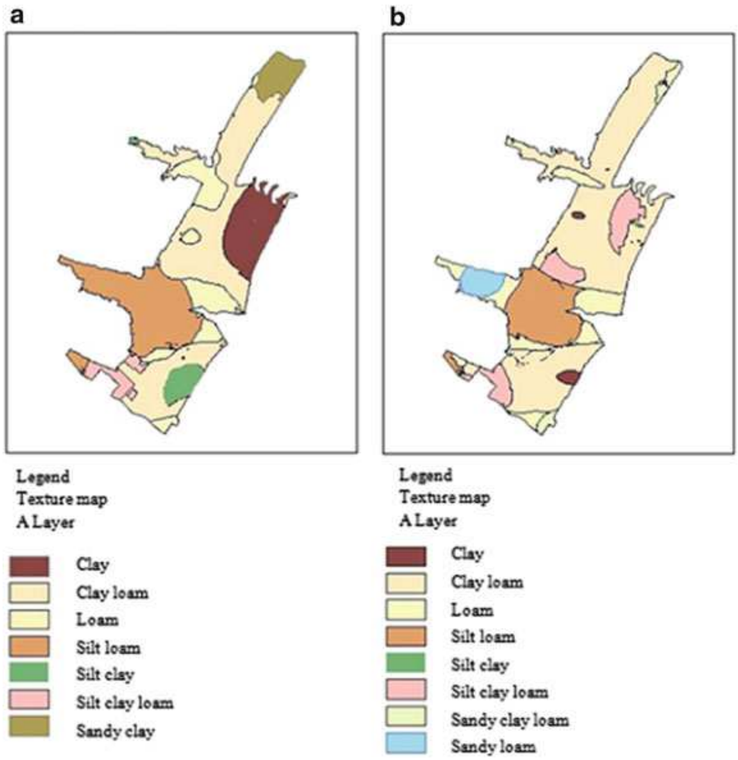

Fig. 2 Texture map for layers (**a**) and (**b**)

2.2.2 Precipitation, Temperature and Evapotranspiration

Climate data on a daily basis for the 1999–2009 period for all the climatic stations localised in the area of interest were provided by Regional Agriculture Services. The *Voronoi algorithm* was used for spatial partitioning of the study area according to the subarea of influence of each rainfall station. The *Voronoi* cells for the area under study are shown in Fig. 3.

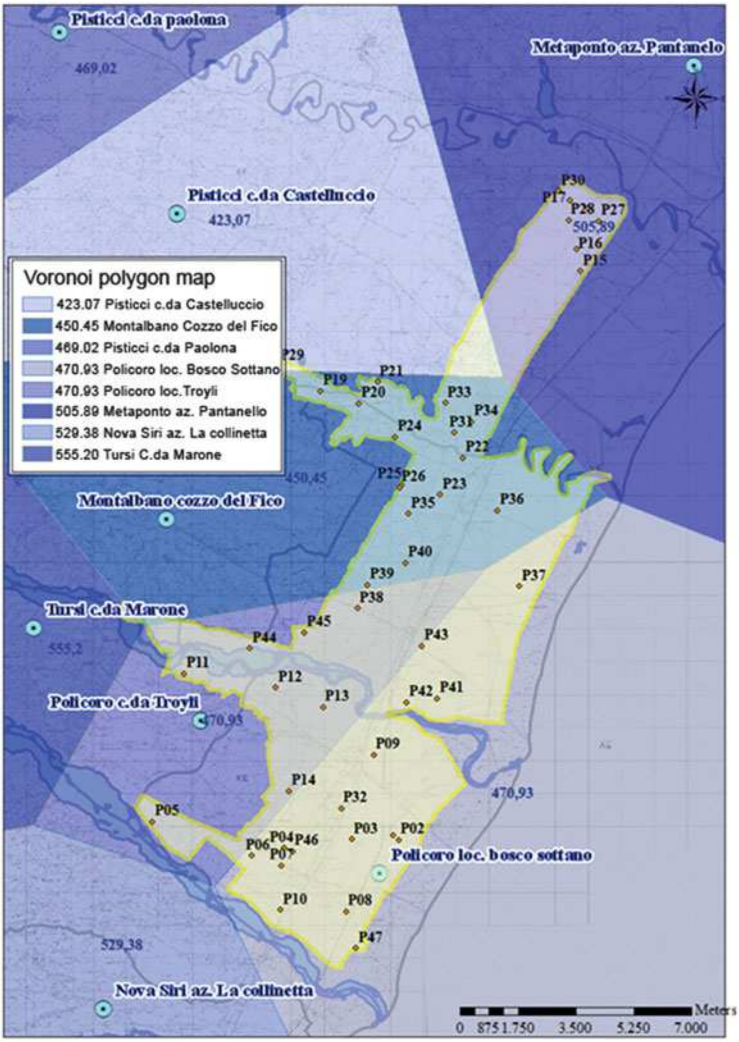

Fig. 3 Positions of meteorological stations and Voronoi polygons of the study area. *Alphanumeric codes* identify the soil profiles used for this study

2.2.3 Elevation

Contour lines on IGM 1:5,000 base maps were digitised, and a triangulated irregular network was created from them and finally converted into a raster dataset. From elevation grid, slope grid was derived as well.

2.2.4 Depth to Groundwater

The laboratory of Soil and Contaminant Hydrology of the University of Basilicata provided tabular data for 192 measuring wells, 51 of which were located within the study area. Once imported into GIS as a point feature dataset, groundwater depth at measuring stations was interpolated using Kriging, thus resulting in a continuous surface (map not shown).

2.3 Geoprocessing and Data Handling

The role of GIS in this study was to provide hydrological modelling with a spatial database carrying all the necessary information for leaching assessment: textural class, soil depth, water table depth and net water recharge.

In order to achieve such goal, datasets carrying spatially distributed information of these data, collected as described above, were aggregated at homogenous soil units level on one common layer enabling further data manipulation and derived variable creation, such as water recharge.

Homogenous soil units (being areas characterized by sufficiently similar leaching behaviour) were defined intersecting soil texture information for layers A and B through geoprocessing tools, which finally resulting in a polygon feature vector dataset. Each polygon defines a combination of two overlaying textural classes; in all there were 31 possible texture combinations classes.

Finally zonal attribute transfer was then performed from land use, rain, freatimetry, temperature, slope and elevation datasets to soil unit feature dataset, in order to associate to each soil unit such spatially distributed information averaged for each polygon surface. Furthermore for each soil unit potential evapotranspiration (ETp) was calculated using the Thornthwaite formula (USDA 1975).

At this point the output spatial database was set up with all calculated, estimated and derived physical attributes related to each polygon representing an instance of a homogeneous soil unit. In Table 3 are shown three explanatory records out of the total 7,872. Such database was implemented in hydrological modelling as discussed in the following section.

Table 3 Spatial database for three explanatory records

Polygon ID	Texture overlay	Land use	Mean depth layer A	Mean depth of groundwater table	Annual mean ET_p	Annual net water recharge
1	Clay loam on clay	Fruit tree	0.628	26.238	900	623
2	Clay loam on clay loam	Olive orchard	0.611	15.682	1,099	1,261
3	Clay loam on clay loam	Fruit tree	0.595	11.024	988	1,340

2.4 *Stochastic Development of TF_{tb}*

2.4.1 Texture-Based Hydraulic and Solute Travel Time Distributions

A large dataset of hydraulic properties was already available for the textural classes of the area. They were measured in the laboratory on undisturbed soil samples (490 samples) collected at the soil surface during several previous measurement campaigns.

Soil water retention was described by the unimodal $\theta(h)$ relationship proposed by van Genuchten (1980) and expressed here in terms of the scaled water content (S_e) as follows:

$$S_e = \frac{\theta - \theta_r}{\theta_0 - \theta_r} = [1 + |\alpha_{VG} h|^n]^{-m} \tag{1}$$

where α_{VG} (cm^{-1}), n and m are curve-fitting parameters and h the pressure head.

Mualem's expression was used to calculate relative hydraulic conductivity, K_r (Mualem 1976); assuming $m = 1 - 1/n$, van Genuchten (1980) obtained a closed-form analytical solution to predict K_r at a specified volumetric water content

$$K_r(S_e) = \frac{K(S_e)}{K_0} = S_e^{\tau}\left[1 - \left(1 - S_e^{1/m}\right)^m\right]^2 \tag{2}$$

where τ is a parameter accounting for the dependence of the tortuosity and the correlation factors on the water content and K_0 is the hydraulic conductivity at $h = 0$.

For each soil sample a detailed particle-size distribution (PSD) was also available. PSD data were used as a basis for estimating soil water retention (and the corresponding parameters in Eq. (1) of soil horizons of each of the observation soil profiles by using the physico-empirical PTF approach proposed by Arya and Paris (1981). Hereafter, such an approach will be referred to as the AP approach. The original formulation based on a single optimisation parameter (αAP) was thus made more flexible by assuming a variable αAP(h) with the pressure head h.

Arya et al. (1999) also derived an expression to compute $K(\theta)$ directly from the PSD, based on the same soil structure model leading to the $\theta(h)$ function. We opted for using the method only for estimating the saturated hydraulic conductivity. The whole hydraulic conductivity curve was estimated by using Eq. (2), with retention parameters and K_0 estimated by the AP method and setting $\tau = 0.5$. A specific αAP(h) curve was obtained for each of the textural class present in the investigated area. The measured hydraulic properties were partly (200 samples) used for the PTF calibration, by keeping the remaining data for the PTF validation.

In synthesis, site-specific PTF allowed estimating a complete set of hydraulic parameters (θ_0, θ_r, α_{VG}, n, K_0 and $\tau = 0.5$), for each of the textural classes found in the area. A Kolmogorov–Smirnov test showed that all the parameters were normally distributed. The mean and the covariance matrix for the five parameters (all but τ) were computed for each of the textural classes encountered along the soil profiles. Thus, random field of the five parameters was produced with a Monte Carlo procedure from the correlated multivariate normal distribution for any textural classes by generating a vector x of independent standard normal deviates and then applying a linear transformation of the form $x = \mu + Lr_n$, where μ is the desired vector of means and L is the lower triangular matrix derived from the symmetric covariance matrix $V = LL^{\mathrm{T}}$ decomposed by Cholesky factorisation. In other words, the procedure generated random field with correlated parameters by multiplying the lower triangular Cholesky decomposition of the covariance matrix with vectors, r_n, containing five $N(0,1)$ randomly distributed numbers and by summing up the result to the mean of the parameters. We recall that using the statistical moments of the parameters of the hydraulic functions for generating the random field to be used in Monte Carlo simulations implies the assumption that soil hydraulic variability can be described by the statistical distribution of such parameters. This widely used approach is conceptually simple and is based on the idea of approximating stochastic processes by a large number of equally probable realisations. In this study, 400 sets of equally probable hydraulic parameter realisations were generated for each of the textural classes.

As for solute transport, solute travel time distributions were deduced by applying the method proposed by Scotter and Ross (1994), which estimates breakthrough curves of a tracer at a given depth for a given soil starting with the hydraulic conductivity function of that soil. According to the transfer function model (TFM), the flux concentration at a depth z, $C^{\mathrm{f}}(z, I)$, given a time-varying flux concentration at the input surface $C^{\mathrm{f}}(0, I)$ is given by

$$C^{\mathrm{f}}(z,I) = \int_0^z C^f\left(0, I - I'\right) f^f(z,I)dI' \tag{3}$$

where $f^{\mathrm{f}}(z, I)$ is the steady-state travel time distribution (travel time pdf) defining the changes in the normalised concentration in the drainage as the cumulative drainage I builds up. For steady-state flow conditions, $I = qt$, where q is the steady-state flow rate and t is the time. Scotter and Ross (1994) assumed a gravity-induced water flow, a conservative and nonreactive solute and a purely convective flow, thus ignoring any convective mixing of solute flowing at different velocities and the effects of molecular diffusion. With these assumptions, the $f^{\mathrm{f}}(z, t = I/q)$ for a pulse input of solute can be obtained as

$$f^{\mathrm{f}}(z,t) = \frac{\mathrm{d}C^{f}(z,t)}{\mathrm{d}t} = -\frac{1}{q}\frac{\mathrm{d}K(\theta)}{\mathrm{d}t} \tag{4}$$

For a log-normal distribution of the cumulative drainage (or of travel times) the analytical expression for the pdf is a log-normal density function

$$f(I) = \frac{1}{\sqrt{2\pi}\sigma I}\exp\left[-\frac{(\ln I - \mu)^2}{2\sigma^2}\right] \tag{5}$$

in which μ and σ are the parameters of the log-normal pdf.

For the case of a stochastic–convective with log-normal distribution of travel time (CLT) model, if the $f^{\mathrm{f}}(z, I)$ is known at a given depth z_1, then the TFM model allows for scaling that pdf to a depth z_2 according to the equation

$$f^{\mathrm{f}}(z_2, I) = \frac{z_1}{z_2}\left(z_1, I\frac{z_1}{z_2}\right). \tag{6}$$

This means that $z_1 = z_2$ and $z_2 = z_1 + \ln(z_2/z_1)$. If, to the contrary, the transport process obeys to the advection–dispersion (AD) model, $z_2 = 0.5z_1(z_1/z_2)$ and $z_2 = z_1 + \ln(z_2/z_1) + 0.5{z_1}^2(1 - z_1/z_2)$.

For each of the hydraulic parameter random vectors obtained for each textural class, a corresponding fictitious breakthrough curve, $f^{\mathrm{f}}(z, I)$, at an arbitrary depth of $z = 40$ cm was calculated according to Eq. (4) for a solute pulse injection at the surface. An inert, non-adsorbed (a tracer) solute was selected for simulation purposes. In order to calculate the cumulative drainage I, an hourly inflow rate was calculated by assuming that all the net recharge (the rainfall infiltrated in the soil minus the evapotranspiration) was uniformly distributed over the year and that storage and surface run-off were negligible.

By simply averaging over the 400 simulated breakthrough curves $f^{\mathrm{f}}(z, I)$, an upscaled probability density function was obtained. Effective parameters $\mu(\mu_{\mathrm{ef}})$ and $\sigma(\sigma_{\mathrm{ef}})$ at 40 cm for each textural class were estimated by fitting Eq. (5) to the upscaled curve.

2.4.2 Upscaled Solute Travel Time Distribution for Textural Sequences

By assuming the independence between two successive layers along a textural profile, assumed to consist of two layers A and B, the mean $E(I, z = 80\text{ cm})$ and variance VAR(I, $z = 80$ cm) were obtained by summing up the E(I, $z = 40$ cm) and VAR(I, $z = 40$ cm) of the two textural classes for any textural sequence. The E(I, z) and the VAR(I, z) were calculated as

$$\begin{aligned} E(I, z) &= \exp\left(\mu_z + 0.5\sigma_z^2\right) \\ \mathrm{VAR}(I, z) &= \exp\left(2\mu_z + \sigma_z^2\right)\left[\exp\left(\sigma_z^2\right) - 1\right] \end{aligned} \tag{7}$$

Once the upscaled 80 cm pdf was obtained, it was scaled with depth down to the water table according to the following hypothesis:

1. The transport mechanism in the second layer down to the water table is the CLT (the effective parameters were scaled according to the CLT model).
2. The transport mechanism in the second layer down to the water table is the CDE (the effective parameters were scaled according to the CDE model).

3 Results and Discussions

The outputs of the numerical simulations, carried out in a stochastic framework, were interpolated for producing continuous maps of the modal travel time, along with the corresponding uncertainty levels. Modal travel times for each of the textural sequences and for both the assumed transport mechanisms are synthesised in the maps in Fig. 4a, b; they exhibit remarkable differences in terms of travel time estimations for same soil textural classes due to the underlying transport approaches and soil layer conceptualisations.

Independently on the mechanism assumed, the spatial variability of textural layers was a major factor influencing the field water and solute transport in alluvial soils. Results showed large differences in the magnitude of the different travel times and related uncertainties among different profiles. The lower or higher vulnerability was found to be mainly related to the average silt content of the soil profiles. Higher travel time uncertainty was mainly related to the clay content in the range 20–40 %.

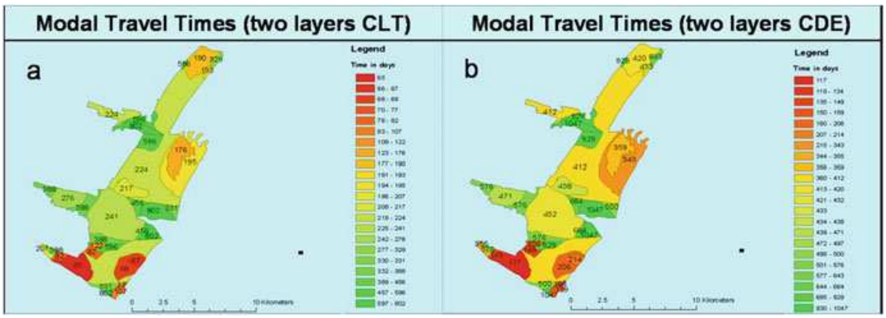

Fig. 4 (**a**) Modal travel time map for CLT process; (**b**) modal travel time map for AD process

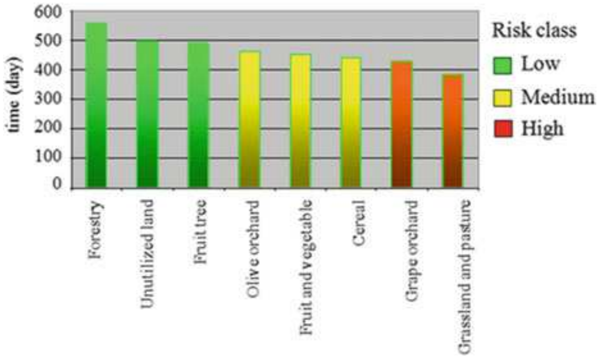

Fig. 5 Vulnerability risk for land use classes

As for the CDE mechanism, travel times are generally higher than for the CLT by an average of 88 %, a minimum of 30 % (loam on loam) and a maximum of 220 % difference (silty clay on clay). Highly vulnerable areas, being characterised by a shorter travel time, showed to be more subject to estimation value fluctuations depending on the transport mechanism compared to more protected areas.

Of course, the local travel time should be interpreted according to the specific local conditions, especially in terms of land use, crop, water table depth and rainfall. Referring to CDE transport mechanism, travel time values were reclassified using natural breaks classification method into three main vulnerability classes: low risk, medium risk and high risk. In figure 5 is showed a comparison between land use classes versus vulnerability risk classes, using a spatial join constraint. Very low vulnerability resulted associated with areas not subject to intensive agrochemical inputs such as forest, to unutilized areas and to fruit tree orchards; fruit and vegetables together with olive orchards and cereals classes showed an average medium risk. Finally grape orchards and grassland/pasture land are associated with high risk.

Spatial distribution, fragmentation and perimeter to area ratio of land use patches were taken into account to ensure data homogeneity during generalisation of travel times and subsequently land use class risk rankings (Batty and Longley 1994).

4 Conclusions

All the past efforts to evaluate solute travel times to groundwater at the regional scale have frequently been hindered by the problem of how to account for the variability of soil layering. Past studies tended to decompose a profile into several (usually three to four) functional horizons and assumed that they are identical within a certain area when the water flow and the solute transport are modelled. This method may be suitable for some genetic soils that consist of intrinsic genetic horizons and do not vary significantly in the thickness of every horizon within a certain area. However, for alluvial soils, which are widely distributed in the alluvial plain investigated in this paper, the textural layering is very complex. Accordingly, to accurately quantify the solute transport process at regional scale, we took the spatial variability of textural layers explicitly into account. Information on soil textural profiles was coupled with a texture-based transfer function solute transport model to conduct a stochastic analysis of the solute transport in the Metaponto area (Basilicata region, South Italy). The aim was to assess the effect of spatial variability of textural layers on the solute travel times, along with their probability distributions. The strength of the methodology becomes apparent especially if compared to qualitative models that, while being the most common solution for regional studies, rely uniquely on empirical conceptualisations of chemical leaching processes and give as outputs only general qualitative indication rankings without quantification of risk in terms of travel times.

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Grazing and Biodiversity Conservation: Highlights on a Natura 2000 Network Site

Pierangelo Freschi, Mauro Musto, Rosanna Paolino, and Carlo Cosentino

Abstract This paper provides a summarisation of information on the biodiversity of Natura 2000 sites of Basilicata and the impacts of grazing on protected habitats and species. Besides, using a case study of a site particularly rich in biodiversity as an example, we described the application of the Driving Force, Pressure, State, Impact and Response (DPSIR) framework to evaluate the impacts of grazing and to propose corrective measures for ensuring restoration and conservation of habitats.

Similar situations to those described on grazing in the study site can arise for any kind of anthropogenic disturbance, which makes the approach here described and discussed suitable for a large-scale use.

However, the challenge for Natura 2000 network in Basilicata is not strictly to propose measures aiming at conserving biodiversity, but rather to build a better awareness of the 'natural heritage' concealed within the sites, in order to create an active involvement of the stakeholders in the process of devising policies toward biodiversity conservation.

1 Introduction

The agroecosystems of Basilicata region and, more in general, of south of Italy, have been shaped over the centuries through the perpetuation of traditional agricultural practices (e.g. grazing, mowing and burning), based on the balance between exploitation and conservation of available resources. Seminatural Mediterranean grasslands are a paradigmatic example of sustainable exploitation of natural resources in this regard.

Nowadays, a major threat to flora and fauna of many European agroecosystems such as those of Basilicata is the rapid mutation of agricultural practices: seminatural grasslands, heathlands, arable steppes and agroforestry systems are actually experiencing significant loss of biodiversity of flora and fauna. This is mainly due to

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_18

the intensification of agriculture on productive sites (Dorrough and Scroggie 2008) and to the concurrent abandonment of traditional practices in marginal areas (MacDonald et al. 2000).

Relaunching traditional agricultural practices is often seen as a potential solution to biodiversity loss. The establishment of the Natura 2000 network in application of Council Directives 79/409/EEC on the conservation of wild birds and 92/43/EEC on the conservation of natural habitats and of wild fauna and flora may represent a promising restoration strategy to relaunch these traditional practices. Once fully operational, this ecological network will consist of a system of protected areas [i.e. Special Areas of Conservation (SACs) and Special Protection Areas (SPAs)] designated to assure the long-term survival of Europe’s most valuable and threatened species and habitats.

An innovative feature of this ecological network is to ensure the protection of biodiversity taking account of ‘economic, social and cultural requirements and regional and local characteristics’ (Directive 92/43/EEC, art. 2). This means that the areas making up the network are not considered as exclusively reserved, inviolable and fully protected areas where any human activity is forbidden, but rather as areas in which man’s traditional activities must be compatible with the conservation of habitats and rare, endangered or vulnerable wild species (fauna and flora), seeking a sustainable management from the ecological, economic and social point of view.

Among traditional agricultural activities, grazing is considered as a complex disturbance capable of altering natural processes, affecting species persistence and influencing the structure and composition of plant communities (Olff and Ritchie 1998). Grazing influence on biodiversity is generally negative when livestock are managed in a way which is not ecologically rational (Bakker 1998; Rook et al. 2004). For instance, high stocking rates may result in a homogenising of the vegetation pattern (Bakker 1998). Conversely, if properly managed and carefully controlled, grazing can be a promising tool to maintain or restore open landscapes, to hinder forest encroachment and, hence, to preserve and enhance biodiversity (Bakker 1998; Pykälä 2004; Sutherland 2002).

In order to relaunch grazing through the enhancement of its ecological role, it is important to identify its critical factors affecting negatively biodiversity to define appropriate actions which ensure a sustainable management of land resources.

This paper describes the grazing impacts on the integrity of Natura 2000 sites of Basilicata, focusing especially on the problems of biodiversity conservation concerning a site particularly affected by poor grazing management. The challenge for a site like this is not only to identify some policy measures capable of enhancing the positive and mitigate the negative effects of grazing, but also to involve the stakeholders in the process of devising policies toward biodiversity conservation.

2 Overview of Basilicata's Natura 2000 Network

In Basilicata there are 50 Sites of Community Importance (SCI), which protect rare, endangered or vulnerable natural habitats and species of plants or animals (other than birds) of European importance, and 17 Special Protection Areas (SPA), which protect significant numbers of wild birds and their habitats. The overall extension of these sites is 170,479 ha (17.1 % of the regional area); the total area of SPAs is 160,540 ha (16.1 % of the regional area), whereas the surface of the SCIs is equal to 61,179 ha (6.1 % of the regional surface).

Overall, these sites comprise a complex spatial pattern of biodiversity as Basilicata region has a remarkable morphological and geological variability. In fact, its territory (9,992 km^2) comprises mountains (70 %), hills (20 %) and plains (10 %); besides, it comprises small coastal areas, which are situated along the Ionian and Tyrrhenian Seas.

3 Community Habitats of Basilicata's Sites

To provide a better understanding of the complex mosaic of different habitats found in Basilicata, the regional sites can be distinguished in terms of altitude according to three main areas:

1. Mountain environments (ME)
2. Hills and plains (HP)
3. Coastal relieves and shoreline (CS)

Concerning the 50 SCIs, most of them (29) fall in mountain areas, whereas the remainder is distributed between hills and plains (13) and coastal relieves and shoreline areas (8) (Musto et al. 2013).

These sites protect 303 habitat types listed in Annex 1 of the Habitats Directive. Most of them are distributed between ME (142; 46.86 %) and CS (102; 33.66 %) SCIs, whereas the remainder (59; 19.47 %) has been found in HP SCIs. This means that ME and CS sites support greater biodiversity than HP sites.

The most common habitat found in these sites is the 6210 [seminatural dry grasslands and scrubland *facies* on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)]: it has been recorded in 26 SCIs on 50. In most of the cases (84.62 %), the habitat falls in ME SCIs, whereas the remainder (15.38 %) is equally distributed between HP and CS SCIs. Other common habitats in Basilicata's sites are 91 M0 (Pannonian–Balkanic turkey oak–sessile oak forests), 9210 (Apennine beech forests with *Taxus* and *Ilex*) and 9180 (*Tilio-Acerion* forests of slopes, screes and ravines). These habitats have been identified mainly in ME SCIs (91 M0: 69.57 %; 9210: 95.45 %; 9180: 87.50 %) and, to a lesser extent, in CS SCIs (91 M0: 30.43 %; 9210: 4.55 %; 9180: 12.50 %). The third most common habitat is the 6220 [Pseudo-steppe with grasses and annuals of the *Thero-*

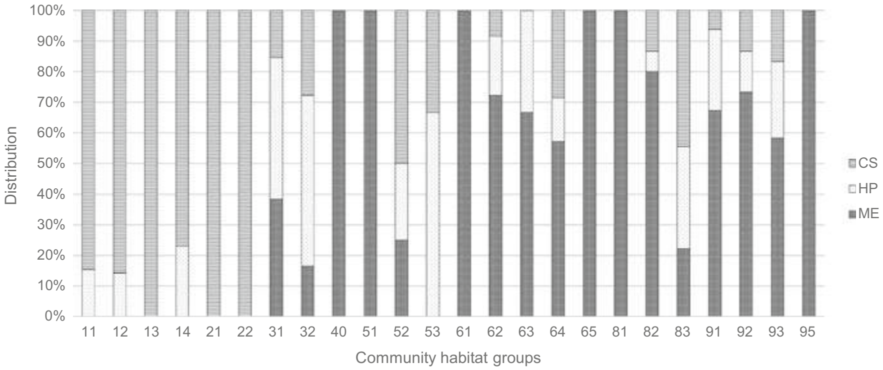

Fig. 1 Distribution of community habitat groups found in Basilicata by site type. Community habitat group codes: 11 = open sea and tidal areas; 12 = sea cliffs and shingle or stony beaches; 13 = Atlantic and continental salt marshes and salt meadows; 14 = Mediterranean and thermo-Atlantic salt marshes and salt meadows; 21 = sea dunes of the Atlantic, North Sea and Baltic coasts; 22 = sea dunes of the Mediterranean coast; 31 = standing water; 32 = running water—sections of water courses with natural or seminatural dynamics (minor, average and major beds) where the water quality shows no significant deterioration; 40 = temperate heath and scrub; 51 = sub-Mediterranean and temperate scrub; 52 = Mediterranean arborescent matorral; 53 = thermo-Mediterranean and pre-steppe brush; 61 = natural grasslands; 62 = seminatural dry grasslands and scrubland facies; 63 = sclerophyllous grazed forests (*dehesas*); 64 = seminatural tall-herb humid meadows; 65 mesophile grasslands; 81 = scree; 82 = rocky slopes with chasmophytic vegetation; 83 = other rocky habitats; 91 = forests of Boreal Europe; 92 = Mediterranean deciduous forests; 93 = Mediterranean sclerophyllous forests; 95 = Mediterranean and Macaronesian mountainous coniferous forests

Brachypodietea (*important orchid sites)]: it has been found in 12 sites, and most of them are ME SCIs (50 %), while the remainders are CS and HP SCIs (both 25 %).

The habitats found in Basilicata can be aggregated into 24 community habitat groups by using the classification scheme according to the Interpretation Manual of European Union Habitats (European Commission—DG EUR27 2007). As shown in Fig. 1, some groups are present only in some type of sites (e.g. 40, 51, 61, 65, 81 and 95 only in ME SCIs). Instead, other groups are shared by two (e.g. 11, 12, 14, 53 and 63) or three site types (e.g. 31, 32, 52, 64, 82, 83, 91, 92 and 93).

The conservation status of the community habitat groups is quite varied (Table 1). It ranges from 'bad' to 'good' in ME and CS SCIs, with some groups (e.g. 61 and 83 in ME SCIs; 31 in CS SCIs) showing bad structure with insufficient conservation and unfavourable future prospect. Conversely, the habitat groups found in HP SCIs are in a better conservation status, with most of them being at good conservation status, and two at excellent status (i.e. 81 and 82).

Table 1 Conservation status[a] of community habitat groups found in Basilicata by site type (mean + SD)

Habitat group[b]	Natura 2000 SCI types[c]		
	ME	HP	CS
11	–	–	1.44 + 0.49
12	–	–	1.71 + 0.49
13	–	–	2.00 + 0.00
14	–	1.67 + 0.58	2.30 + 0.45
21	–	–	1.40 + 0.42
22	–	–	1.53 + 0.24
31	2.12 + 0.25	1.70 + 0.84	1.00 + 0.00
32	2.00 + 0.00	1.57 + 0.53	2.00 + 0.00
40	2.00 + 0.00	–	–
51	2.50 + 0.71	–	–
52	2.00 + 0.00	–	1.50 + 0.71
53	–	2.00 + 0.00	2.00 + 0.00
61	1.00 + 0.00	–	–
62	1.98 + 0.33	1.86 + 0.38	1.67 + 0.56
63	2.00 + 0.00	2.00 + 0.00	–
64	2.00 + 0.00	2.00 + 0.00	2.00 + 0.00
65	2.00 + 0.00	–	–
81	2.00 + 0.00	3.00 + 0.00	–
82	2.04 + 0.47	3.00 + 0.00	2.33 + 0.58
83	1.00 + 0.00	–	2.00 + 0.00
91	2.09 + 0.24	1.83 + 0.41	2.25 + 0.50
92	2.06 + 0.22	1.25 + 0.50	1.90 + 0.22
93	2.14 + 0.38	2.33 + 0.58	2.00 + 0.00
95	1.75 + 0.50	–	–

[a]Within the Natura 2000 Standard Data Form, the degree of conservation of the structure and functions of each habitat is recorded into three levels, 1, 2 and 3, respectively, indicating an average or reduced, good and excellent conservation status. – not present. *SD* standard deviation
[b]Community habitat group codes: 11 = open sea and tidal areas; 12 = sea cliffs and shingle or stony beaches; 13 = Atlantic and continental salt marshes and salt meadows; 14 = Mediterranean and thermo-Atlantic salt marshes and salt meadows; 21 = sea dunes of the Atlantic, North Sea and Baltic coasts; 22 = sea dunes of the Mediterranean coast; 31 = standing water; 32 = running water —sections of water courses with natural or seminatural dynamics (minor, average and major beds) where the water quality shows no significant deterioration; 40 = temperate heath and scrub; 51 = sub-Mediterranean and temperate scrub; 52 = Mediterranean arborescent matorral; 53 = thermo-Mediterranean and pre-steppe brush; 61 = natural grasslands; 62 = seminatural dry grasslands and scrubland *facies*; 63 = sclerophyllous grazed forests (*dehesas*); 64 = seminatural tall-herb humid meadows; 65 mesophile grasslands; 81 = scree; 82 = rocky slopes with chasmophytic vegetation; 83 = other rocky habitats; 91 = forests of Boreal Europe; 92 = Mediterranean deciduous forests; 93 = Mediterranean sclerophyllous forests; 95 = Mediterranean and Macaronesian mountainous coniferous forests
[c]SCI types: *ME* mountain environments, *HP* hills and plains, *CS* coastal relieves and shoreline

4 Livestock Farming within Basilicata's Sites

Livestock production is underrepresented in Natura 2000 Basilicata Network, as most of farms with livestock are located in the surroundings of the sites, with only a few farms within the site boundaries.

These farms vary widely in the number and kind of livestock (Freschi et al. 2013). Some raise few but different livestock, primarily for home consumption, whereas others specialise in a single livestock type, especially the larger farms. In some cases, livestock are raised in semi-extensive or extensive system, whereas in others animals are kept in confined conditions.

Many of the farms also raise crops, but others specialise in animal production and have few hectares. However, most of the sampled farms are small- and medium-sized farms with pastured livestock types (e.g. sheep, goats and cattle) and few other livestock (e.g. horses, pigs and poultry).

During hiking, Podolian cattle were found to be the most common breed kept in the sites. This breed is the most important Italian cattle breed raised in extensive conditions of south of Italy, and it is particularly widespread in Basilicata, where it is observed the highest consistence (Anabic 2014). The spread of this breed is mainly due to its ability to exploit marginal areas and to display site-specific adaptations. This type of rearing is based on cow–calf production system, with livestock grazing on the pastures almost year-round. The adoption of this system often has a dual-purpose, producing milk (mainly to make Caciocavallo cheese) other than meat. For this autochthonous cattle breed, the occurrence of a seasonal migration to high pastures was also observed in some sites: between June and October, some herds of Podolian cattle from neighbour regions (e.g. Campania and Calabria) were found to graze within the sites on summer pastures.

Small-sized flocks/herds of sheep and goat were also observed to graze/browse extensively and seasonally on sites' surfaces. These animals of local hardy breeds are characterised by relatively low nutritional requirements, high resistance to disease and low productivity (they are mainly used for cheeses and meat). Small herds of two or three horses kept at pasture were also met, but to a lesser extent than cattle, sheep and goats.

5 Grazing Impacts on Basilicata's Sites

Within the Natura 2000 Standard Data Form, grazing is listed as an impact (code: 140) that may have an influence on the conservation and management of the site. Information available on grazing impact within and around each site includes the following:

– Influence, recorded into three categories: positive, negative or neutral
– Surface (i.e. the percentage of the surface area of the site affected by grazing)

– Intensity, recorded into three levels, 1, 2, 3, respectively, indicating a low, medium and high intensity

These data were elaborated to provide a better understanding of how the vegetation resources of the sites are used by livestock.

Our results showed that over a half (53.85 %) of the grazing impacts recorded in the Natura 2000 Standard Data Forms exert a negative influence on Basilicata's SCIs. As shown in Table 2, half of the cases of negative influence have been observed on ME SCIs, where the largest percentage of surface damaged by livestock has been found (50 %). The remainder cases of negative influence are distributed between HP (28.57 %) and CS (21.43 %) SCIs, where the percentage of damaged surface is around 30 %. In ME and HP SCIs, grazing intensity has a mean value >2, indicating that grazing exerts an influence that goes beyond the threshold of a medium influence. The cases of neutral influence on Basilicata's SCIs account for 34.62 %; they have been mainly found on ME SCIs (77.78 %; Table 2) and to a lesser extent on the other sites (11.11 % for both HP and CS SCIs). The percentage extension in which grazing's neutral influence has been recorded ranges from 20 (HP SCIs) to 44.43 % (ME SCIs), whereas the intensity ranges from 1.50 (both HP and CS SCIs) to 1.64 (ME SCIs). A few cases of positive influence have been observed (11.54 %) and are equally distributed in ME and in CS SCIs (50 % in both; Table 2). The percentage extension is greater in ME SCIs than in CS SCIs (30.66 % vs. 16.67 %, respectively), whereas no difference has been observed in terms of intensity.

The negative influence of grazing manifests itself through a series of degradation phenomena, such as reduction of ground cover, trampling and fouling, soil compaction, increased or accelerated erosion, loss of vegetation as a result of selective grazing or browsing, increased species rarity as a result of excessive grazing/browsing, bush encroachment, weed invasion and damage to nesting birds and other wildlife. These phenomena are responsible for the low conservation status of some community habitat groups (e.g. 61, 95, and 62; Table 1), and are essentially due to:

1. Overgrazing, as livestock food requirements exceed the productive capacity of the grazing land
2. A poor distribution of livestock, with overutilisation of some areas of the sites and over-resting of others

Conversely, positive effects on biodiversity have been observed in those sites characterised by positive and, in many cases, neutral influence of grazing. For instance, moderate levels of grazing have been found important for increasing fertility soils and promoting species richness at the local scale as well as vegetation cover, which contributes to protecting the soil from erosion. Moreover, grazing at a low stocking rate was also important for controlling the succession of scrub into woodland. Besides, in some lightly grazed patches of grasslands, grazing resulted in higher plant species diversity with many precious floristic elements flowering

Table 2 Distribution, extension and intensity of grazing on Basilicata's SCIs by site type

SCIs	Influence of grazing								
	Negative			Neutral			Positive		
	Distribution[a]	Extension[b]	Intensity[c]	Distribution[a]	Extension[b]	Intensity[c]	Distribution[a]	Extension[b]	Intensity[c]
ME	50.00	52.21	2.21	77.78	44.43	1.64	50.00	30.67	1.67
HP	28.57	31.13	2.38	11.11	20.00	1.50	0.00	–	–
CS	21.43	30.00	1.67	11.11	33.50	1.50	50.00	16.67	1.67

[a]Percentage distribution of cases of grazing's influence by site type
[b]Mean percentage extension of sites' areas where grazing exerted its influence
[c]Average value of the intensity of grazing's influence on the integrity of the sites
– Not present

(e.g. *Anacamptis morio*, *Orchis italica*, etc.), thus confirming that grazing is very important for the conservation of orchids (Pihl et al. 2001).

Reducing negative grazing's impacts is a major need to maintain and enhance these examples of biodiversity within Basilicata's sites. This can be achieved by determining thresholds for optimum herbage utilisation and land resource conservation and, hence, by developing and encouraging the adoption of appropriate grazing management practices. In the following pages, we present the detrimental effects of grazing on a site and delineate the directions of future changes for assuring a sustainable conservation of the site.

6 A Focus on Grazing Impacts on a Basilicata's Site

The SCI Valle Basento Grassano Scalo-Grottole (IT9220260) is situated in the centre (longitude: 16°14´37´´; latitude: 40°35´53´´) of Basilicata and extends for 882 ha into four municipalities (Calciano, Garaguso, Grassano and Grottole) of the Province of Matera. With an altitude ranging between 172 and 309 m above sea level, the site represents a stretch of the Basento river, one of the five rivers which cross the regional territory.

Several aspects make this site a territory of huge natural interest. A particular feature is the presence of ravines, characterised by gorges with vertical walls and originated from clayey ground. The vegetation along the river comprises a riparian forest, whose arboreal and shrubby hygrophilous elements are associated with grassy steppe elements. Thanks to its geomorphological and microclimatic conditions, the site hosts 94 animal species of the Nature Directives: 88 birds, 3 fishes, 1 mammal species and 2 reptiles declared 'endangered' and put under protection status through EU Directives 79/409 and 92/43. Moreover, this area is one of the breeding sites of otters (*Lutra lutra*), birds of prey (e.g. *Ciconia nigra*, *Milvus migrans*, etc.) and endemic insect fauna.

The site protects seven habitat types of the Habitats Directive (Table 3), with one of them being a priority habitat: 6220*. A high proportion (>20 %) of the site is covered by the grasslands included in this habitat. In general, its occurrence is related to extensive grazing (sheep and cow), though its pastoral interest is low (San Miguel 2008). The second largest habitat is the habitat 92A0 (*Salix alba* and *Populus alba* galleries), accounting for 148.18 ha (16.80 % of the whole site extension). The smallest habitat is 3250 (constantly flowing Mediterranean rivers with *Glaucium flavum*) with only 1.76 ha (Table 3).

Overall, the community habitats cover an area of 521.27 ha (>59 % of the whole site territory), and the priority habitat alone accounts for >34 % of the total area of the community habitats. The Natura 2000 Standard Data Form of the site shows that, in most cases, the degree of conservation of the structure and functions of the community habitats has been classified as 'average', meaning that their conditions should be monitored, albeit they are not so severely damaged. Conversely, the

Table 3 Main characteristics of the habitat types present on the site

Habitat		Habitat assessment			
Type	Cover (ha)	Representativity[a]	Surface[b]	Conservation[c]	Assessment[d]
1430—Halo-nitrophilous scrubs (*Pegano-Salsoletea*)	3.53	A	C	B	B
3250—Constantly flowing Mediterranean rivers with *Glaucium flavum*	1.76	A	C	B	B
3280—Constantly flowing Mediterranean rivers with *Paspalo-Agrostidion* species and hanging curtains of *Salix* and *Populus alba*	71.44	A	C	B	B
5330—Thermo-Mediterranean and pre-desert scrub	112.90	B	C	B	B
6220—Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	179.93	A	C	B	B
92A0—*Salix alba* and *Populus alba* galleries	148.18	B	C	C	B
92D0—Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)	3.53	B	C	C	C
Total	521.27	–	–	–	–

[a]The degree of representativity of the natural habitat type on the site can be excellent (A), good (B) or significant (C)
[b]The area of the site covered by the natural habitat type in relation to the total area covered by that natural habitat type within the national territory can be classified as follows: A (15.1–100 %), B (2.1–15 %) and C (0–2 %)
[c]The degree of conservation of the structure and functions of the natural habitat type can be excellent (A), good (B) or average or reduced (C)
[d]The global assessment of the value of the site for conservation of the natural habitat type can be excellent (A), good (B) or significant (C)

conditions of the habitats representing the vegetation along the river (i.e. 92A0 and 92D0) are a matter of high concern, as their conservation status is ‘reduced’.

According to the Natura 2000 Standard Data Form, there are three main activities influencing negatively the conservation status of the site: grazing (code: 140),

Fig. 2 Cattle grazing on a floodplain of the Basento river

cultivation (code: 100) and leisure fishing (code: 220). Whereas cultivation and leisure fishing have been identified as 'external' activities, grazing has been listed as the only one activity exerting its negative influence within the site (Fig. 2). Therefore, to restore, maintain and preserve the integrity of the site, it is essential to explore the reasons behind the impacts of grazing on the habitats of the sites.

6.1 *Application of DPSIR Framework to Analyse Grazing Impact Within the Site*

Nowadays, the need to make the economic growth and development compatible with preservation of natural resources and the environment cannot prescind from the adoption of strategies enabling the parallel assessment of socio-economic and environmental parameters. This goal can be achieved by using the DPSIR framework (EEA 1999). In recent years, this framework has become widely adopted by the majority of the European Community nations, as it is the best way to structure environmental information concerning specific environmental problems and to reveal existing causes, consequences, effective responses and trends and the dynamic relationships between these components (Pillman 2002). This is possible thanks to the definition of policy-relevant indicators (i.e. sets of physical, biological or chemical variables) in order to describe (1) the driving forces, (2) the resulting environmental pressures, (3) the state of the environment, (4) the impacts resulting from environmental changes and (5) the possible societal response.

The application of this framework allows the identification of the driving forces (e.g. industry, transport, tourism, agriculture, etc.) that produce pressures on the environment (e.g. pollution, soil excavation, climate change, etc.), which then degrade the state of the environment, which then impacts on ecosystems and human health, causing society to respond with various policy measures (e.g. regulations, information and taxes), which can be directed at any other part of the system.

In the following sections, we describe the application of DPSIR framework to assess the impacts of grazing on the habitats of the SCI Valle Basento Grassano Scalo-Grottole. The components in the DPSIR framework were defined as follows.

Driving forces Only three farms are situated within the site (Fig. 2). Most of the animals (369 on 375) owned by these farms are sheep (308) and goats (61) reared under semi-extensive rearing conditions (Table 4). This means that grazing is usually limited: its duration is variable and is about 4–6 h per day, usually in the late morning or evening. The animals are then housed and given some forages, crop residues or concentrates.

Overall, these animals do not pose a real threat to the habitats of the site. However, as the protected area is not fenced, the natural resources of the site are important sources of forage also for grazing livestock from farms situated in the surroundings of the site. Indeed, the site is also attractive to livestock for the presence of Basento river, which represents the only available water source to drink in the area.

Therefore, to assess the impacts of these farms on the habitats of the site, we used a geographic information system to create different buffer zones of 500-m radius around the site and recorded all those farms situated within a distance of 2.5 km from the boundaries of the site. As can be seen in Fig. 3, there are many farms in the surroundings of the site, which may explain the impacts on the habitats of the site. To better asses this phenomenon, we analysed the main characteristics (i.e. rearing system, species and their consistence) of all the farms located within two different buffer zones (with radii of 500 and 1,000 m) around the site. We restricted the analysis to a distance of 1 km because the farms located within this distance are more likely to be responsible for the conservation status of the habitats. However, this restriction does not exclude the possibility that livestock reared under semi-extensive or extensive conditions from farms located at a greater distance may also graze on the site.

As shown in Fig. 3, four farms are located within the 500-m buffer zone. In these farms, there are, under semi-extensive conditions, 113 cattle, 398 sheep, 45 goats and 6 horses (Table 4). A total of 1,022 animals are reared in the three farms located within the 1,000-m buffer zone (Fig. 3; Table 4). However, the semi-extensive rearing system is adopted only by one farm, which raises 115 animals (45 cattle, 7 sheep, 4 goats and 59 horses).

Pressures Our inspections showed that the livestock reared under semi-extensive or extensive conditions are among the main pressures in the site, as the animals

Table 4 Livestock population within and in the surroundings of the site

Rearing system	Domestic species	Distance from boundaries of the site (m)			Total animals
		0	500	1,000	
Semi-extensive or extensive	Cattle	0	113	45	158
	Sheep	308	398	7	713
	Goats	61	45	4	110
	Pigs	0	0	0	0
	Horses	0	6	59	65
	Total	369	562	115	1,046
Intensive	Cattle	6	137	7	150
	Sheep	0	0	0	0
	Goats	0	0	0	0
	Pigs	0	0	900	900
	Horses	0	0	0	0
	Total	6	137	907	1,050

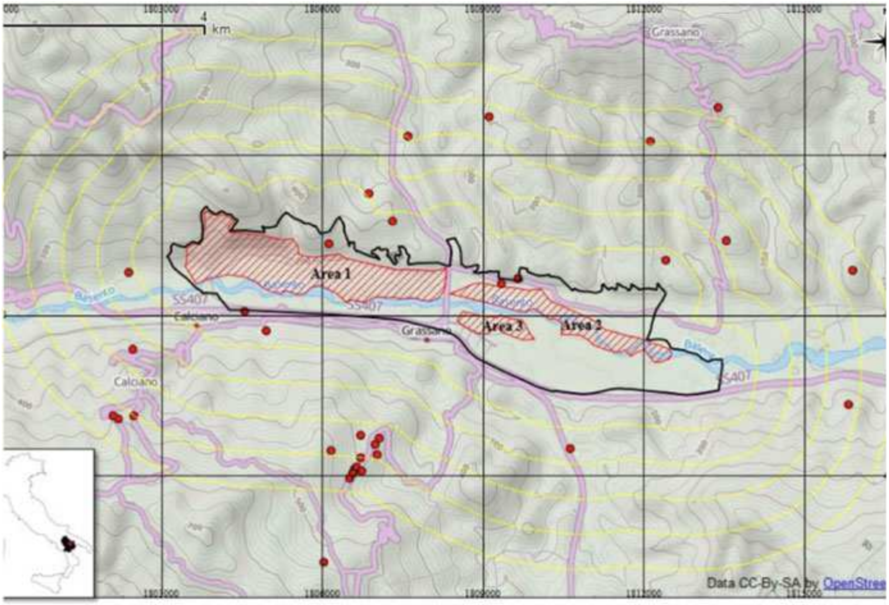

Fig. 3 Map showing the farms (*points*) located within (*black solid line*) and in the surroundings of the site. *Lighter lines* represent buffer zones of 500-m radius around the site. Polygons filled with *diagonal stripes* indicate the areas where the negative effects of grazing were mainly observed

exert a significant impact on its vegetation. The key factors responsible for grazing land degradation are essentially:

1. Excessive animal density

2. Lack of rotation
3. Grazing at inappropriate times relative to the flora productivity cycle

Grazing is often 'uncontrolled', with Podolian cattle usually grazing all the year round, whereas small ruminants are grazing for a fraction of the day. Moreover, cattle, sheep, goats and horses often graze together on most of the grasslands and other habitats of the site. According to the European Corine Land Cover classification, the extent of the available surface for grazing is 464.70 ha (52 % of the whole site extension). Considering this surface and the number of grazing animals from farms located in the surrounding of the site (<1,000 m), the grazing pressure (number of grazing animals per ha of grazing surface) is 0.65 livestock units (LU) per ha. Indeed, this density value may be undervalued: as stated before, the grazing animals from farms located at a distance greater than 1,000 m were excluded from our analysis, although they may reach the site to graze and drink.

State The pressure exerted by grazing produced many negative effects on the state of the site, such as deterioration of vegetation cover, change in state of threatened species and endemic species, soil degradation, etc. This is particularly evident in the three main areas (Fig. 3), which together account for 46.96 % (414.22 ha on 882 ha) of the total surface of the site and 89.14 % of the total grazing surface (414.22 ha on 464.70 ha). By combining the current vegetation biomass available for grazing, its nutritional value and the nutritional requirements of livestock, the grazing capacity of these areas should not exceed 0.25 LU ha^{-1} year^{-1}. In the remaining part of the site, grazing does not produce negative effects. However, the grazing capacity in these areas should prudently remain at moderate levels for habitat conservation (i.e. 0.35 LU ha^{-1} year^{-1}). These proposed values for this site are consistent with those for year-round grazing reported in literature (Piek 1998; Putfarken et al. 2008).

Impacts In the three main areas of the site (Fig. 3), the conservation status of much of the vegetation is very poor as a consequence of selective grazing. In many parts of these areas, selective grazing leads to a homogenisation or trivialisation of the floristic composition. Under uncontrolled grazing, in fact, livestock tend to repeatedly graze the most palatable species leaving behind the less or non-desirable species such as *Eryngium campestris*, *Ononis spinosa*, *Silybum marianum*, *Onopordum acanthium* and *Asphodelus microcarpus*.

The productivity and biodiversity of these areas are also affected by fouling: faeces and urine caused some patches of these areas to be unattractive to livestock. In other parts, we observed the destruction of much of the herbaceous vegetation as livestock compacted soil by trampling it, making paths and tracks, or repeatedly congregating in the same areas. Among them, some riparian zones within the area 1 (Fig. 3) were very crowded especially in hot weather as livestock congregate along the Basento river to graze and drink. They overgrazed and trampled riverside plants, leaving bare banks and depositing manure and urine in concentrated areas around riparian areas or directly into the river. In these areas, soil compaction by trampling also reduced water infiltration and increased surface run-off and erosion.

Moreover, in some points, livestock trampled and break down riverbanks through the pressure exerted by the hooves. The reduction (and, in many cases, the destruction) of vegetation by trampling was also observed on the slopes, where soil erosion and sediment transport were increased by the reduction of both the interception of rainfall by plants and the resistance to run-off created by the plants themselves.

Overgrazing is also detrimental to the wild fauna of the site. For instance, some grasslands of the areas 1 and 2 (Fig. 3) belong to the habitat 6220*, which is considered the ideal habitat for many threatened or rare bird species (San Miguel 2008). However, changes in its vegetation structure and species composition associated with uncontrolled grazing are the most likely cause for some breeding failures. It has been reported that grazing alters habitat structure and thus the suitability of the sward for nesting and feeding birds (Vickery et al. 2001). This has probably led to a decline of some birds such as stone curlew (*Burhinus oedicnemus*) in the grasslands of the site.

Responses To tackle the identified pressures and minimise their impacts on the site, the responses (measures) to be developed should be effective in restoring or maintaining the habitats and wildlife that have been disturbed by overgrazing. Therefore, the measures should aim at promoting a rational use of existing vegetation resources for grazing. To achieve this goal is fundamental the introduction of regulating grazing: the farmers who want to use the vegetation resources of the site have to evaluate the nutritional needs of livestock, assess forage quality and quantity, regulate the acreage of access and control which parts of the pasture/range that the animals have access to. By controlling livestock density and through appropriate rotation periods, farmers can improve the forage production, while still being beneficial to the land.

In this context, the introduction of some management facilities is important. Permanent and/or temporary fences may be used to keep livestock from particular areas at specific times of the year or to exclude it from vulnerable areas such as the riparian zones. Fencing off these areas of the site as a vegetative buffer is perhaps the only way to limit livestock river access and protect riverbanks from hoof traffic or overgrazing. The exclusion of livestock from riparian zones makes essential to consider the introduction of drinking troughs in different areas of the site, where water may be pumped from near or far sources by the use of solar-powered pumps. According to Putfarken et al. (2008), the placement of such management facilities should be carefully considered when different herbivore species are kept on the same pastures as they guarantee that all habitats are grazed and thus are kept in a management status favourable to conservation.

An improvement of grazing management may also be achieved by introducing alternating grazing between different species of livestock into the habitats of the site, since they differ in diet preferences, terrain use and their potential to influence vegetation development (Walker 1994; Bakker 1998; Rook et al. 2004). As a general rule, cattle should be used to graze off tall late season grasslands initially, to be followed by sheep or horses once the grassland height has been reduced to a level that these other grazers can cope with more effectively. The adoption of an alternate grazing system does not necessarily imply the cessation of the year-round grazing system adopted for the Podolian cattle, but rather a rethinking of its role as a tool to maintain or to create highly diverse ecosystems involving minimal livestock care. Moreover, at low densities, a year-round grazing system comprising both cattle and sheep appears to be suitable for the conservation of diverse pasture landscapes, since both species have complementary feeding preferences, and these also show seasonal changes (Putfarken et al. 2008).

A better management of the different grazing behaviours of cattle, sheep, goats and horses found in the site may lead to the consumption of different species and parts of plants, resulting not only in a better utilisation of grazing resources (Frame 1992; Rinehart 2006) but also in a substantial improvement of biodiversity of flora and fauna (Bakker 1998; Osoro et al. 1999; Evans et al. 2006). It has been reported that the 'multispecies grazing' at low stocking rates may both increase the structural and compositional variation of the vegetation and help to control the encroachment of woody species (Bakker 1998). According to Osoro et al. (1999), the management of mixed flocks of goats with other livestock under moderate grazing pressure may contribute to the diversification of the production and to enhance animal performance of other domestic herbivores, landscape biodiversity by reducing fire risk and the economic conditions in marginal areas. Moreover, it has also been reported that, on condition that stocking rates are low, the abundance of some bird species may be enhanced in areas that have seen significant shifts from mixed livestock grazing to grazing dominated by single species of animals (Evans et al. 2006).

7 Conclusion

Achieving conservation objectives within Natura 2000 sites may represent a big challenge, since protection cannot be accomplished simply through a suite of measures aimed at restricting and/or forbidding the use of the available resources, as it happens in other protected or conservation areas.

As stated before, the idea underpinning the creation of the Natura 2000 network is that certain human activities inside a site should be performed in order to contribute to the biodiversity conservation. Obviously, this implies an understanding of the relationships between anthropogenic disturbance regimes and biodiversity, thus allowing the adoption of targeted protection policies aimed at avoiding the most negative impacts and enhancing the positive interactions among activities.

Concerning grazing, in this paper we focus on the main impacts of this traditional activity on the integrity of Basilicata's sites and provide recommendations for improving its management and ensuring biodiversity conservation. However, this translates not only into the proposition of corrective measures, but it also requires an active stakeholder participation, as farmers or other individuals who are potentially affected by the measures need to be involved and contribute to the setting of priorities and objectives of the management plans of the sites.

Therefore, managing grazing activities in the sites presents a challenge in terms of devising policies that are compatible with the ecological integrity mandate and that are acceptable to stakeholders. This means that the establishment of the Natura 2000 network has, above all, to contribute to the forging of a culture promoting the concept of 'natural heritage', in order to value, utilise and conserve the available resources in Basilicata appropriately for the benefit of all, present and future.

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Evaluation of Native Grasses for Sustainable Turfgrass in the Bioclimatic Mediterranean Region

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Abstract This study reports the results of a research project (*Mi.T.E.A.Med*) funded by the Italian Ministry of Agriculture. The research was organised in two phases: the first one involved the screening of the study area (Southern Italy) to find suitable turfgrass species and the second one focused on ex situ cultivation to test the ecotypes with salinity resistance. During the first step of the research, 11 sites from 6 regions of Southern and Central Italy were identified. In these sites, 24 ecotypes of *Cynodon dactylon* (L.) Pers. were collected and their habitus, phenology, and some biometric parameters have been determined. During the 2 years of research, both botanic and agronomic characterisation of the collected *C. dactylon* ecotypes was carried out. Some native accessions showed a behaviour similar to commercial cultivars, while an ecotype from the Abruzzo Region showed better results compared to the commercial cultivars for several quality indices. The results of this project showed that Mediterranean-adapted native grass species (e.g. *Cynodon dactylon* (L.) Pers.) are worth investigating for turfgrass, making for their performance and low resource requirement (especially water). This species can be used as promising alternatives to conventional non-native turfgrasses.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_19

1 Introduction

The production and planting of turfgrasses is a fast-developing business with a growing demand for easy-to-use materials that usually involves the use of non-native species. Unfortunately, most of these species are invasive that may pose a threat to the biodiversity conservation of natural ecosystems (Celesti-Grapow et al. 2009)

Furthermore, the low adaptability of foreign varieties to the prevailing pedo-climatic conditions in Italy (Panella 1980, 1981; Veronesi and Panella 1985) prompted the beginning of a research programme to detect suitable native grass species for turfgrass uses. Unlike forage varieties, those considered for turfgrass should have limited growth thin leaves, ability to recover rapidly after thinning and resistance to trampling.

In Italy the most interesting turf species are grasses belonging to the subfamilies Festucoideae and Eragrostideae. The former are also defined as 'cool-season grasses' because of their preferential adaptation to cool and moist environments. The target species for turf uses in this subfamily are Kentucky bluegrass (*Poa pratensis* L.) characterised by a strong rhizomatous habitus and adapted to form long-lasting turfs of intermediate texture; perennial ryegrass (*Lolium perenne* L.) for fast-grown establishment; creeping red fescue (*Festuca rubra* L. subsp. *rubra*) and chewings fescue (*Festuca rubra* L. subsp. *commutata* Gaudin.), which are both with fine texture and rather tolerant to shading (the former has a rhizomatous habitus and is suited to sport lawns, the latter is tufted and less tolerant to trampling); tall fescue (*Festuca arundinacea* Schreb.), which has a rough texture but good tolerance to turf wearing; and creeping bentgrass (*Agrostis stolonifera* L.), characterised by the finest leaf texture and suited to high-quality turfs (Veronesi and Panella 1985). In Italy, the utilisation limit for all these species is represented by summer heat and drought stresses that typically affect the Mediterranean areas (Volterrani et al. 1997; Russi 2004; Annicchiarico and Russi 2005; Marchione 2004, 2008).

On the contrary, species of Eragrostideae subfamily are defined as 'warm-season grasses', being characterised by good growing ability under high temperatures and by vegetative standstill with low temperatures (Volterrani et al. 1997).

In particular, Bermuda grass (*Cynodon dactylon* (L.) Pers.) is the most rising species for turf establishment in the Mediterranean coastal and southern environments of Italy, where the climatic conditions are not suitable to cool-season grasses.

In Italy, many turfgrasses species have been introduced from foreign countries, but they showed a low adaptability to the prevailing Mediterranean climatic conditions (Panella 1980; Veronesi and Panella 1985). In fact, the plants come almost exclusively from environments different from those of the Mediterranean and the unsatisfactory performance is mainly due to the high susceptibility to summer stress and reduced growth in winter.

In this context, the availability of genetic material tolerant to summer drought and salinity has become a strong need for the sector of turfgrasses in the

Mediterranean area, especially following the spreading of turfgrass landscapes in arid and seashore areas.

The indigenous grass species are an important source of genetic variability that can provide better performance in terms of tolerance to salinity. In fact, some recent studies revealed that indigenous grass species display high phenotypic variability (Potenza et al. 2014).

Herein we provide the main results of the Mi.T.E.A.Med research project (improved turfgrass in Mediterranean environment: use of autochthonous species of plant and optimisation techniques) funded by the Italian Ministry of Agriculture.

This study was carried out on several native populations of Bermuda grass (*Cynodon dactylon* (L.) Pers.) that were evaluated for turf characteristics with the aim of selecting the most promising ecotypes in terms of lower water requirements and tolerance to salinity.

2 Materials and Method

The research was organised in two phases: the first one involved the screening of the study area flora (Central and South Italy) to find suitable turfgrass species characteristics for the Mediterranean bioclimate, while the second one focused on ex situ cultivation to test the ecotypes with salinity resistance.

The collection was carried out during summer 2011 and winter 2012. Samples of several macrotherm native species were collected in coastal and hilly, especially on sandy substrates dry and/or salty. Consequently to a preliminary screening, we selected for the detailed investigation only native populations of *C. dactylon* sampled in 11 sites (Fig. 1) distributed across 6 administrative regions in three distinct areas: the centre (regions of Lazio and Abruzzo), the south-west (regions of Basilicata, Calabria, Campania) and the south-east of Italy (Table 1).

The average annual temperatures of the collection sites ranged from 14 to 18 °C with annual rainfall of less than 600 mm received predominantly in the autumn and winter (Biondi and Baldoni 1995). Altitude of the collection sites ranged from 0 to 400 m a.s.l.

Every specimen was sampled from each location following the approach suggested by Romani et al. (2002) by walking on a transect. Whole plants (including roots embedded in soil) at the vegetative stage were collected every 2–5 m along the transect. A total of 24 samples of *Cynodon dactylon* were collected across the 10 sites.

Stolon fragments were transplanted into plastic pots in open field at Potenza (40°38′N; 15°48′E; 728 m a.s.l.), Southern Italy. The 450 cm^3 plastic pots were filled with 300 cm^3 of a specially formulated substrate for turf (Compo Sana 'Terriccio per tappeti erbosi', COMPO Agro Specialities—private society in Italy).

Each plant received 500 ml of water every 3 days. Morphological variables were measured both in situ and ex situ during the growing season (May–October 2012). Successively, plant samples were vegetatively multiplicated by transplanting stolon

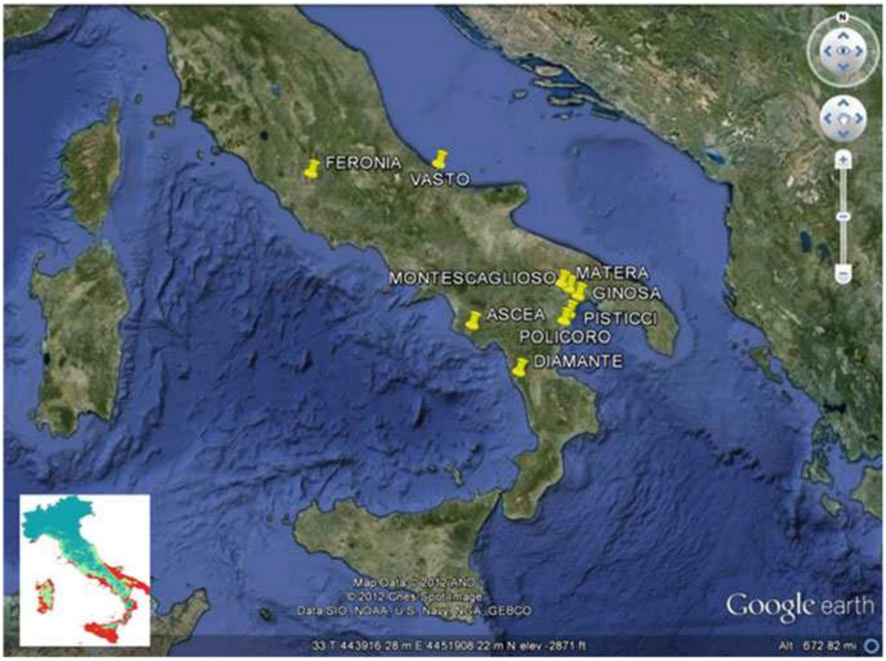

Fig. 1 Collected sites in the bioclimatic Mediterranean region

fragments into plastic pots in a cold greenhouse at Pantanello farm (+40°23′N, +16°47′E; 8 m a.s.l.), Metaponto. When vegetative material was enough, field plots were established at 'Lucana Prati' sod farm (+40°22′N, +16°47′E; 6 m a.s.l.), Metaponto (Fig. 2).

The soil of the experimental area was clay textured (64 % clay, 17 % silt and 19 % sand), with good total nitrogen (1.1 ‰) and available phosphorus (25 ppm) and rich in exchangeable potassium (350 ppm). The 24 samples of Bermuda grass were compared in a randomised complete block design with three replications. Plot surface area was 2.25 m^2 (1.5 m × 1.5 m).

Between the first and the second year (December 2012–March 2013), the colour loss interval was determined by calculating the duration (d) of vegetative stasis on the basis of **colour and ground cover** of each turf plot.

During the second year, from May to September 2013, the following data were recorded: **Growth rate**: it is measured by a turfmeter as weekly vertical growth of turfs maintained at 45 mm cutting height by a rotary mower. **Colour index**: it represents the intensity of the green colour, and it is influenced by genetic characteristics of the species, environmental stress (water and/or thermal stress), nutritional deficiencies and parasitic attacks. This parameter has been monthly measured using a Turf 500 NDVI-Turf Color Meter (Spectrum Technology, Aurora, USA) that measures the reflected light in the spectral bands of red (600 nm) and infrared (850 nm) which correlate with the concentration of chlorophyll pigments in the

Table 1 List of sample sites for *Cynodon dactylon* collection

Samples	Location	Altitude (m a.s.l.)	Latitude (UTM)	Longitude (UTM)
1	Massafra (TA)	30	677949	4492375
2	Vasto (CH)	5	478443	4661223
3	Vasto (CH)	5	478443	4661223
4	Vasto (CH)	5	478443	4661223
5	Vasto (CH)	5	478443	4661223
6	Vasto (CH)	5	478443	4661223
7	Pisticci (MT)	43	634308	4476229
8	Pisticci (MT)	167	631894	4470852
9	Pisticci (MT)	6	651327	4462126
10	Ginosa (TA)	5	666275	4484012
11	Ginosa (TA)	5	666275	4484012
12	Ginosa (TA)	5	666275	4484012
13	Montescaglioso (MT)	302	650379	4491214
14	Feronia (RM)	408	301916	4668620
15	Diamante (CS)	0	578877	4376962
16	Conversano (BA)	100	678146	4537292
17	Conversano (BA)	105	678146	4537292
18	Matera (MT)	268	640701	4501305
19	Metaponto (MT)	72	654410	440640
20	Ascea (SA)	5	515761	4438447
21	Ascea (SA)	5	515761	4438447
22	Ascea (SA)	5	515761	4438447
23	Ascea (SA)	5	515761	4438447
24	Ascea (SA)	5	515761	4438447

leaves. From the measurement of NDVI, a colour index on a scale from 1 (= brown) to 9 (= dark green) can be calculated. **Turf quality**, a synthetic index evaluated by visual observations: it is influenced by the uniformity, density, turf colour, leaf texture, percentage of coverage and presence of weeds and insect and disease damage. It varies from 1 (poorest quality) to 9 (highest quality—ideal turf). Ground cover percentage (GCP): it is an assessment of the ground cover of the plot; this index was evaluated monthly by visual estimation.

Contemporary, stolon fragments were transplanted in honeycombed styrofoam containers filled with a small quantity of peat (Fig. 3). These containers were placed over plastic containers containing 15 L of aerated Hoagland nutrient solution ($EC = 2.5$ dS m^{-1}; $pH = 6.0$) formulated with tap water (Hoagland and Arnon 1950). Solution contained the following nutrients as mmol L^{-1}: NO_3^- 13.5, NH_4 1.5, PO_4^{3-} 1.0, K^+ 6.0, Ca^{2+} 5, Mg^{2+} 2.0 and SO_4^{2-} 2.0. Styrofoam containers were subemerged to the soil surface in the solutions. Loss of nutrient solution was compensated by a weekly substitution. Nutrient solution pH was daily adjusted to get 6.5–7.0; it was constantly aerated and maintained at a constant volume. An automated heating system started working each time air temperature dropped under

Fig. 2 Field plots established at 'Lucana Prati' sod farm (+40°22′N, +16°47′E; 6 m a.s.l.), Metaponto

18 °C, while the greenhouse roof opened as soon as the temperature exceeded 25 ° C. An automatic weather station was placed in the greenhouse in order to measure meteorological data.

After 10 days of establishment and turf adjustment in the greenhouse, a salt treatment was imposed. Plants were subjected to one level of salt stress, 15 dS m^{-1}, corresponding to 150 mM NaCl through NaCl addition (commercial salt). There was a control treatment maintained at a 2.2 dS m^{-1} salt level. Each experimental treatment was replicated three times arranging the pots according to a randomised block factorial scheme. In each pot, there were three plants for a total of nine plants per experimental treatment. In order to avoid osmotic shock to plants, NaCl addition to the nutrient solution occurred gradually.

Growth measurements were carried out during the experiment, the following morphological parameters were measured biweekly with a digital calliper: leaf length (l), leaf width (L) and distance between internodes of the latest fully expanded leaf (i) with five measurements per characteristic plant. Measurements were taken at a regular interval of 14 days. After 60 days, plants were harvested: dry matter and leaf number were obtained and counted, respectively. Total dry matter (hypogeous and epigeous) was obtained drying the samples in a ventilated oven at 75 °C until constant weight. Leaf area was measured at the end of the experiment trial, by a surface electronic detector (Model 3100, Li-Cor, Inc., Lincoln, NE, USA).

At the end of the experiment, Na^+ and Cl^- ion concentration of leaf tissue was measured. Samples were oven dried at 70 °C and finely ground. A subsample of leaves from each of the two treatments was dried, ground and extracted in HNO_3

Fig. 3 Honeycombed styrofoam containers filled with a small quantity of peat of aerated Hoagland nutrient solution

(65 % v/v) to measure Na^+ concentrations on leaf extracts using a flame spectrophotometer (Flame Spectrophotometer, Varian 220 FS). Another subsample was ashed at 60 °C for one night, and subsamples of dry matter were used for extraction of Cl^-, using a carbonate and sodium bicarbonate solution. Cl^- was measured by a titration with silver nitrate solution.

2.1 Statistical Analysis

All data were analysed with ANOVA procedure and means were compared with Duncan's test, using SigmaPlot 11.0 for Windows (Systat Software Inc., San Jose, CA, USA). Significant differences were identified by Tukey's test with 5 % and 1 % significance. Afterwards, to assess the different patterns in behaviour of the ecotypes in response to aesthetic and agronomic characteristics, cluster analysis was performed with the procedure CLUST using Ward's method (Ward J. 1963) of significantly affected parameters (monthly growth, *colour index, aesthetic general appearance (AGA), green cover percentage, interval loss of green colour).* In addition all salinity data were subjected to a cluster analysis (CA) using Ward's method (Ward J. 1963). These analyses were performed using Statistica V.10 (StatSoft Inc., USA).

3 Results and Discussion

The results of the agronomic behaviour carried out in 2012 and 2013, of the 24 native ecotypes of *C. dactylon*, are shown in Tables 2, 3, 4 and 5.

Table 2 Monthly and cumulative growth of ecotypes collected in Central and Southern Italy

Samples	Monthly assessed growth (mm)										Cumulative	
	May		June		July		August		September			
1	44	d	62	hi	49	d	42	bc	33	ef	230	c
2	28	hi	34	o	24	mn	21	h	27	h	135	p
3	26	ij	44	l	25	lm	18	i	29	gh	142	n
4	18	mn	39	n	19	op	25	g	12	kl	114	r
5	32	fg	58	j	29	k	32	e	33	ef	184	i
6	22	kl	35	o	25	lm	28	f	35	ce	146	m
7	22	kl	39	n	46	e	40	c	27	h	174	j
8	31	fg	43	lm	29	k	41	bc	24	i	168	k
9	22	kl	30	p	16	q	15	jk	10	lm	94	t
10	12	o	36	o	21	no	12	l	20	j	101	s
11	24	jk	53	k	44	ef	40	c	26	h	188	h
12	5	p	12	q	17	pq	18	i	10	lm	63	v
13	25	j	63	gh	35	i	35	d	29	gh	188	h
14	38	e	72	bc	41	gh	48	a	27	h	226	d
15	30	gh	60	ij	28	kl	36	d	37	c	192	g
16	17	n	35	o	30	jk	24	gh	10	lm	116	q
17	24	jk	41	mn	29	k	29	f	13	k	137	o
18	19	mn	35	o	15	q	14	kl	9	m	92	u
19	20	lm	74	b	42	fg	42	bc	34	de	213	f
20	33	f	68	de	40	gh	41	bc	30	g	212	f
21	55	b	65	fg	33	ij	41	bc	36	cd	230	c
22	43	d	58	j	20	op	13	kl	24	i	158	l
23	63	a	137	a	59	a	49	a	50	a	359	a
24	36	e	69	d	52	c	29	f	27	h	213	f

Values not having any letter in common are significantly different at $P \leq 0.05$ (Duncan's test)

The accessions caused significant difference in each of the tested parameters when subjected to analysis of variance. For simplicity, the results for each parameter have been analysed separately.

The 'ecotypes' showed significant differences in each of the tested parameters when subjected to analysis of variance. For simplicity, the results for each parameter have been analysed separately.

3.1 Total Growth

The mean total growth during the period May–September was 170 mm (Table 2), with extreme variations observed between ecotype 12 (63 mm) and ecotype 23 (359 mm). A similar behaviour was also found by Marchione (2008) on 12 commercial varieties of Bermuda grass.

Table 3 Colour index and days of winter colour loss interval of ecotypes during the trial period (2012–2013)

Samples	May		June		July		August		September		Mean May–Sept (2013)		Winter colour loss interval (d)	
1	6.8	bd	6.7	ab	6.8	a	6.0	ce	6.0	de	6.5	ab	133	j
2	6.5	d	6.2	ef	6.3	be	6.1	bd	6.0	de	6.2	ce	146	f
3	7.0	ab	6.6	ac	6.4	bd	6.2	ac	6.1	cd	6.5	ab	125	k
4	7.0	ab	6.7	ab	6.3	be	5.5	hj	5.4	i	6.2	ce	146	f
5	6.7	cd	6.3	cf	5.9	fg	6.0	ce	5.8	fg	6.1	df	151	e
6	6.7	cd	6.3	cf	6.1	ef	6.3	ab	6.3	ab	6.3	bd	146	f
7	6.8	bd	6.2	ef	6.3	be	6.1	bd	6.1	cd	6.3	bd	143	g
8	6.8	bd	6.6	ad	6.2	de	5.6	gi	5.7	gh	6.2	ce	151	e
9	6.8	bd	6.1	fg	6.1	ef	5.8	eg	6.3	ab	6.2	ce	152	de
10	6.7	cd	6.3	cf	6.5	b	6.0	ce	6.3	ab	6.4	ac	146	f
11	6.8	bd	6.6	ad	6.4	bd	6.1	bd	6.2	bc	6.4	ac	138	i
12	6.2	e	5.9	g	5.6	h	5.7	fh	6.0	de	5.9	f	145	fg
13	6.7	cd	6.3	df	6.2	ce	6.1	bd	6.1	cd	6.3	bd	146	f
14	6.8	bd	6.7	ab	6.5	b	6.0	ce	6.2	bc	6.4	ac	157	c
15	6.9	ac	6.5	ad	6.3	be	6.4	a	6.2	bc	6.5	ab	138	i
16	6.7	cd	6.2	ef	6.2	ce	5.3	j	5.5	hi	6.0	ef	153	d
17	7.0	ab	6.2	ef	6.2	ce	5.6	gi	5.3	i	6.0	ef	166	b
18	6.8	bd	6.4	be	6.3	be	5.6	gi	5.8	eg	6.2	ce	173	a
19	6.7	cd	6.4	be	6.2	ce	5.8	eg	5.5	hi	6.1	df	141	h
20	6.9	ac	6.5	ad	6.5	b	5.9	df	6.2	bc	6.4	ac	133	j
21	6.8	bd	6.3	df	6.3	be	5.9	df	5.9	ef	6.2	ce	138	i
22	6.8	bd	6.3	df	5.8	gh	5.6	gi	5.9	ef	6.1	df	146	f
23	7.1	a	6.5	ad	5.7	gh	5.7	fh	5.8	eg	6.2	ce	138	i
24	6.8	bd	6.3	cf	6.1	ef	5.4	ij	5.7	fg	6.1	df	143	g

Values not having any letter in common are significantly different at $P \leq 0.05$ (Duncan's test)

The extreme variability observed among the accessions compared is due in part to the genotypic characteristics of each accession and in part to an attack of phytoplasma 'BGWL', which resulted in an arrest of the vegetation and the discolouration of the leaf blades especially for accessions 12, 18, 9, 10 and 16.

A prostrate growth habit lowered the values of the cumulative growth for the accessions 2, 3, 4 and 17; on the contrary, accessions that showed the greatest growth were 23 (359 mm) and 21, 1 and 14, all with values ranging around 230 mm.

Table 4 Turf quality of ecotypes during the trial period (2013)

Samples	May		June		July		August		September		Mean May–Sept (2013)	
1	6.01	cd	6.02	de	6.00	de	5.04	cd	5.04	c	5.08	d
2	4.09	k	4.08	lm	4.09	k	4.08	hi	4.07	gi	4.08	j
3	7.02	a	7.03	a	6.07	a	6.02	a	6.00	a	6.07	a
4	5.03	hi	5.04	hi	5.03	j	5.01	fg	5.00	de	5.02	gh
5	5.01	ik	4.06	mn	4.03	m	4.06	jk	4.07	fi	4.07	j
6	5.04	h	5.03	hj	5.00	k	5.02	ef	4.09	df	5.02	gh
7	4.09	k	5.02	ij	5.00	k	5.07	b	4.07	fi	5.01	hi
8	5.03	hj	5.01	jk	5.00	k	5.01	fg	5.00	de	5.01	hi
9	5.08	f	4.09	kl	4.02	m	4.04	kl	4.05	ij	4.08	j
10	6.01	cd	5.08	g	5.06	h	5.00	gh	5.00	de	5.05	ef
11	6.00	ce	5.09	fg	5.00	k	5.06	bc	5.01	d	5.05	ef
12	3.08	m	3.05	o	2.09	n	3.00	m	3.03	l	3.03	l
13	6.04	b	6.02	cd	6.01	cd	6.00	a	5.06	bc	6.01	c
14	6.01	cd	6.03	bd	6.02	c	5.06	bc	5.05	bc	5.09	d
15	5.08	ef	6.00	ef	5.07	g	5.06	bc	5.07	b	5.08	d
16	4.06	l	4.05	n	4.02	m	4.03	l	4.04	j	4.04	k
17	4.09	k	4.09	kl	4.06	l	4.07	ij	4.09	dg	4.08	j
18	5.00	jk	5.02	ij	4.09	k	4.08	hi	3.09	k	4.09	ij
19	5.05	gh	5.03	hj	5.03	ij	4.09	hi	4.08	eh	5.01	hi
20	6.01	cd	6.01	df	5.09	ef	5.05	cd	5.04	c	5.08	d
21	5.07	fg	5.08	g	5.08	fg	4.09	hi	5.00	de	5.04	fg
22	5.03	hj	4.09	kl	4.08	k	4.04	l	4.04	j	4.08	j
23	5.03	hj	5.04	hi	5.03	ij	4.09	hi	4.09	df	5.02	gh
24	5.08	df	5.05	h	5.05	hi	5.03	de	4.06	hi	5.04	fg
Mean	5.09		5.02		4.49		4.39		4.29		4.47	

Values not having any letter in common are significantly different at $P \leq 0.05$ (Duncan's test)

3.2 Colour Index

Data in Table 3 show for this characteristic a mean value above sufficiency and equal to 6.2.

From May to September 2013, ecotypes 1, 3 and 15 showed higher values; on average this index was equal to 6.5. In contrast accessions that showed the lowest value, equal to 6, were accessions 12, 16 and 17. These results are similar to those obtained in other researches who studied 40 accessions of native *C. dactylon* collected in Sicily (Southern Italy) in order to identify biotypes with good qualities for broadscale turf in the Mediterranean region (Leto et al. 2008).

Table 5 Ground cover percentage of ecotypes during the trial period (2013)

Samples	Monthly assessed ground cover (%)										Average	
	May		June		July		August		September		May–Sept (2013)	
1	77	fg	82	fi	82	bc	80	b	63	bd	77	d
2	68	ij	57	o	61	j	49	m	60	df	59	l
3	97	a	98	a	88	a	86	a	65	ac	87	a
4	78	ef	67	lm	69	gh	50	lm	51	ij	63	k
5	62	k	63	mn	59	j	56	ij	57	fh	59	l
6	67	j	69	l	64	ij	68	cf	58	eg	65	ij
7	68	ij	61	no	62	j	62	gh	62	ce	63	k
8	72	hi	71	kl	62	j	59	hi	58	eg	64	jk
9	72	hi	60	no	59	j	52	lm	52	ij	59	l
10	87	b	85	df	78	ce	64	fg	58	eg	75	e
11	77	fg	76	j	62	j	70	c	58	eg	69	h
12	22	m	22	p	18	k	19	n	28	k	22	n
13	97	a	94	ab	87	ab	78	b	67	ab	84	b
14	87	b	84	eg	86	ab	67	cf	57	fh	76	e
15	73	gh	78	ij	70	gh	68	ce	63	bd	71	g
16	48	l	63	mn	60	j	55	jk	50	j	55	m
17	73	gh	71	kl	67	hi	61	gh	58	eg	66	i
18	73	gh	75	jk	67	hi	53	kl	50	j	64	jk
19	83	bd	83	fh	77	df	66	df	56	fh	73	f
20	87	b	87	de	78	ce	69	ce	53	hj	75	e
21	79	df	80	gi	73	fg	61	gh	60	df	71	g
22	86	bc	85	df	73	fg	57	ij	55	gi	71	g
23	73	gh	78	hj	75	ef	65	ef	53	hj	69	h
24	82	ce	85	df	80	cd	61	gh	58	eg	73	f
Mean	74.5		73.92		69.04		61.5		56.25		67.08	

Values not having any letter in common are significantly different at $P \leq 0.05$ (Duncan's test)

3.3 *Turf Quality*

During the entire period of experimentation, ecotypes that showed the highest mean values were 3, 13 and 14, respectively, with 6.7 to 6.1 and 5.9; they also showed a good preservation of quality from May 2013 to September 2013. Accessions 12 and 16 were ranked at the lowest level, with values respectively equal to 3.3 and 4.4. These extremely low values were due partly to the genotypic characteristics of accession and to a considerable extent of phytoplasma BGWL attacks, which have widely affected the aesthetic quality of ecotypes. The lower values of these ecotypes have strongly influenced the mean of turf quality during the whole period and also for single months.

Table 6 Results of salinity measurements

Samples	LA	FW	DW	RDW	R/S	l_f	L_f	l_i	Na^+ (mg/g)	Cl^- (mg/g)
1n_s	523.33	24.33	5.9	0.25	0.04	52.68	3.67	65.11	2.98	6.53
2n_s	404.33	17	3.37	1.1	0.43	33.77	3.96	53.08	2.085	6.51
3n_s	1049.33	57.69	10.52	3.63	0.37	36.96	3.65	50.43	1.36	7.35
4n_s	135	11.15	2.33	1.06	0.95	39.24	3.82	63.49	1.83	10.945
5n_s	191	17.55	3.14	1.17	0.52	24.72	4.01	33.27	1.975	9.09
6n_s	166.67	12.88	3	0.91	0.35	24.65	3.56	47.05	1.985	7.115
7n_s	359	37.95	6.31	2.5	1.45	44.56	4.2	35.81	1.985	7.685
8n_s	330.67	31.63	6.07	1.84	0.33	35.78	4.58	51.64	2.735	10.16
9n_s	178.67	14.11	2.72	1.41	0.52	37.98	4.37	35.03	2.255	9.465
10n_s	264.33	26.24	5.1	3.51	0.7	47.32	4.44	48.77	1.08	8.39
11n_s	302	28.19	5.06	2.76	0.58	50.6	4.28	66.12	2.38	9.92
12n_s	204	16.07	2.82	1.79	0.68	37.27	3.84	48.44	1.65	12.56
13n_s	139	14.42	2.67	2.1	0.89	44.39	5.7	49.83	1.86	21.035
14n_s	155.67	12.94	2.24	1.04	0.66	49.84	5	53.27	2.13	8.13
15n_s	241.33	19.67	4.13	1.83	0.45	38.55	4.08	48.01	1.835	9.965
16n_s	289.33	28.3	4.61	1.54	0.38	47.18	3.76	84.19	1.31	15.235
17n_s	136	11.21	2.91	0.17	0.06	24.53	3.19	34.12	1.22	7.725
18n_s	140.67	11.91	2.18	1.56	0.72	26.99	2.88	30.77	1.33	10.205
19n_s	161.33	15.9	2.69	1.05	0.46	33.7	4.32	56.26	1.725	7.495
21n_s	173	13.6	2.83	1.82	0.82	44.87	5.28	65.32	1.82	7.425
22n_s	274.33	23.57	4.54	1.45	0.67	31.79	3.33	61.34	2.065	9.81
23n_s	251	21.17	4.02	1.67	0.64	38.03	3.59	72.4	1.57	8.935
24n_s	295	28.24	5.12	0.9	0.18	58.31	4.25	53.49	2	9.96

3.4 Green Cover Percentage

The coverage percentage showed a mean value generally equal to 67 %, in accordance with the findings of Volterrani et al. (1997) and Croce et al. (2001) in other Italian sites. Among the ecotypes compared, the one which showed the highest mean value was ecotype 3 (87 %); satisfactory values were also reported for accessions 13 and 1, with mean values equal to 84 and 77 %.

The lowest value was reached by genotype 12 (22 %). This anomalous value is partly imputable to the massive attack of BGWL, which continued during the entire period of the research.

The results of the experimental salinity carried out in 2013, of the 24 native ecotypes of *C. dactylon*, are shown in Table 6.

The salinity conditions have always had a depressing effect on all measured parameters (leaf area, dry weight, dry weight of roots, root/shoot ratio, etc.) as widely shown in Table 7.

Leaf area on average reduced to 296 cm^2 from 824 cm^2, while dry weight on average reduced to 4.5 from 8.1 g $plant^{-1}$. The significant effect of salinity conditions on all studied accessions and significant difference between accessions as regards the ability to support salts into the nutrient solutions were observed. The interaction effect on leaf area parameter was also significant. Root/shoot ratio on average increased as the effect of salinity conditions, as expected. It increased on average to 0.55 g g^{-1} from 0.33 g g^{-1}. On this parameter only salinity resulted in a significant effect. The dry weight percentage reduction of all studied accessions was also calculated.

3.4.1 Uptake of Na^+ and Cl^-

There was no significant difference between accessions as regards Cl^- uptake. As regards Na^+ leaf tissue concentration on average, it has increased respect to control, 12.0 mg g^{-1} and 1.2 mg g^{-1}, respectively. It was also observed that the ability to limit the accumulation of sodium ions into leaf tissue varies between the different compared accessions.

The dendrogram which is obtained from the cluster analysis is a graphical representation of the level of aggregation among the studied accessions (Fig. 4). It clearly shows that the group of accessions on the left is well separated from other groups in the right. The samples on the left showed a greater resistance to salinity. In particular accession 3 is the best ecotype about salinity stress. This ecotype could be considered in future research programmes.

Table 7 Depressing effect of salinity on all measured parameters

Samples	LA	FW	DW	RDW	R/S	l_f	L_f	l_i	Na^+ (mg/g)	Cl^- (mg/g)
1s	523.33	24.33	5.9	0.25	0.04	52.68	3.67	65.11	16.99	27.1
2s	404.33	17	3.37	1.1	0.43	33.77	3.96	53.08	11.88	14.4
3s	1049.33	57.69	10.52	3.63	0.37	36.96	3.65	50.43	9.13	23.95
4s	135	11.15	2.33	1.06	0.95	39.24	3.82	63.49	10.97	21.6
5s	191	17.55	3.14	1.17	0.52	24.72	4.01	33.27	8.785	17.5
6s	166.67	12.88	3	0.91	0.35	24.65	3.56	47.05	9.06	29.7
7s	359	37.95	6.31	2.5	1.45	44.56	4.2	35.81	6.11	18
8s	330.67	31.63	6.07	1.84	0.33	35.78	4.58	51.64	15.475	24.65
9s	178.67	14.11	2.72	1.41	0.52	37.98	4.37	35.03	30.3	43.65
11s	302	28.19	5.06	2.76	0.58	50.6	4.28	66.12	14.15	17.3
12s	204	16.07	2.82	1.79	0.68	37.27	3.84	48.44	18.405	33.55
13s	139	14.42	2.67	2.1	0.89	44.39	5.7	49.83	16.215	22.9
14s	155.67	12.94	2.24	1.04	0.66	49.84	5	53.27	21.18	32.85
15s	241.33	19.67	4.13	1.83	0.45	38.55	4.08	48.01	12.915	22.75
16s	289.33	28.3	4.61	1.54	0.38	47.18	3.76	84.19	11.44	23.25
17s	136	11.21	2.91	0.17	0.06	24.53	3.19	34.12	11.08	30.95
18s	140.67	11.91	2.18	1.56	0.72	26.99	2.88	30.77	9.075	34.1
19s	161.33	15.9	2.69	1.05	0.46	33.7	4.32	56.26	6.75	17.95
21s	173	13.6	2.83	1.82	0.82	44.87	5.28	65.32	7.41	17.75
22s	274.33	23.57	4.54	1.45	0.67	31.79	3.33	61.34	5.1	21.7
23s	251	21.17	4.02	1.67	0.64	38.03	3.59	72.4	8.11	23.45
24s	295	28.24	5.12	0.9	0.18	58.31	4.25	53.49	9.24	36.8

Samples 1–24n_s = samples without salt; Samples 1–24 s = samples with salt; Measured parameters: *LA* leaf area, *FW* fresh weight, *DW* dry weight, *RDW* root dry weight, *R*/*S* root/shoot ratio, *l_f* leaf length, *L_f* leaf width, *l_i* distance between internodes, [Na^+] leaf tissue concentration, [Cl^-] leaf tissue

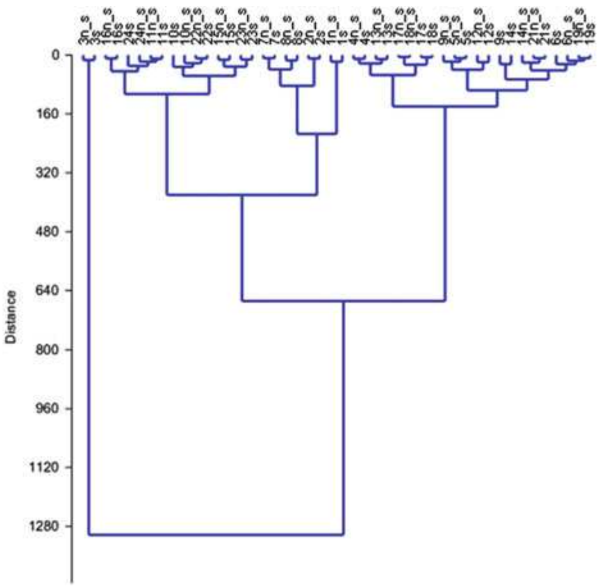

Fig. 4 Tree based on the relationship between morphometric data, aesthetic, chemical and salt stress among 24 autochthonous Bermuda grass ecotypes with Ward's method and Euclidean linkage. Note: Samples 1–24n_s = samples without salt; Samples 1–24 s = samples with salt. Measured parameters: *LA* leaf area, *FW* fresh weight, *DW* dry weight, *RDW* root dry weight, *R/S* root/shoot, *l_f* leaf length, *L_f* leaf width, *l_i* distance between internodes, $[Na^+]$, $[Cl^-]$

4 Conclusions

The research project was of particular interest in increasing knowledge on Bermuda grass germplasm in Central and Southern Italy.

The bio-agronomic evaluation of 24 ecotypes of *Cynodon dactylon* (L.) Pers. showed high variability in the collected germplasm as far as the biometric and qualitative parameters were concerned.

Many of the ecotypes compared resulted susceptible to phytoplasma BGWL attacks, which influenced all the considered parameters with the exception of ecotypes 1, 3, 13, 14, 21, 23 and 24. Susceptibility to phytoplasma is a factor to be considered for the selection of ecotypes for turf.

The native accession 3 from Vasto (Abruzzo Region) achieved the best results among native accessions. For some parameters, several ecotypes (1, 13, 14 and 20) showed good biometric and qualitative performances and could result in great interest for selecting future Bermuda grass cultivars for turfgrass use.

As can be seen clearly from the data shown, only some of the ecotypes studied showed a reduction of leaf length (l_f), leaf width (L_f) and distance between internodes (l_i), at least 50 %, and in some cases any reduction in the growth rate as in the case of the ecotypes 1, 3, 6 and 17 was not observed.

Further studies are needed to better characterise the above native accessions of *C. dactylon*. in order to promote them in the turfgrass market and to assess the potential benefits compared to alien species in the Mediterranean environments.

Acknowledgements Findings in this paper are the preliminary results of research work financially supported by the Italian Ministry of Agriculture (Mi.T.E.A.Med project). The authors wish to thank Aleksandra Dimitrijevic and Mauro Musto for their linguistic revisions, which improved the clarity of the manuscript.

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Biodiversity of Hypogeous Fungi in Basilicata

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Abstract During the last two decades, systematic studies were carried out on biodiversity of hypogeous fungi in forestry territories of the two Basilicata (southern Italy) provinces, Matera and Potenza. Identification of fungus taxa found in the region was commonly accomplished on the basis of macro- and microscopic features, and only in a few instances, molecular analyses were utilized. Thanks to these investigations, Basilicata now occupies, among Italian regions, the first and fourth positions for number of *Tuber* species, varieties or forms and total number of hypogeous fungi (*Ascomycota*, *Basidiomycota* and *Zygomycota*) naturally growing in its woodlands and Mediterranean maquis areas. In fact, the last up-to-date acquirements on the topic bring up to 29 and 53 the number of *Tuber* taxa and that of the other hypogeous and semi-hypogeous (only three entities) fungi present in the region, respectively. In this chapter, the essential information regarding these fungi is given, so updating to 2014 the relative available knowledge. Among the *Fungi*, object of this review, the *Ascomycota Pachyphloeus conglomeratus* and *Tuber malençonii*, the *Basidiomycota Hymenogaster decorus*, *H. hessey*, *H. rehsteineri*, *Schenella pityophilus* and *Myriostoma coliforme* as well as the *Zygomycota Youngiomyces multiplex* deserve a particular mention because of their rarity.

1 Introduction

In the last two decades, several researches have been carried out on biodiversity of hypogeous fungi of Basilicata, an Italian region characterized by a very heterogeneous territory for cenotic diversity deriving from its great geomorphologic complexity. The first studies accomplished on the topic by Cerone et al. (1994) and by the Potenza group of *Associazione Micologica G. Bresadola (Trento)* (Tagliavini 1999) showed that all the commercial species, varieties and forms of truffles were present in the region along with some unmarketable taxa, *i.e. Tuber excavatum* Vittad., *T. fulgens* Quél., *T. rufum Pico*: Fr. var. *rufum*, *T. rufum* var. *nitidum*

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_20

(Vittad.) Montecchi & Lazzari, *T. gibbosum* Harkn., *T. maculatum* Vittad., *Choiromyces meandriformis* Vittad. and *Balsamia vulgaris* Vittad. The Institute of Plant and Forestry Pathology of the Agriculture Faculty of University of Basilicata [now School of Agricultural, Forestry, Food and Environmental Sciences (SAFE)] subsequently carried out systematic investigations on these fungi. Initially, with the graduation thesis entitled "Il tartufo in Basilicata" (Marino 1999), additional documented information was given on the above taxa, and presence of another hypogeous fungus, belonging to *Basidiomycota*, *Hymenogaster popouletorum* Tul. & C. Tul., was reported in Potenza province. Further studies (Cerone et al. 2000, 2002; Marino et al. 2003) allowed to bring up to 16 and six the numbers of Lucanian hypogeous fungi belonging to *Ascomycota Pezizales* and to *Basidiomycota*, respectively. Thanks to successive investigations (Marino et al. 2005; Rana et al. 2008, 2010, 2011, 2013a, and unpublished data), the number of hypogeous fungi naturally growing in Basilicata, including only three semi-hypogeous taxa, grew up to 82 entities as shown in Table 1. Although all fungi, object of the article, are well-known species, varieties or forms, *exsiccatae* of almost all specimens found in Basilicata were deposited in *Herbarium Lucanum* (*HLUC*) of SAFE. In this chapter, the essential information on these fungi is briefly reported. For those here mentioned for the first time, the main macro- and microscopic features along with the relative *exsiccata* number, date and site of finding are mentioned. For details about the great majority of Lucanian taxa, the available specific literature and truffle treatises by Montecchi and Sarasini (2000), Riousset et al. (2001), Gori (2005), and Granetti et al. (2005) should be consulted. The nomenclature and taxonomic classification adopted for fungi object of the article are those reported on the MycoBank website (Crous et al. 2004; Robert et al. 2005).

2 Lucanian Hypogeous and Semi-hypogeous Fungi

2.1 Ascomycota

2.1.1 ***Pezizomycotina*, *Eurotiomycetes*, *Eurotiomycetidae*, *Elaphomycetales*, *Elaphomycetaceae* (Tul. & C. Tul.) Paol.**

The following three species of *Elaphomyces* grow in nature in the region: *E. leveillei* Tul. & C. Tul., *E. asperulus* Vittad. and *E. muricatus* Fries. The first one was found in a mixed wood of Pignola (PZ) communal territory (Cerone et al. 2000); the second and the third ones were collected under oak and beech plants in Terranova di Pollino (PZ) area (Rana et al. 2008).

Table 1 Hypogeous and semi-hypogeous fungi found in Basilicata between 1994 and 2014, listed in the taxonomical order reported in the article

Division	Family	Species/Var/Form
Ascomycota		
	Elaphomycetceae	*Elaphomyces leveillei*, *E. asperulus* and *E. muricatus*
	Helvellaceae	*Balsamia vulgaris*, *Choiromyces meandriformis*, *Fisherula macrospora*, *Leucangium chartusianum* and *Picoa lefebvrei*
	Pezizaceae	*Pachyphloeus citrinus*, *P. ligericus*, *P. conglomeratus* and *Sarcosphaera coronaria* var. *coronaria*
	Pyronemataceae	*Genea fragrans*, *G. hispidula*, *G. lespiaultii*, *G. sphaerica*, *G. verrucosa*, *G. papillosa*, *Geopora clausa*, *G. sumneriana* and *Stephensia bombycina*
	Terfeziaceae	*Terfezia arenaria* and *T. olbiensis*
	Tuberaceae	*Reddellomyces donkii*, *T. aestivum*, *T. aestivum* var. *uncinatum*, *T. asa-foetida*, *T. bellonae*, *T. borchii*, *T. brumale*, *T. brumale* var. *moschatum*, *T. dryophilum*, *T. excavatum*, *T. foetidum*, *T. fulgens*, *T. gibbosum*, *T. hiemalbum*, *T. macrosporum*, *T. maculatum*, *T. malençonii*, *T. magnatum*, *T. magnatum* var. *Vittadinii*, *T. melanosporum*, *T. mesentericum*, *T. oligospermum*, *T. panniferum*, *T. puberulum*, *T. regianum*, *T. rufum* var. *apiculatum*, *T. rufum* fo. *ferrugineum*, *T. rufum* fo. *lucidum*, *T. rufum* fo. *nitidum* and *T. rufum* var. *rufum*
Basidiomycota		
	Strophariaceae	*H. aromaticus*, *H. bulliardii*, *H. decorus*, *H. hessei*, *H. luteus* var. *luteus*, *H. luteus* var. *subfuscus*, *H. lycoperdineus*, *H. olivaceus*, *H. populetorum*, *H. rehsteineri* and *H. vulgaris*
	Melanogastraceae	*Melanogaster ambiguus* var. *ambiguus*, *M. broomeanus*, *M. tuberiformis*, *M. umbrinigleba* and *M. variegatus*
	Octavianiaceae	*Octavianina asterosperma*
	Rhizopogonaceae	*Rhizopogon vulgaris*
	Geastraceae	*Geastrum fimbriatum*, *G. triplex*, *Myriostoma coliforme* and *Schenella pityophilus*
	Gomphaceae	*Gautieria graveolens* var. *graveolens*, *G. graveolens* var. *otthii* and *G. morchellaeformis*
	Hysterangiaceae	*Hysterangium inflatum*, *H. nephriticum* and *H. stoloniferum*
Zygomycota		
	Endogonaceae	*Youngiomyces multiplex*

2.1.2 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Helvellaceae* Fries

Balsamia vulgaris seems able to grow quite commonly in the region under *Quercus* spp. or in mixed woods (Cerone et al. 1994; Marino et al. 2005; Rana et al. 2011). It has been refound in "Mantenera-Malcanale" mixed wood (Tricarico, MT) in 2014

(Rana et al. unpublished data). *B. polysperma* Vittad. was so far never found in Basilicata and appears limited to northern Italian regions (Montecchi and Sarasini 2000). *C. meandriformis* is enough distributed in Basilicata. It was at first found by Cerone et al. under *Quercus pubescens* Willd. (*s.l.*) and *Fagus sylvatica* L. (1994 and 2000) and repeatedly discovered in mixed woods of Tricarico (MT), Abriola and Brindisi di montagna (PZ) in successive years (Rana unpublished data). Findings of *Fischerula macrospora* Mattirolo, a taxon apparently limited to Italy (Montecchi and Sarasini 2000), occurred in territories of Tricarico (MT) in 2006 and Abriola (PZ) in 2011 (Rana et al. 2008, 2011) under *Q. pubescens* (*s.l.*) and *F. sylvatica*, respectively. *Picoa carthusiana* Tul. & C. Tul. [= *Leucangium carthusianum* (Tul. & C. Tul.) Paol.] and *P. lefebvrei* (Pat.) Maire were both only once reported in the communal mixed wood of Tricarico (PZ) (Rana et al. 2008, 2010).

2.1.3 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Pezizaceae* Dumortier

The hypogeous fungus genera naturally growing in Basilicata and belonging to this family are *Pachyphloeus* Tul. & C. Tul. and *Sarcosphaera* Auersw.

Two species of *Pachyphloeus* were discovered under oaks in Basilicata in 2002 and 2003, *P. citrinus* Berk. & Br. and *P. ligericus* Tul. & C. Tul., respectively (Marino et al. 2005) Another species, *Pachyphloeus conglomeratus* (Berk. & Br.) Doweld (*exsicc*. n. 88), has been recently discovered in the region. More in detail, five ascomata were complexively found: two of them under *Salix elaeagnos* Scop. and *Populus alba* L. in Roccanova territory (PZ) in October 2013 and the remaining three in the "Montecaruso" mixed wood of Filiano (PZ) in November of the same year. The macro- and microscopic features (see Fig. 1a, b, c) of the fungus were very like if not identical to those already described for the *Pezizacea* (Montecchi and Sarasini 2000). The poisonous *Sarcosphaera coronaria* var. *coronaria* (Jacq.) J. *Schröt* [= *S. crassa* (Santi: Strudel) Pouzar] is quite common under pine woods in Basilicata (Tagliavini and Tagliavini 2011) at the end of winter or in spring. Its last documented finding occurred under *Pinus halepensis* Mill. in "Mantenera-Malcanale" wood (Tricarico, MT) 4 years ago. DNA extracted from a Lucanian ascoma of the fungus, subjected to PCR with primers ITS4 and ITS5 (White et al. 1990), gave an amplification product of about 562 bp. The same sequence was deposited in EMBL database under accession code FR827862 and matched at 89 % ($E = 0$) two sequences, DQ200843 and DQ200844, of the same *Pezizacea* (Rana et al. 2011).

2.1.4 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Pyronemataceae* Schröter

The hypogeous fungi of this family found in Basilicata belong to genera *Genea* Vittad., *Geopora* Harkn., *Hydnocystis* Tul. & C. Tul. and *Stephensia* Tul. & C. Tul.

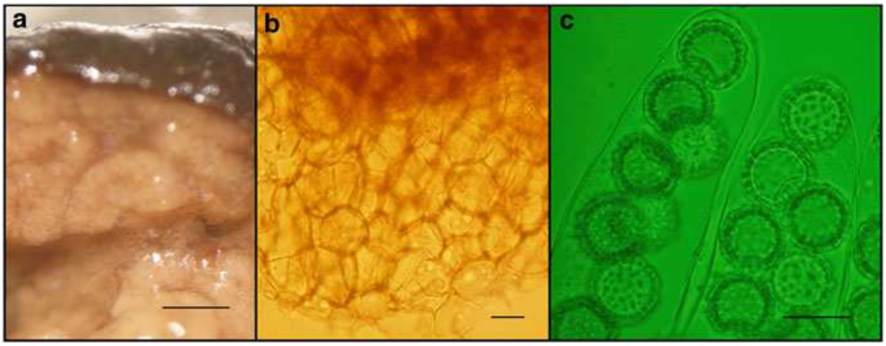

Fig. 1 Gleba cross section (**a**), pseudoparenchymatic structure of peridium (**b**), asci and spores (**c**) of a Lucanian ascoma of *Pachyphloeus conglomeratus*. Bars: (**a**) 15 mm, (**b**) 10 μm and (**c**) 20 μm

Findings of *Genea* species present in Basilicata are reported by Cerone et al. (2000) and Marino et al. (2002) for *G. verrucosa* Vittad. and *G. lespiaultii* Corda, Marino et al. (2005) for *G. fragrans* (Wallroth) Paol. and *G. hispidula* Berk. & Br. and, finally, Rana et al. (2011, unpublished data) for *G. sphaerica* Tul. & C. Tul. and *G. papillosa* Vittad., the last of which is thought to be a bay-brown form of *G. verrucosa* (Montecchi and Sarasini 2000).

Two species of *Geopora*, *G. sumneriana* (Cooke) Kers and *G. clausa* (Tul. & C. Tul.) Burds., and one of *Stephensia* (Tul. & C. Tul.), *S. bombycina* (Vittad.) Tul., result in inhabitation of some areas of the region. Tagliavini and Tagliavini (2011), about the first species of *Geopora*, wrote that "it is rare but abundant in the sites where it grows". *G. clausa* (Tul. & C. Tul.) Burds. [= *Hydnocystis clausa* (Tul. & C. Tul.) Ceruti] is present in Bernalda (MT) area and exactly in the "Biogenetic Natural Reserve of Metapontum and Marinella—Stornara" (BNR) (Rana et al. 2011). *Hydnocystis piligera* Tul. & C. Tul., that has been reported in the extended Apulian portion (1,456 ha) of BNR, was so far never encountered in Basilicata.

Finally, *S. bombycina* (Vittad.) Tul. & C. Tul. was firstly reported under *Quercus cerris* L. in Corleto Perticara (PZ) territory in 2006 (Rana et al. 2010) and subsequently refound for two–three times in Filiano (Rana et al. 2011) and Rionero in Vulture (PZ) territories (Rana et al. unpublished data).

2.1.5 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Terfeziaceae* Fischer

The species of *Terfezia* Tul. & C. Tul. so far found in Basilicata are *T. arenaria* (Moris) Trappe (= *T. leonis* Tul. & C. Tul), sniffed by a well-trained Lagotto dog under *Quercus* spp. in the inland Lucan territory of Brindisi di montagna town (PZ) in June 2013 (Rana et al. unpublished data), and *T. olbiensis* Tul & C. Tul.

which grew close to *P. halepensis* and *Cistus salvifolius* L. in the before mentioned "Mantenera-Malcanale" wood.

It is conceivable to hypothesize that two other *Terfezia* species, i.e. *T. leptoderma* Tul. and *T. boudieri* Chatin, present in the close region Apulia, the first, between Torre dell' Orso and Melendugno towns (LE) and, the second, in the Apulian BNR surface (Rana et al. 2010), could also grow in the Lucanian part (45 ha) of the same reserve.

2.1.6 *Pezizomycotina*, *Pezizomycetes*, *Pezizomycetidae*, *Pezizales*, *Tuber*aceae Dumortier

Tuber aestivum and *T. aestivum* fo. *uncinatum* are the most common black truffles of Basilicata; their natural beds are located in broad-leaved and coniferous woods of 93 and 37 Lucanian communes, respectively (*Bollettino Ufficiale Regione Basilicata-BURBas* 2004). Prudential estimates indicate that a single professional truffle hunter can pick up two–three q/year of their ascomata. Both truffles can be successfully cultivated in the region and ascomata weighting 400–700 g are not rarely produced. In nature, an exceptional Lucanian ascoma weighting 1,006 g was collected under oaks in Rieti (PZ) area during October 2006 (Rana and Marino 2007).

The other truffles, which are marketable according to the national and regional laws n. 752 of June 20th 1985 and n. 35 of March 27th 1995, are, in decreasing order for quantity and economical importance, *T. borchii* Vittad. (including all truffles of *T. puberulum* Berk. et Br. group as well as *T. gibbosum* Harkness), *T. magnatum* Pico, *T. brumale* Vittad. and its fo. *moschatum* (Ferry) Montecchi & Lazzari, *T. macrosporum* Vittad., *T. bellonae* Quél., *T. hiemalbum* Chatin, *T. melanosporum* Vittad. and *T. mesentericum* Vittad. (complex species which probably comprehends more than three taxa) (Leonardi et al., manuscript sent to Fungal Biology). The last *Tuber* species and, more specifically *T. mesentericum* (*s. s.*), although abundant in beech wood of Basilicata at 1,000–1,300 m a.s.l. and appreciated in Campania, is scarcely used in kitchen in the Lucanian region. *T. borchi* grows either in coastal pine woods or under oaks on the Basilicata mountains in more than 20 natural sites (*BURBas* 2004).

The tasty *T. melanosporum* was found growing in small natural beds of Fardella, Marsicovetere, Muro Lucano, Teana and Rotonda (PZ) (*BUR-Bas* 2004).

The precious *T. magnatum* grows in loamy-sandy, calcareous soil along the banks of more or less large torrents and streams located between Agri and Sinni rivers as well as along Basentum in territories of about 20 Lucanian towns (*BURBas* 2004). Cerone et al. (2002) described the ecological characteristics of a natural bed of this *Tuber* species existing in Chiaromonte (PZ) territory where *Populus canescens* (Aiton.) Sm. predominantly grows. A realized niche of the species, located in upper Sinni river area, was recently studied using GIS, direct in situ survey and genetic diversity at DNA marker loci (Figliuolo et al. 2013).

Furthermore, 89 ascomata of *T. aestivum*, *T. borchii*, *T. brumale*, *T. magnatum* and *T. mesentericum* from 41 different Basilicata sites were object of a biodiversity study (Pomarico et al. 2007) employing molecular tools.

T. macrosporum grows in limited areas of oak and beech woods in a few communal territories of the region (Marino et al. 2002; *BURBas* 2004; Rana unpublished data).

Among the numerous unmarketable Lucanian truffles, *T. excavatum* Vittad. and *T. rufum* var. *rufum* are very abundant; *T. malençonii* Donadini, Riousset et Chevalier is, on the contrary, very rare (Rana et al. 2013a) whereas *T. regianum* Montecchi and Lazzari, *T. maculatum* Vittad., *T. foetidum* Vittad., and *T. dryophylum* Tul. et C. Tul. can be rarely encountered (Rana et al. 2011, 2013a, unpublished data).

Tuber gibbosum Harkness was only found under *Pseudotsuga menziesii* (Mirbel.) Franco in territories of Abriola, Campomaggiore and Teana (PZ), *T. oligospermum* (Tul. & C. Tul.) Trappe and *T. asa-foetida* Tul. & C. Tul. in pine woods of the Lucanian Jonian coast (Marino et al. 2003) and *T. panniferum* under *Q. ilex* L. in Tursi and Marsicovetere areas (Cerone et al. 2000) and, on July 9th, 2012 and June 22th, 2014, in Calciano (MT) area and in the "Mantenera-Malcanale" mixed wood, respectively (Rana et al. unpublished data).

Finally, *Reddellomyces donkii* (Malençon) Trappe was found in the BNR surface of Basilicata under *P. halepensis* in 2007 and 2008 (Rana et al. 2010).

2.2 Basidiomycota

2.2.1 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Agaricales* *Strophariaceae* Singer & A. H. Sm.

The species of *Hymenogaster* Vittad. so far reported in Lucanian territories are listed hereafter: *H. populetorum* Tul. & C. Tul., *H. luteus* Vittad. var. *luteus* and *H. vulgaris* Tul. & C. Tul. that were found in territories of Trivigno, Marsicovetere, Pignola, Vaglio di Basilicata, Campomaggiore, Corleto Perticara and Anzi (PZ) in the first years of research (Cerone et al. 2000); *H. aromaticus* Velenovski. [= *Protoglosum aromaticum* (Velen.) J.M. Vidal.] presence of which in the region (Cerone et al. 2002) needs to be confirmed, because some of the original *exsiccata* resulted to be *H. populetorum*; *H. lycoperdineus* Vittad., collected under *Quercus* spp., *F. sylvatica* L. and *Ilex aquifolium* L. in Gorgoglione (PZ) and Tricarico (MT) territories from 2002 to 2004 (Marino et al. 2005); *H. bulliardii* Vittad. and *H. luteus* var *subfuscus* Soehner, found in the "Mantenera-Malcanale" wood and Pignola area (PZ) (Rana et al. 2008); *H. olivaceus* Vittad. collected in a cultivated truffle ground planted in Ruoti (PZ) territory (Rana et al. 2011).

Furtherly, presence of the following other *Hymenogaster* species is here reported for the first time: *H. decorus* Tul. & C. Tul. (*exsicc*. n. 89), collected under oaks at about 1,000 m a.s.l. in Rionero in Vulture (PZ) area on February 2013 and identified thanks to the spore morphology and average dimensions (20–25 × 12–15 μm), the loose and markedly knotted perisporium and the typical two-spored basidia (Montecchi and Sarasini 2000) (see Fig. 2a), *H. hessey* Soehner (*exsicc*. n. 90),

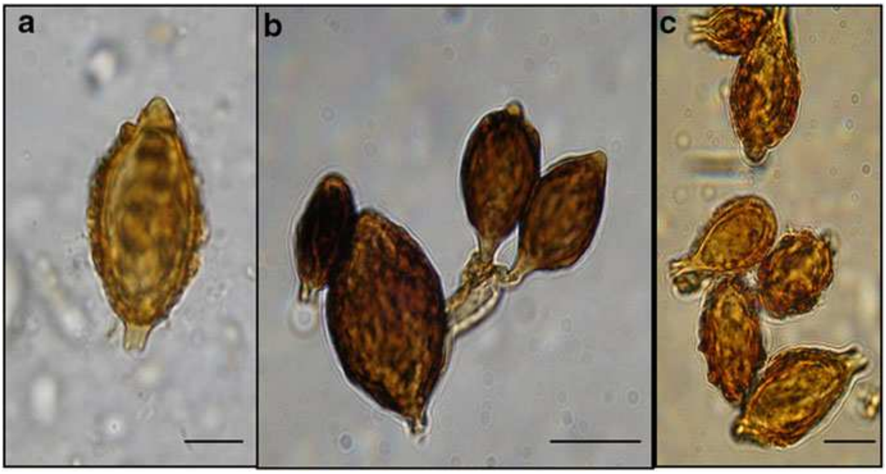

Fig. 2 Basidiospores of *Hymenogaster decorus* (**a**), *H. hessei* (**b**) and *H. rehsteineri* (**c**). *Bars:* (**a**) and (**c**) 10 μm, (**b**) 15 μm

found in the same regional zone and date and recognized on the base of sour and pungent scent of its basidiomata, gold-yellow colour of its unripe spores and average dimensions of the mature ones (21–24 × 15–16 μm) which were morphologically much variable (see Fig. 2b) and, finally, *H. rehsteineri* Bucholtz (*exsicc.* n. 91) (see Fig. 2c), found under *P. canescens* in Chiaromonte (PZ) territory at about 300 m a.s.l. at the end of October 2014. Useful for identification of the last species were the variable scent of its basidiomata and spore morphology that matched almost perfectly that described by Montecchi and Sarasini (2000).

Some recent findings of *H. albus* (Klotzsch) Berk. & Br. and *H. niveus* Vittad. under *Eucalyptus camaldulensis* Dehnh. and oaks, respectively (Rana unpublished data), still request to be confirmed.

2.2.2 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Boletales*, *Melanogastraceae* Fischer

Five out of the ten known *Melanogaster* Corda species result present in Basilicata:

M. ambiguus var. *ambiguus* (Vittad.) Tul. & C. Tul. and *M. umbrinigleba* Trappe & Guzmàn found under *Q. cerris* in Filiano (PZ) territory and under *P. halepensis* in the above-mentioned "Mantenera-Malcanale" wood in 2011 and 2009, respectively (Rana et al. 2011); *M. tuberiformis* Corda under *Q. cerris* in Corleto Perticara (PZ) area in 2006 (Rana et al. 2008); *M. variegatus* (Vittad.) Tul. & C. Tul., that is the most common *Melanogaster* species in the region, and *M. broomeanus* Berk. apud Tul. & C. Tul. in Brienza and Pietragalla (PZ) mixed woods (Cerone et al. 2000; D'Auria et al. 2014; Rana et al. unpublished data).

2.2.3 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Boletales*, *Octavianiaceae* Loquin ex Pegler & Young

The genus *Octavianina* Kuntze is known in Europe for the presence of a single species, *O. asterosperma* (Vittad.) Kuntze that has been found in Basilicata under *Q. cerris*. and *F. sylvatica*. on Volturino mountain in Marsicovetere (PZ) territory in spring–summer 2001 (Marino et al. 2003). Basidiomata of the same fungus were often refound in region [*e.g.* in a mixed wood of Tricarico territory on July 2011 and June 2012 as well as under oak in a zone between Satriano di Lucania and Brienza (PZ) during June 2013] (Rana et al. 2011 and unpublished results).

2.2.4 *Agaricomycotina*, *Agaricomycetes*, *Agaricomycetidae*, *Boletale*, *Rhizopogonaceae* Gäumann & Dodge

Rhizopogon vulgaris (Vittad.) M. Lange is the only species of the genus *Rhizopogon* Fries so far discovered in Basilicata. After its first finding in the region under *Pinus pinaster* Ait. in Policoro (MT) territory in 2001, it was again encountered under *E. camaldulensis* and *P. halepensis* in BNR (Bernalda, MT) in April 2011 (Rana et al. 2011).

2.2.5 *Agaricomycotina*, *Agaricomycetes*, *Phallomycetidae*, *Geastrales*, *Geastraceae* Corda

Geastrum fimbriatum Fries and *G. triplex* fo. *triplex* Jungh. have been often found in Basilicata (Tagliavini and Tagliavini 2011; Rana et al. 2013b, unpublished data). The last findings are referred to the "Mantenera-Malcanale" wood and, for the close Apulia, to BNR and Corigliano d'Otranto (LE) territories. Another hypogeous fungus, belonging to this family and found under *P. halepensis* in the region (Rana et al. 2011), is *Schenella pityophilus* (Malençon and Riousset) Estrada & Lado. It was previously considered rare in Europe, but it seems common enough along the Adriatic and Jonic coasts of Apulia and Basilicata, respectively (Signore et al. 2008). It was again encountered in "Mantenera-Malcanale" mixed wood in the region in February 2014 (Rana unpublished data). Molecular analysis, accomplished as before summarized on one of its basidiomata, gave an ITS gene amplicon of 625 bp. Its sequence resulted very like (similarity coefficient = 91 %) that present in GenBank under accession number GU184106 for *S. pityophilus*. The sequence obtained from the Lucanian sample of *S. pityophilus* was deposited into the EMBL database under FR821766 accession number (Rana et al. 2011). *Myriostoma coliforme* (Dicks.) Corda, a rare, semi-hypogeous *Geastracea*, was found in two localities of the region, "Villa Caivano" (Picerno, PZ) and "Manferrara" (Pomarico, MT), at 700 and 400 m a.s.l. in autumn of 2008 and 2009, respectively (Rana et al. 2013b).

2.2.6 *Agaricomycotina*, *Agaricomycetes*, *Phallomycetidae*, *Gomphales*, *Gomphaceae* Donk

Three varieties of *Gautieria graveolens* Vittad. were so far found in Basilicata:

G. graveolens var *graveolens* Vittad., *G. graveolens morchellaeformis* var. *morchellaeformis* Vittad. and *G. graveolens* var. *otthii* (Trog) Zeller & Dodge. A single basidioma of the second variety was firstly found in Brienza (PZ) territory during February 2006. Presence of the third and the first varieties was reported under *Q. pubescens* (*s.l.*) in Corleto Perticara (PZ) area (Rana et al. 2010) and in a mixed wood of *Q. cerris* and *Carpinus betulus* L. in Gorgoglione (PZ) territory in 2009 (Rana et al. 2011). Although molecular analyses were carried out, identification of the first variety was based mainly on basidiospore morphology and dimensions. A 775 bp ITS gene DNA sequence of a Lucanian specimen of the same *G. graveolens* variety was deposited in NCBI database under accession code FN666413 (Rana et al. 2011).

2.2.7 *Agaricomycotina*, *Agaricomycetes*, *Phallomycetidae*, *Hysterangiales*, *Hysterangiaceae* Fischer

Three species of *Hysterangium* Vittad. were so far found in Basilicata: *H. stoloniferum* Tul. & C. Tul. under *Q. cerris* in Corleto Perticara (PZ) area (Rana et al. 2008), *H. inflatum* Rod. under *Eucalyptus* spp. in BNR in 2007 (Rana et al. 2010) and *H. nephriticum* Berk. under oak in "Mantenera-Malcanale" forest (Tricarico, PZ) in 2012 (Rana et al. 2013a).

2.3 *Zygomycota*

2.3.1 *Mucoromycotina*, *Endogonales*, *Endogonaceae* Paoletti

Only one species of *Youngiomyces*, *Y. multiplex* (Taxter) Yao (= *Endogone multiplex* Taxt.), has been reported in the region under *P. pinaster* in winter 2000. Its identification was mainly achieved considering spore morphology and dimensions (Marino et al. 2003).

3 Concluding Remarks

On the basis of the up-to-date information available for hypogeous and semi-hypogeous fungi naturally growing in Basilicata, a reckoning of 82 taxa comes out as shown in Table 1. The fungal entities so far found belong to 14, nine and one genera of *Ascomycota*, *Basidiomycota* and *Zygomycota*, respectively. Among

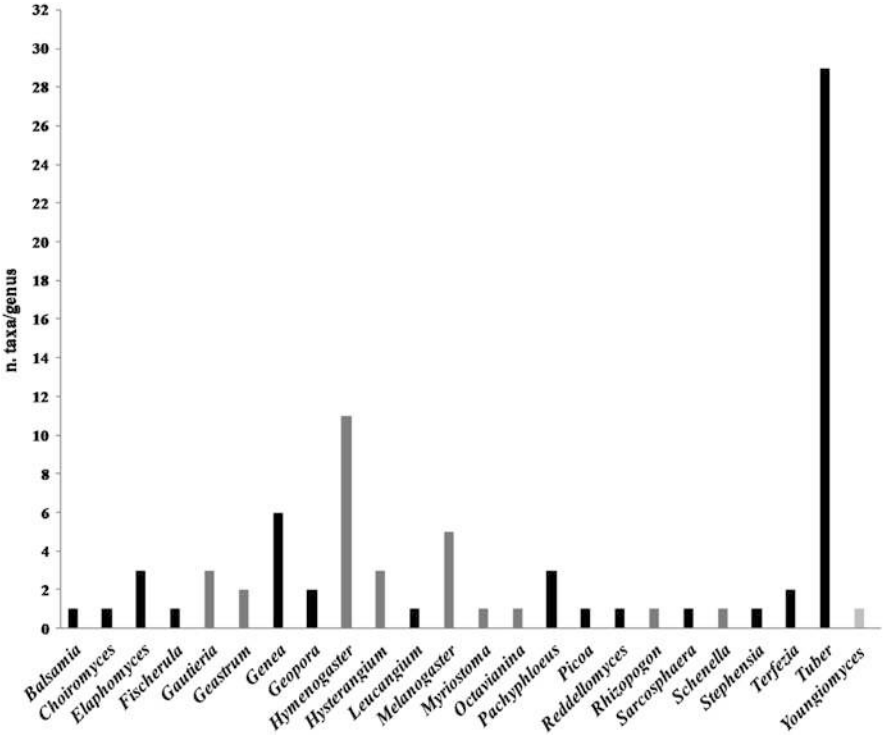

Fig. 3 Number of taxa/genus of hypo- and semi-hypogeous *Ascomycota* (*black*), *Basidiomycota* (*grey*) and *Zygomycota* (*light grey*) growing in nature in Basilicata

Ascomycetes, the most numerous genus is *Tuber* Micheli: Wiggers which includes, except for *T. gennadii* (Chatin) Patouillard (= *Terfezia gennadii* Chatin), all the taxa described by Montecchi and Sarasini (2000) and Riousset et al. (2001) as well as the hypothetical variety *vittadinii* of *T. magnatum* (Daprati 2007) for a total of 29 taxa.

A more restrictive estimate, considering that *T. aestivum* is identical to *T. aestivum* var *uncinatum*, i.e. *T. uncinatum* Chatin, either morphologically (Tanfulli and Di Massimo 2002) or molecularly (Wedén et al. 2005), *T. brumale* to its var. *moschatum* (Gandeboeuf et al. 1997) and *T. hiemalbum* to *T. melanosporum* (Dupré et al. unpublished data, as reported by Riousset et al. 2001), would reduce the above number to 25 (see Fig. 3). Anyway, Basilicata, 4 years after a previous review (Venturella et al. 2011), for the number of *Tuber* taxa which can grow in its territory, confirms its first position among Italian regions.

Other genera enough represented in the region are *Hymenogaster* (11 taxa), *Genea* (6), *Melanogaster* (5), *Gautieria*, *Elaphomyces*, *Pachyphloeus* and *Hysterangium* (3).

The region has an enviable biodiversity of hypogeous and semi-hypogeous fungi. Some of them, as the marketable *Tuber* species, play an important economical role for human beings. The other *Tuber* species and *taxa* belonging to the various *Ascomycota* and *Basidiomycota* mentioned certainly are precious for some components of wild fauna as squirrels (Venturella et al. 2011), field-mouse, mole, fox, etc.

Despite of the high number of hypogeous fungus *taxa* already identified in the region, some zones (*e.g.* Italian State's and Basilicata Region's properties and protected areas) still remain unexplored in this respect and numerous semi-hypogeous and hypogeous fungi are waiting to be discovered.

The drawback is that the natural *Tuber* production showed a progressive marked decrease in Italy and other main truffle producing European countries (France, Spain) in the last 20 years (Hall et al. 2007). This negative trend occurred also in Basilicata due to the massive presence of wild boars on its woody areas and the excessive and the often illegal exploiting of its natural truffières.

This situation renders necessary and pressing the widespread diffusion of the available know-how to extend truffle cultivation in the region and to preserve, through *in situ* conservation programmes, the survival of some hypogeous fungi which risk extinction before being known. In this mode, the future generations will inherit this fascinating and incommensurable patrimony of the Nature.

Acknowledgements The authors are grateful to Dr. Mariano Annarita (Basilicata Region, PZ) who provided basidiomata of *Hymenogaster decorus*, *H. hessey* and *H. rehsteineri* and to Cerroni Andrea and Cerroni Nazzareno (Pignola, PZ) who found sporophores of *Pachyphloeus conglomeratus*, *Terfezia arenaria* and *Melanogaster broomeanus*.

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Part III
New Technologies

New Technologies for the Sustainable Management and Planning of Rural Land and Environment

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Abstract New technologies could be adequately introduced for an improved analysis aimed to the sustainable management and planning of the rural land, as well as its environment and landscape. Nowadays, this analysis is easier and more complete through the use of powerful and reliable tools. Several changes can be considered to be as models of territorial development, useful for an appropriate planning of the human interventions in a rural area. Remote sensing techniques could be employed for the monitoring of agricultural land variation, while Geographical Information Systems are excellent tools for landscape modeling and three-dimensional analysis. In this chapter, land-use changes in a rural area located in southern Italy were analyzed by comparing some historical cartographic supports with modern maps, in order to evaluate the morphological and vegetation variations of the agroforestry land during time. Moreover, a landscape analysis was conducted through the implementation of digital terrain models, which were enriched by draping land cover pictures over them. These elaborations finally enabled an evaluation in a scenic way of the aesthetic quality of the agroforestry landscape, allowing a virtual jump back to time periods when digital aerial photography was not yet even possible. This multi-temporal analysis with the support of GIS techniques revealed to have a great potential for assessing and managing landscape diversity and changes of vegetation, as well as for planning sound interventions over the landscape structures.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_21

1 Introduction

Planning and managing the rural land and its environment are one of the most intriguing examples of technical challenge where a multidisciplinary approach plays a crucial role (Picuno et al. 2012). The agricultural production, both food and nonfood, the social role of rural settlements, the state and diffusion of the infrastructural networks, and the rural architectonic heritage that in many countries constitutes a major positive value should be appropriately considered and synergistically interlaced for a sound planning of the agricultural biosystems. Human activities impose a transformation of the extra-urban land that may lead to the modification of the frail equilibrium of whole ecosystems. Sound planning strategies should be therefore pursued, employing a multidisciplinary approach that should take into account geographical, environmental, and landscape factors as variables interacting among themselves and with the social and economic aspects. In order to simultaneously analyze all these properties, tools able to manage, interpret, and integrate several data are necessary.

Extra-urban land planning must pursuit, as a main goal, environmental sustainability, since sustainable development has been perceived all over the world by social awareness and sensibility and is constantly been considered by new laws and regulations whose attempt is the natural resources protection. In this scenario, an accurate analysis of performing variations and a global monitoring of ecosystems are necessary in order to propose environmental protection politics.

The farmer as a producer has traditionally been in focus when changes in agricultural landscapes are studied. Decisions about husbandry, rotational systems, machinery, fertilization, and pest management do indeed affect the landscape in a crucial way, and landscape dynamics cannot be understood if the farmer's decision-making and the surrounding technology, socioeconomics, and organizational structure are ignored. However, normally, the farmer is not the only decision-maker. Often, the farms leased land and the owner may be an equally important actor concerning landscape changes. Farmers are important agents in rural landscape management, as they modify landscape elements to suit their needs. The industrialization and intensification of agriculture over the last 50 years had a negative impact on landscape diversity and habitat values. During the last two decades, farmers have become increasingly engaged in landscape activities, to maintain or create habitats on their property. For the sustainable development of rural settlements, at least four characteristics should be protected: balance between nature and built-up area, historic traditional entities, local communities, and the countryside as an own culture.

2 New Technologies for Rural Land and Environment Analysis

New leading technologies could be adequately introduced for an improved analysis of the rural environment. The most currently interesting are:

- Geographical Information Systems
- Remote sensing
- Three-dimensional landscape analysis

2.1 Geographical Information Systems

Geographical Information Systems (GIS) are excellent tools for landscape modeling and three-dimensional analysis. They allow an easy digitalization of geographical information and coverage structure, as well as they facilitate graphical representation. An evaluation of the aesthetic impact produced on the rural environment becomes therefore possible, paving the way for landscape simulations and possible minimizations of the landscape impact. GIS allows an easy digitalization of geographical information and coverage structure, as well as facilitating graphical representation (Hernández et al. 2004).

A specific landscape analysis conducted by a GIS approach has shown how positive results of the applied agronomic practices, in terms of CO_2 fixation, have been able to contrast heavy emissions of greenhouse effect gases in the atmosphere by urban settlements (Capobianco et al. 2004).

2.2 Remote Sensing

Remote sensing techniques could be employed for the monitoring of agricultural land variation. A wide spread of crops covered with plastic can damage the visual landscape, although they are detectable through remote sensing techniques. Some scientific efforts were conducted in order to allow a better monitoring and planning of these uses. Using a field spectrometer, Levin et al. (2007) studied the spectral properties of a sample of polyethylene sheets and various nets used in Israel through the detection of three major absorption features around 1,218, 1,732, and 2,313 nm. Carvajal et al. (2006) presented a methodology able to detect greenhouses from 2.44 m pixel size QuickBird image, based on an Artificial Neural Network algorithm. Thanks to the information introduced through training sites, they "teach" to the mathematical model to classify the image considering its radiometric and wavelet texture properties. Classification accuracy was evaluated using multisource data, comparing results including and non-including wavelet texture analysis. A methodology based on supervised classification of the image was found as the most adequate to the classification of crop shelters. According to this methodology, suitable classes were selected on the basis of signatures related to specific sample areas. The classification was then refined by using neighborhood and contiguity analysis algorithms. The results of the analysis allowed to recognize and localize the crop shelters and to quantify their planimetric area. The latter was also compared with the attributes of georeferenced feature classes based on visual recognition. Finally, Capobianco and Picuno (2008) implemented remote sensing techniques aimed to the analysis of the rural land use, with special attention paid to greenhouse and other application of plastics in protected cultivation, inside a study area located near the coast border between the Italian regions of Basilicata and Apulia, where plastic in agriculture is widely used. The analysis was realized using Thematic Mapper of multi-temporal Landsat images through supervised classification, image processing, vectorization, and GIS tools. For the study, band 7 (2.08–2.35 μm), band 5 (1.55–1.75 μm), and band 3 (0.63–0.69 μm) were used, together with other suitable cartographic information. The results that were obtained enable the possibility to create a routine in IDL and ENVI software for the autodetection of the plastic covers.

2.3 Three-Dimensional Landscape Analysis

Through the implementation of a digital terrain model (DTM), enriched with the drape of land cover pictures, Capobianco et al. (2004) evaluated in a scenic way the morphological and vegetation variations of agroforestry landscape.

Solid modeling techniques, moreover, could contribute to the analysis and planning of the rural environment. The implementation of a digital terrain model (DTM), enriched with the drape of land cover pictures, enables the evaluation in a scenic way of the morphological and vegetation variations of agroforestry landscape. From the digitalization of historical cartography, enabling the analysis of the natural and anthropic changes of rural land using a Geographical Information System and image processing techniques, Tortora et al. (2006) analyzed the aesthetic impact that the use of plastic coverings produces on the rural environment, so enabling landscape simulation and examining possible minimizations of the landscape impact.

The digitalization of historical cartography, finally, allowed (Picuno et al. 2011) the simulation of a hypothetical and virtual historical jump backward, so facilitating the analysis of the natural and anthropic changes of rural land during time.

3 Application of New Technologies on Historical Maps for the Analysis of the Agroforestry Land Evolution

Sound planning strategies should be pursued, employing a multidisciplinary approach that takes into account geographical, environmental, and landscape factors as variables interacting among themselves and with social and economic aspects (Tortora et al. 2006). Over recent years, different systems have been developed with the aim of providing support to policy makers in the field of agricultural development (Van Delden et al. 2010). According to this scenario, an accurate analysis of the performed variations and the global monitoring of all ecosystems are necessary to propose suitable environmental protection politics (Picuno et al. 2011). The visualization of spatial information in the form of maps is critical to facilitating decision-making in environmental management (Iosifescu-Enescu et al. 2010).

Moreover, the technical and spatial analysis methodologies that have been recently developed could ensure both the proper management and planning of land, especially if tailored to environmental protection and to efficient control of the agricultural and forestry resources. Suitable models for policy impact assessment (Brown and Brabyn 2012) should help to harmonize the EU agricultural policies and socioeconomic processes at different levels and in different sectors (i.e., local zoning regulations, infrastructure planning, and interaction between these sectors) as well as external factors such as climate change and socioeconomic drivers (Van Delden et al. 2010). Landscapes are spatially diverse, leading to the unequal distribution of landscape services over an area. An evaluation of the policy effects should therefore be spatially explicit as policies are likely to have a location-specific effect on the provision of landscape services (Willemen et al. 2010). An ex-ante evaluation of the consequences of spatial planning and policy on the supply of landscape services can support effective decision-making (Verburg et al. 2009).

The analysis of the historical landscape and the influential driving factors of landscape development may provide an essential basis for tackling current environmental questions in spatial planning (Haase et al. 2007). The landscape should be understood as a dynamic and open system where biophysical, social, and economic factors interact to define the current structure. The knowledge of historical landscape development ought therefore to be a starting point for long-term landscape monitoring. In most landscapes, large-scale patterns of geological, topographical, and morphological alteration are overlaid by smaller-scale variations in microclimate and disturbance patterns. Landscape processes are nested in a spatio-temporal hierarchy, from large-scale, slow processes like geological change to smaller-scale, rapid processes like plant competition and succession (Gillson 2009).

In order to evaluate the processes involved, suitable information about the landscape, the land-use structure, and the environment are required. The spatio-temporal dynamics of traditional rural mountain landscapes reflect the land-use evolution over the centuries resulting from the long-standing interaction between people and the environment and recent changes due to the impact of population migrations and policies influencing land use (Cullotta and Barbera 2011). That interaction between man and environment led to the development of traditional landscapes whose characteristics are closely linked to many features of the local geography, climate, water availability, soils, and the historical occupation of a region (Pôças et al. 2011). A time series can be used to predict future general trends in the case of assumed constant political and economic frameworks. The generated scenarios can be considered a projection of future land-use changes or a description of the relationships between the driving forces of environmental changes and their evolution. In order to generate these future scenarios, the dynamics of land-use patterns can be "simulated" taking into account the initial state of the system, the participating factors in land-use dynamics, and the rules that produce the dynamics that drive the evolution of actual cities.

Regional and local investigations of landscape change (Schneeberger et al. 2007) enable land-use trends and developments to be differentiated by region and hence support analysis of the causes of the changes (Haase et al. 2007). A multi-temporal analysis of land, with the support of GIS and historical documents, is very important for monitoring landscape diversity (Yeh and Huang 2009) and for investigating changes in vegetation and landscape structure (Leyk et al. 2006).

Vegetation plays an important role in human life and economic activity. The economic role of vegetation is dependent on its ecological function, which is of particular importance like determines the top priority of taking them into account in the system of rational nature management. In addition to vegetation, there are other elements that have a correlation with the landscape, such as buildings, which should be appropriately considered in data processing (Picuno 2012). There is often a difficult relationship between rural buildings and the landscape (Jeong et al. 2012). European landscape planning policy has particular building codes that protect local cultural identity and promote landscape quality (Council of the European Union 2001).

To understand the territorial and landscape changes that have occurred over the years, especially in Europe, it is important to recognize the limits of expert approaches and to integrate them with the use of various tools (participatory GIS, semi-directed meetings, photo-elicitation, cognitive mapping, etc.), which allow individual evaluations to be established (Domon 2011).

Geographical Information Systems (GIS) are excellent tools for landscape modeling, for knowing about changes of vegetation, and for conducting three-dimensional analyses. They allow an easy digitalization of geographical information and coverage structure, and they facilitate graphical representation (Hernández et al. 2004). The morphological and vegetation variations of agroforestry in the landscape may be evaluated through the implementation of a digital terrain model (DTM), over which the land cover picture is draped; further elements can be successively introduced in a rural landscape and may be included with the aim of understanding the changes occurring in the landscape. Spatial data combined with GIS-based modeling and interpretation using detailed Digital Elevation Models (DEMs) and orthophotos are very useful tools as well. Spatial information is, as a rule, visualized using photographic and thematic maps (Gehrke et al. 2006). While photographic maps claim to be an accurate reproduction of the original settings, thematic maps portray their content in an abstract form, while the topology of spatial units is maintained (Olbrich et al. 2002). Here, GIS was used to integrate and manage different kinds of data and to create high-quality maps that incorporated many other layers of information. Also, orthophotos, maps, and models were integrated in a 3D viewer to improve interpretations. Partial results from each approach were coordinated and iterated to obtain the best fitting result (Elez et al. 2013). Strengthened by the knowledge of the importance of time as a dimension, and relying on the advances in the field of cartography and spatial analysis, several studies have examined the dynamics generated by the transformation of agricultural or forest exploitation contexts, as much for landscape (spatial composition and organization) as for ecological (in support of biodiversity) reasons.

However, specifically during the last two decades, three strong tendencies have led to the relative importance of these resources to local rural economies being questioned. Firstly, the increased mechanization and concentration of exploitation have resulted in a general decrease in the importance of the primary sector (agriculture and forestry) within rural communities, with their socioprofessional structure increasingly resembling that of more urban environments. The new technologies cited are therefore here used to analyze land-use dynamics and topographic changes over almost two centuries (from 1848 to 2012).

3.1 Study Area

The study area (about 25 km^2) is a part of the Ruoti Municipality (Fig. 1), located in the central-western part of the Basilicata region of southern Italy (40° 43′ 05.43″ N, 15° 40′ 32.12″ E). The Basilicata region embodies much of the variability of landscapes found in southern Italy. In addition to the geological variability, the territory of the region has a remarkable morphological variability, with the presence of surfaces dating to very different ages and a great variability of soils that were

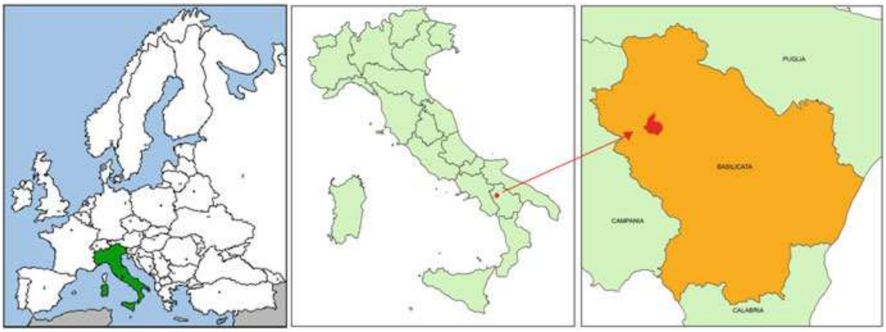

Fig. 1 Study area located in Basilicata region (southern Italy)

formed within these environments. This area is characterized by a hilly/mountainous terrain, and elevations are within the range of 400–1,000 m. The rainfall during the year is on average 751 mm. This area includes two fundamental complexes, one limestone and dolomite (carbonate series) and the other is largely terrigenous and defined by flysch. The geomorphological features of this area are related to the character of the outcrops. The study area is crossed by the Fiumara di Avigliano and is bounded in the south by the Fiumara di Ruoti. Both rivers are part on the hydrographic basin of the river Sele. The study area is predominantly occupied by agricultural land (57 %), forested and seminatural land area (38 %), and artificial surfaces (5 %). The high hilly landscape of the study area is characterized by arable land, which is present especially in the hills, with wide pastures and vineyards in the northern area. The mountains are covered with rich woodlands, consisting mainly of underwood, such as fir-wood, with elements of *Abies alba* (a biotope surveyed by the Italian Botanical Society).

The Municipality of Ruoti is characterized by an economy that is mainly based on agriculture, but some industrial activities are present. Cereal crops are widespread, as well as herds of sheep and goats, whose milk gives an excellent cheese. Wheat, fodder, and vegetables are grown, and there are olive groves, orchards, and vineyards, the latter producing the well-known Asprinio wine. The industry is mostly aimed to the food sector, the main product being milk.

Ruoti is a center of ancient origin, dating back to pre-Roman times, as demonstrated by a series of finds. The territory has been subjected over the centuries to domination by different groups, as evidenced by historical and architectural finds such as churches and monuments.

3.2 Cartography

To understand the changes that have affected the study area during the last two centuries, four different time steps (years) were analyzed: 1848, 1877, 1953, and 2012. The maps were firstly scanned and digitized within a Geographical Information System, then the land-use categories and elevations from each map were extracted, and the differences among the different time levels were evaluated (Tucci and Giordano 2011). Through the digital processing of the maps that were found, it was possible to reconstruct the three-dimensional shape of the land in the study area and, thanks to a photomosaic procedure, achieve a virtual reconstruction of the land during these different time periods. However, before using the information contained in old maps for historical studies, its quality had to be assessed and some aspects need to be considered: the topographic accuracy that denotes the quantity and quality of information about landscape objects; the chronometric accuracy, in other words, the dating of the map and the dating of the information contained in the map; and the planimetric completeness (or geometric accuracy) (Jenny and Hurni 2011).

3.2.1 The 1848 Historical Map

The first historical maps were produced after border disputes by legal experts; an historical map of the Municipality of Ruoti was produced in 1848 to resolve border disputes and it remained the main document of the historical memory, representing the whole territory for investigations of the land. This map shows the land that was studied and measured during the division of the former feudal domains and the subsequent controversy. It constitutes a complete cartographic support with thematic information about the land use at that time. The map reports on the town and the surrounding area and shows the main rivers in the area (Fiumara di Ruoti and Fiumara di Avigliano); in the north of the area, there are lands present that can be classified as nonirrigated arable land and irrigated land; in the central part of the territory, there is an alternation of olive groves and arable crops; while in the eastern part, a set of symbols describes the layout of the vineyards. It also appears that a portion of land is classified as woodland. The legend located with the western part of the map shows the territorial extension of the categories of vegetation that are here represented. The place names of various districts are reported too; however, the farms and the roads within the area are unfortunately not reported at all.

3.2.2 The 1877 Map

The morphology and land use for 1877 were analyzed through a topographic map of the Italian Topographic Military Institute (ITMI), named after 1882 as Italian Geographic Military Institute (IGMI). The scale of the map was 1:50,000; it has been digitized through a process of scanning and georeferencing. The map shows in black and white contour lines with an equidistance of 10 m and gives some information about the toponyms and the presence of farms. The projection is an amended Flamsteed, and the coordinate's origin is at the intersection of the meridian of Naples with the 40th parallel. The study area falls into two sheets (sheet no. 65 "Avigliano," both its western and eastern part).

3.2.3 The 1953 Map

The stereoscopic aerial coverage of the national territory was made through photogrammetry (each photogram was shot with a camera equipped with a lens with focal length of 152 mm, the size of the photo is 230×230 mm, and its approximate scale is 1:33,000). The analysis of the land use relative to 1953 was possible by an aerial photogrammetric survey that was performed in the 1950s, from which the different categories of land use of the study area were obtained. From the morphological point of view, a map of IGMI (scale 1:25,000) was used as the basis for entering the contour lines. So, it was possible to derive the elevations of the area and subsequently, through appropriate GIS elaborations, the Digital Elevation Model.

3.2.4 The 2012 Map

To determine the land use for 2012, digital orthophotos were utilized. Digital orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. Unlike a standard aerial photograph, relief displacement in orthophotos has been removed so that ground features are displayed in their true ground position. This allows for the direct measurement of distance, areas, angles, and positions. The orthophotos are able to display actual ground features; in the ideal situation, one aerial photograph will be used to create an entire orthophoto which allows the identification of a great level of detail. The photography is scanned and converted into a digital image from which it is subsequently possible to identify a great number of elements: land use, farms, vineyards, olive groves, and basins for water collection. The morphology of the land was derived from the Digital Elevation Model (DEM, with a cell size of 20 m). In addition, using specific tools—namely, slope (the inclination of a surface) and aspect (that can be generated from continuous elevation surfaces, usually measured in degrees from north)—the main features of the studied area were evaluated.

3.3 Data Analysis

For each considered time period, and taking into account the different base maps that were presented above, various categories of land use were identified, considering the symbols available on the map and the level of detail of the cartographic base. In the case of the historical map, the different categories of land use were well marked and six categories have been identified. Through the Italian Topographic Military Institute (ITMI) map, the analysis even of the suburban nucleus in the area has been identified, in addition to various forms of vegetation. Eight different categories of land use have been therefore identified. The land use for 1953 was derived from the analysis of georeferenced aerial photos, which showed a greater degree of detail, where it is possible to identify 10 categories; finally, in the color orthophotos for the 2012 map, no. 11 different categories of land use have been identified. In order to make the data more uniform and allow a more direct comparison, the main categories of land use have been therefore aggregated and defined as “elements.”

In the study area, four major “elements” were identified. For each of them, using the GIS function, the total area expressed in hectares (ha) and the percentage of the study area were calculated. Their variation over the years was also calculated. The most important elements found in this area are rivers, urbanized areas, natural land, and agricultural land described as follows:

Rivers These were considered in their areal extent, that is, the bed of the river and the vegetation present along the river, both as their linear extension. Streams and rivers cause erosion, sediment transport, and changes in the flood plain and floods.

Most of the erosion process is accomplished both by rainwater and by surface waters that flow downstream. Streams and rivers, through their action, are able to change the morphological structure through their erosive action by creating channels, canyons, and valleys and by transporting deposits of solid material to flood plains and deltas. Much of the current landscape is the result of an erosion process.

Urbanized Area This includes the town, the old buildings and those from recent expansion, and the buildings and farms present in rural areas. Most of the current urbanized land is covered by structures.

Natural Land This includes forest and transitional woodland and shrubland. Forests are mainly composed of vegetation, principally trees, but also include shrub and bush understory, where broad-leaved species are prevalent. Transitional woodland can represent either woodland degradation or forest regeneration/recolonization. Natural land is formed by bushy or herbaceous vegetation with scattered trees.

Agricultural Land This comprises arable land, olive groves, vineyards, pastures, and natural grassland. Arable land includes cereals, legumes, fodder crops, root crops, and fallow land. It includes trees crops and vegetables, whether in open fields or in greenhouses. The olive groves consist of areas planted with olive trees, where the simultaneous presence of olive trees and vineyards can be detected as well. Natural pastures are areas with spontaneous herbaceous vegetation.

3.4 Results

From the superimposition of the different base maps, it was possible to identify the different categories of land use. The number of classes identified increased at each step in time, mainly due to the improved detail provided by the evolving cartographic information. The results of this territorial analysis are presented in Table 1 and Fig. 2. To make the analysis and the comparison of the categories of land use over the years more uniform, they were suddenly aggregated into only four main "elements": agricultural land, natural area, fluvial zone, and urbanized area.

The analysis of the data related to land use in different periods shows the variation in terms of the percentage with respect to the entire area; the forested

Table 1 Analysis of elements over the years

	Elements			
Year	Fluvial zone (%)	Urbanized area (%)	Natural area (%)	Agricultural land (%)
1848	4	1	10	85
1877	6	1	18	75
1953	7	2	22	69
2012	5	7	44	44

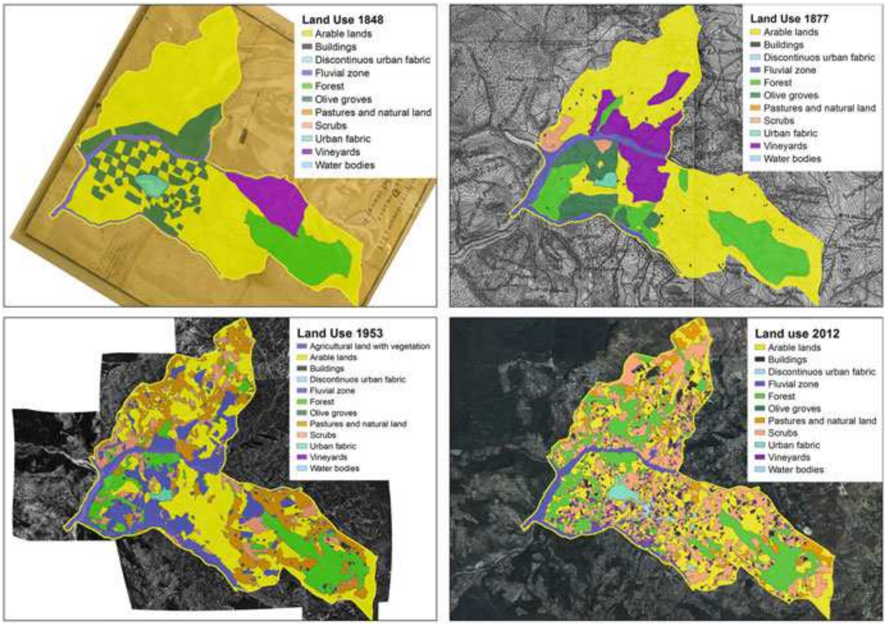

Fig. 2 Land-use categories in different periods

area has increased from about 10 % in 1848 to 18 % in 2012, the river area increased to 7 % in 1953 and then fell to 5 % in 2012, and the percentage of land used for arable land has decreased significantly from 61 % in 1848 to 33 % in 2012, while the urban fabric has increased over the years, especially after the Second World War. The main difference that occurred, as a part of a widespread trend also detected in other areas of the Basilicata region due to deep social and economical modifications occurred on time, was therefore a mutual exchange between the areas of agriculture and crops, which reduced by almost a half, giving more space to the natural areas.

From the analysis of the contour lines derived from maps from the years 1877, 1953, and 2012, it is possible to obtain the digital terrain models (DTM), thanks to an appropriate processing. These data, adequately treated with spatial analysis procedures, allowed an evaluation of the morphological changes in terms of elevation of the study area. All the four elevation profiles have changed over the years. The altimetry has changed, mainly when the lines for the periods 1877 to 1953 are compared, showing a general reduction of the altimetry of the examined area. This event should be probably connected with the general evolution over time of the morphology of the land, mainly connected with natural events like floods, landslides, and soil erosion, so frequent within this area, causing most of the morphological changes that have occurred over the years.

The contour lines obtained from the digitization of the map for 1877 have allowed the development of digital terrain models. Using spatial analysis functions,

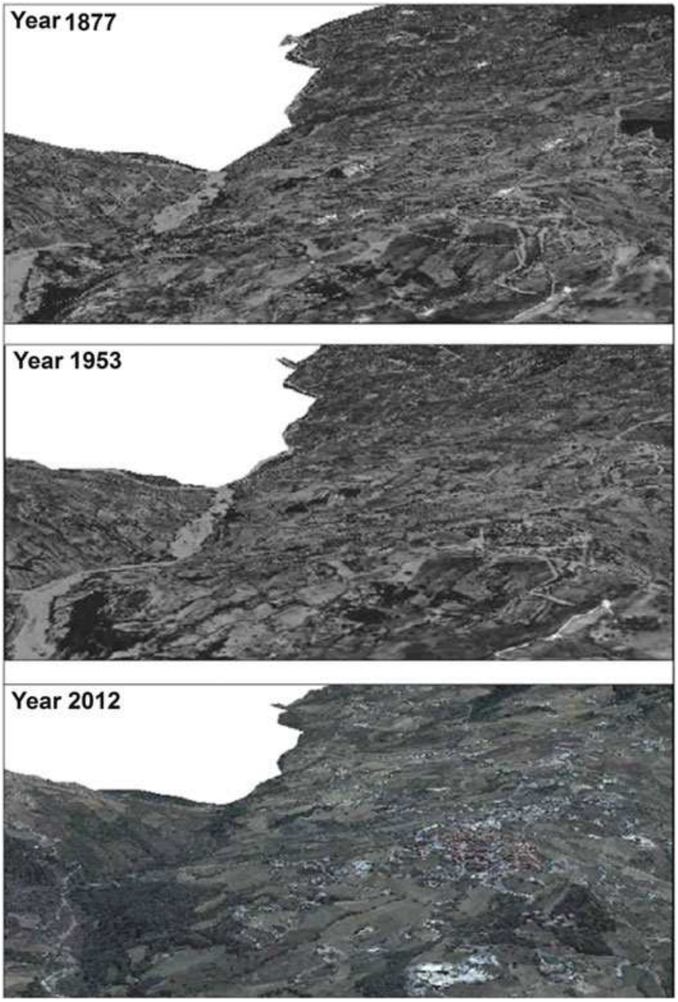

Fig. 3 Comparison of three-dimensional landscape

the map of year 1877 was appropriately correlated to the altimetry (DEM) of that year. Proper spatial analysis procedures have enabled the realization of three-dimensional views in order to appreciate the landscape changes. Figure 3 shows an image obtained from the solid modeling of the 1877 map on which a "virtual orthophoto" of the same year was draped. The virtual orthophoto reported here was associated with the visualization of the land use in 1877 on the aerial photo, so obtaining the reconstruction of the landscape for 1877. The picture was compared with the same images for 1953 and 2012. From the comparison between the three-dimensional reconstructions, it is possible to appreciate the landscape changes qualitatively and the aesthetic quality of the study area in terms of the morphological and vegetative variations of the agroforestry landscape.

4 Analysis of Time Evolution of Agroforestry Land as a Tool for the Sustainable Management and Planning of Rural Land andEnvironment

From the analysis of land-use evolution that was here performed, it can be noticed how, during the investigated time spans of about 160 years, the land used for agricultural production has progressively decreased, to the benefit of the natural areas that have in the meantime expanded, occupying most of the area lost by the former. This phenomenon was probably due to the constant increase of agricultural mechanization and diffusion of chemical products into intensive agriculture, which led many traditional farmers to abandon their estates and to consequently transfer into the urban area. Thus, this phenomenon has allowed a natural vegetation to grow over the years, spontaneously covering areas that were cultivated in the past. The increase in urbanization is the result of the development of this territory, but its expansion without a proper development policy has facilitated the proliferation of residential areas with the consequent abandonment and fragmentation of the rural territory and its landscape.

An appropriate environmental approach could also be revealed to be useful if focused on the balance of carbon dioxide fixation connected to different crop strategies. All the land changes detected in the study area have caused a progressive decrease in carbon dioxide sequestered by the biotic agents embedded in the soil. The cultivation conversion occurred over time and the increase of urban areas caused a consequent constant loss of the CO_2 fixation value, while the heavy emission of greenhouse effect gas in the atmosphere by urban settlements has been increasing at the same time (Statuto et al. 2013).

Considering the elevation profiles obtained, it is possible to observe that the altimetry data relating to 1877 was consistently higher than for later periods. The profiles obtained from the elevations of 1953 and 2012 are very similar to each other, so it is possible to attribute the differences to the presence of small rivers that, over the years, have had a deepening of their beds. This situation is typical of the whole area of the Apennines, since it is connected to a strong hydrogeological instability.

The landscape analysis using the three-dimensional modeling allowed the evaluation of the simultaneous changes both in land use and in the morphological variations that involve landscape modification. Figure 3 shows that a great part of the territory has significantly changed: some of the areas that in 1877 were covered by forests have, over the years, turned into arable land, so determining a clear change in the visual quality of the rural landscape.

The analysis that was performed over the three-dimensional images of the territory has been revealed to be a powerful means of interpretation, since it allows some dynamic effects to be created in a virtual reality system, in which the operator has the opportunity to navigate as walking or flying over the area at that time; thus, the operator is able to visit—with a virtual jump back in time enabled by the simulation of an *ante litteram* flight—real-life scenarios that would be otherwise difficult to imagine and/or reach. Then, all the aspects characterizing that area can be examined in suitable detail and completeness, starting from the analysis of topography and land cover and leading to anthropic components (buildings, roads, and railways, hydraulic infrastructure such as dams, aqueducts, etc.).

5 Conclusions

The role of territorial analysis is extremely important and delicate, especially if carried out to pave the way for proper planning activities. The understanding of the landscape's evolution over the years, both in morphological and vegetation terms, represents a highly valuable database usable by public decision-makers in the normal processes of making economic and political choices for the government of the territory. All of this should be in harmony with the historical changes in the rural territory that current events, according to the modern ways of conceiving the suburban areas, bring into play over social aspects closely related to the traditions and customs of the past.

The evolution of computer technology, coupled with the availability of historical maps, has proved to be a decisive tool in the creation of appropriate instruments for the representation of agricultural land and forest, which could allow an effective step forward to be taken in the process of encouraging sustainable economic development. This phenomenon caused a corresponding increase in the natural vegetation area, but also an increase in surface erosion due to an improper land management.

The analysis of the evolution of land use over a long time period—as in this case, where nearly two centuries were considered—can show how the results of the applied agronomic practices, in terms of CO_2 fixation, would be able to compensate for heavy emissions of greenhouse effect gases in the atmosphere by urban settlements. This would demonstrate how correct rural site management could efficiently balance environmental pollution brought about by human development. The spatial analysis that was conducted allowed to understand the landscape dynamics of the past, current developments, as well as possible future trends. Similar information should be adequately considered to help in addressing the need for suitable development policies and appropriate land management planning.

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Processing Plants and Technologies for a Sustainable Mediterranean Food Chain

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Abstract The growing demand of fresh fruit and vegetable, free of pathogens and chemical residues, requires the application of safe and sustainable technologies for extending the storage life of these products. Furthermore, a very interesting and profitable activity is the isolation/extraction of pure natural (herbal) components that could be used by food, pharmaceutical, and cosmetic companies. In this context, several technologies have been developed in order to preserve fruits and vegetables during postharvest, also by using biocontrol agents, natural antimicrobials, GRAS (Generally Recognized As Safe) agents and physical treatments, and to recover valuable compounds as essential oil (from leaf, skin, pulp, or seed) using the most appropriate technology (extraction, distillation, or drying). In this chapter, authors, focusing on some of Mediterranean basin productions that are components of the Mediterranean diet, describe the main sustainable and innovative technologies and the related plants, suitable for management of fruits and vegetables postharvest and for recovery of essential oils from plant materials.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_22

1 Introduction

Since the early time, many species including temperate fruits, vegetables, and herbs have long been cultivated in Mediterranean basin and became elements of the Mediterranean diet.

In the last century, the health benefits were investigated and the interest of the public and scientific communities increased due to both its sensory and nutritional value and the importance in the human diet of specific components as antioxidants, essential oils, vitamins, and phenolics.

Nowadays, it is well known that in order to fulfill the growing demand of fresh but perishable vegetable products, free of pathogens and chemical residues, application of safe and sustainable technologies for extending the storage life of these products is of utmost importance. In addition, a very interesting and profitable growing branch is the isolation/extraction of pure natural (herbal) components that could be used by food, pharmaceutical, and cosmetic companies.

2 Technologies for the Postharvest Storage of Fruits and Vegetables

Significant quality improvements of perishable products could be achieved by cooling to the optimal storage temperature immediately after harvest and maintaining this appropriate temperature through the whole handling and transportation chain. Generally, the temperature decrease slows metabolic processes such as respiration and ethylene production, by suppressing ripening related to enzymes, and the development of pathogens. However, most perishable horticultural commodities have an optimal shelf life temperature that differs by commodities, whereas storage below this optimal temperature can induce a rapid tissue deterioration (chilling injury). Furthermore, the relative humidity (RH) can also influence water loss, decay development, the incidence of some physiological disorders, and the maintenance of acceptable visual quality, where an appropriate RH range for storage of fruits is 85–95 % and for most vegetables varies between 90 and 95 %.

In the last years, the research about the use of *natural biocontrol agents* or antimicrobials such as plant extract (*essential oil*) and *salts* has been very active. The mechanisms by which microbial antagonists exert their influence on the pathogens have not yet been fully understood. Several modes of action have been suggested to explain the biocontrol activity of microbial antagonist; still, competition for nutrient and space between the pathogen and the antagonist is considered as the major modes of action by which microbial agents control pathogens causing postharvest decay (Ippolito et al. 2000; Ippolito and Nigro 2000; Jijakli et al. 2001).

Essential oils are applied as flavoring agents in foods, and, thanks to their antimicrobial compound content, they have potential as natural food preservation agents. Elizaquivel et al. (2013) proved the efficiency of three essential oils, 1 %

clove, 2 % oregano, and 0.1 % zataria, at 37 °C on the infectivity of the *Murine norovirus*, which has been listed among the five highest-ranking pathogens in terms of the total cost of foodborne illness in the United States.

Salts are inexpensive, easily accepted by consumers, nontoxic, with minor environmental impact at the effective concentrations, and usually used in the food industry. Several inorganic salts show activity against a range of phytopathogenic fungi; in particular, postharvest treatments with calcium chloride and sodium bicarbonate have been proposed as safe and effective alternative means to control postharvest rots of fruit and vegetables. This treatment can be applied alone or in combination with other physical and/or biological treatments (Ippolito et al. 2005; Karabulut et al. 2004).

1-Methylcyclopropene (1-MCP) treatment is an alternative method of slowing ripening which inhibits ethylene action of climacteric fruits. The stable formulation of 1-MCP is a powder in complex with cyclodextrin, which allows to release the product as a gas when the powder comes in contact with water. The highest concentration of 1-MCP approved for use is 1 μl/l (Lurie and Paliyath 2008).

Chlorine dioxide (ClO_2) is an oxidizing agent with strong antimicrobial proper yeasts and molds, and it is 3.5 times as powerful as chlorine or chlorinated water (Artes et al. 2009; Gomez-Lopez et al. 2009); either gaseous or aqueous form can be used for disinfecting fresh fruits and vegetables (Park et al. 2008). Chlorine dioxide was successfully used to control Escherichia coli on apple skin and strawberries, to wash iceberg lettuce, and it was also able to control Salmonella on red chard leaves and tomato (Keskinen and Annous 2009; Trinetta et al. 2010; Tomas-Callejas et al. 2012).

Ethanol is a common food additive with antimicrobial activity which affects ripening and senescence in some fruit and vegetables. Recently, many studies dealing with table grape preservation techniques have evidenced that the use of ethanol suppressed microbial growth and prevented berry decay; these effects were also found in peaches and citrus fruit (Smilanick et al. 1995).

Electrolyzed oxidizing (EO) water is generated by electrolyzing a NaCl solution to release free chlorine into the water. The EO water was reported to be effective in reducing *E. coli* populations on various produce (Pangloli et al. 2009); however, the use of this disinfectant is not sufficient as single treatment, to reduce microbial populations below the desirable safe level, and its effectiveness is also influenced by the presence of organic materials, including fats, carbohydrates, and protein-based materials (Barrera et al. 2012), and by pH, temperature, water hardness, chemical inhibitors, concentration, and contact time (Srey et al. 2013).

Hydrogen peroxide (H_2O_2) is a strong oxidizer and is effective against a wide range of bacteria, yeasts, molds, viruses, and spore-forming organisms. From the safety point of view, H_2O_2 is known to be a safe solution which does not cause allergic reactions, even at concentrations between 0.08 and 0.2 %.

Organic acids are recognized as an ideal antimicrobial agent due to their strong oxidizing capacity; they are mostly used as sanitizers of fresh products. The antimicrobial activity of lactic acid, citric acid, acetic acid, and ascorbic acid was proved against *E. coli* and *Listeria monocytogenes* on iceberg lettuce (Akbas and Olmez 2007), while the malic acid was successfully used to inactivate foodborne pathogens (*E. coli*, *Salmonella typhimurium*, and *L. monocytogenes*) in apple, pear, melon juices, spinach, and lettuce without impairing produce quality (Massilia et al. 2009; Choi et al. 2012).

Ozone (O_3) is a natural substance in the atmosphere and a potent antimicrobial agent that can be used against a wide spectrum of microorganisms as *bacteria*, *fungi*, *viruses*, *protozoa*, and *bacterial and fungal spores* (Srey et al. 2013); it has a strong odor and a powerful oxidant effect on carbon residues dissolved in the washing water as well as on the produce surface. Intermittent ozone treatment (both in air and water) could reduce postharvest losses in orange fruit during long-term storage (Di Renzo et al. 2005), using adequate storage conditions (low temperature and high relative humidity). Authors carried out the trials on *Ovale* and *Valencia* oranges (*Citrus sinensis Linn Osbeck*) inoculated by dipping in a suspension of *P. digitatum Sacc.* and kept at 20 °C for 24 h before the treatment. Control was compared with ozonized water (0.6 mg/L ozone) and chlorinated water (50 mg/L chlorine). After washing, fruits were also stored in an intermittent ozone air mixture (0.25 ppm ozone). Decay incidence was assessed as mold incidence caused by blue mold (*P. italicum Wehmer*) and green mold (*P. digitatum Sacc.*) or as miscellaneous molds of unidentified fungi. Results showed a synergistic effect of ozone and chlorine treatments in water and of fruit exposure to ozone in air, preventing mycelial growth and sporulation on inoculated fruits. Using ozonized air during cold storage reduced weight loss to about 10 % compared to the control. Ozone could be used in substitution of chlorine to control disease incidence during the long-term storage of oranges. Admane et al. (2014) carried out a study in order to maintain the quality of organic table grapes ("Early Superior Seedless 'Sugraone'") with alternative safe treatments to the sulfur dioxide (SO_2), not allowed in organic product. Detached grape berries were pretreated by (1) dipping in ethanol and potassium bicarbonate, (2) massive CO_2 concentrations, and (3) ozone (O_3) fumigation, whereas untreated berries were included in the trial as control. Moreover, all the samples were packed in thermo-sealed bags with MAP of 2 % O_2:5 % CO_2:93 % N_2 and stored at 0 °C for 45 days. Results showed that after 45 days of storage, weight loss was higher in the sample pretreated with both massive CO_2 (70 and 90 %) and control. Both the samples pretreated with CO_2 at 70 % and O_3 at 20 ppm maintained the strength of the berry linked to its pedicel; also the berry and skin firmness were statistically higher in samples pretreated with CO_2 at 90–70 % and O_3 at 20 ppm in comparison with the control. The skin color parameters and titratable acidity decreased, while pH increased in all samples in comparison with their initial value. Soluble solid content increased in samples treated with O_3 at 20 ppm, CO_2 at 70 %, and dipping. Sensory evaluation scores gave the decisive data for the selection of the best combination treatments in order to validate their efficiency and that of the film packaging on late-season organic table grape "Scarlotta/Sugraninteen." Samples pretreated by dipping showed the highest scores for crunchiness, firmness, sweetness, and sourness. In conclusion, the efficiency of both film packaging and MAP inhibited the occurrence of berry decay in all samples including the control. Furthermore, in recent studies, it was reported also a reduction of fungicides residues in Thompson Seedless table grapes fumigated with O_3 (Karaca et al. 2012). O_3 is effective at lower concentrations (1–5 ppm) and shorter contact times (1–5 min) than chlorine (Srey et al. 2013), and it can react with organic matter up to 3,000 times faster than chlorine (Rosenblum et al. 2012). However, it may become ineffective with low amounts of organic materials and dirt that could be on the produce external surface.

Coatings consist of a thin layer of edible materials applied to produce surfaces (Campos et al. 2011). The preservation of fresh produce can also be achieved by the application of edible coatings, by decreasing moisture loss and controlled gas (CO_2/O_2) exchange, resulting in reducing respiration rate (Hernandez-Munoz et al. 2008). It was reported that the chitosan has been found to be an ideal preservative coating material for several fresh commodities including strawberries and cherries by limiting fungal decay and slowing down the respiration and ripening process (Han et al. 2004; Dang et al. 2010); furthermore, chitosan coating on minimally processed carrots and fresh-cut broccoli brought a reduction in the mesophilic aerobic bacterial count, without affecting the overall quality of the processed product (Pushkala et al. 2012; Moreira et al. 2011).

3 Physical Treatments

Cold Storage Management Refrigerated produce (the primary refrigerated produce are bananas, meat, citrus fruit, fish, and seasonal fruit) are widely stored and transported worldwide, and in the last years, the fruit trade from Mediterranean countries toward extra EU countries (especially Japan, United States, Canada) grew continuously, with increased volume of shipped foodstuff. Produce temperature is the most important factor affecting the quality of fruits and vegetables, which remain alive after harvest. The vegetable tissue metabolic activity requires environmental oxygen and produces carbon dioxide and heat. At any point of the cold chain, produce should be held at its lowest recommended storage temperature, and the rapid cooling after harvest (precooling) is essential to maintain the quality of fresh fruits and vegetables during postharvest handling and distribution (Opara and Zou 2007). In order to optimize the cool chain management and to promote rapid and uniform cooling of produce, several factors are fundamental: (1) the power of the cooling equipments should be adequate to the cooling time required, (2) air circulation around the produce should be adequate to the product type and the packaging material used, (3) accurate control of temperature and RH in the storage room, and (4) the refrigeration plant energy efficiency that dramatically affects the cost of storage. Furthermore, precooling to remove the “field heat” is an effective strategy to reduce the period of high initial respiration rate prior to storage and transportation. Authors (Di Renzo et al. 2011) carried out several empirical studies to optimize the precooling step on various citrus species. A pressure cooling plant,

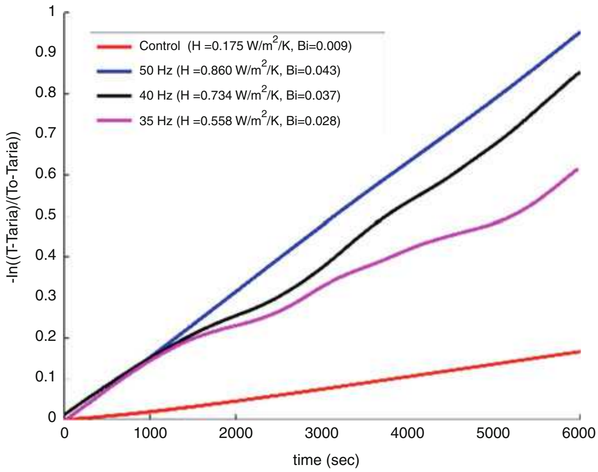

Fig. 1 Heat transfer coefficient calculated during the trials for the "control" (room cooling system) and operating the fans at frequency of 35, 40, and 50 Hz. When operating the fan at 50 Hz frequency, a "h" (heat transfer coefficient) equals to 0.86 $Wm^{-2}\ K^{-1}$ was calculated, five times greater than "h" calculated for the cooling room storage

equipped with a temperature control system, was used to study the cooling rate on Tarocco blood oranges.

In the pressure plant, the fan reduces the pressure level to 96–98 Pa in the space between the pallet rows, and the air velocity around the fruits is generally maintained around 0.8–1 m/s. Results showed that cooling rate is strictly dependent to both fan speed and pressure level. When operating the fan at 50 Hz frequency, a "*h*" (heat transfer coefficient) equal to 0.86 $Wm^{-2}\ K^{-1}$ was calculated, five times greater than "*h*" calculated for the cooling room storage (Fig. 1).

In a recent research, a tunnel-type forced-air cooler was used to rapidly cool oranges, stacked in pallet, before simulating a container cold transport. For this purpose, a refrigerated container (reefer, 40′ High Cube) was used, available at the Oranfrizer Company (Scordia, Catania, Italy). The refrigeration unit was located on the end wall of the container, defrosting operated automatically every 25 h, and each cycle held for about 30 min. Cold air flows around the fruits in the container through the gratings in the floor and then drawn off again below the container ceiling. The circulating fans force the air through the air cooler, which also acts as the evaporator in the cold circuit, and back through the gratings into the cargo. The container was loaded gradually, starting with the pallet to be placed in the end side of the container, and every time a pallet was loaded on the container and before the final placing, also temperature probes were placed into the fruits, making a little hole (about 0.3 cm diameter) in the fruits. Data showed a good result in terms of temperature homogeneity, which varied in a short range (±0.5 °C) depending on probe location inside the container; temperature reached a minimum level of about −0.8 °C during the early stage when cooling system starts. This minimum level can be considered too low for orange fruits, due to the risk of cold damage rising (about −1.0 °C).

Generally, also a 90–95 % relative humidity (RH) is needed to obtain the best shelf life of most fruits and vegetables, except for few species (bulb onions, garlic, winter squashes, ginger). Low RH around the produce causes wilting or shriveling, reducing marketability. When moist air contacts with a cold surface that is at a temperature below the dew point of water vapor in the air, condensation will occur, and frost begins to form if surface temperature is below the freezing temperature of water, so frost growth on heat exchangers placed in the cold room is a common problem for refrigeration systems, and it affects the thermal performance of heat exchangers in several ways (Chen et al. 2003).

Frost growth on heat exchanger surfaces increases the thermal resistance between the fins and the airflow (Na and Webb 2004) and decreases the cooling capacity of heat exchangers used in refrigeration systems and reduces the airflow through heat exchangers and increases the air pressure drop (Chen et al. 2003).

In a recent study (Altieri et al. 2007), authors evaluated the performance of a frosted finned tube heat exchanger for different cooling capacities and heat transfer mechanisms, with the aim to design a new defrosting system based on indirect measure of frost layer present on the heat exchanger surface.

Air temperature, brine temperature, air speed through the cooler fins, and the electric power absorbed by the fans were measured. Data collected during the trials showed that reducing the heat load inside the cold storage room, i.e., increasing the refrigeration power with respect to the same heat load, requires a more frequent defrosting operation and increases energy consumption.

Experimental trials showed that frost deposition is the fastest when the heat transfer mechanism is the free convection. Furthermore, fan power absorption seems to be an optimal marker to control frost on finned tube heat exchanger placed in high-humidity environments. The presence of the frost on the exchanger surface decreased air velocity through the air cooler and caused an increase of fan power absorption around 7 % from the beginning to the end of the test (Fig. 2). The direct correlation between frost thickness and absorbed power makes this parameter suitable to continuous control of defrosting process.

Modified and Controlled Atmosphere Storage A controlled atmosphere (CA) or modified atmosphere (MA) around the produce is created by alterations in the concentrations of the respiratory gases in the storage atmosphere; these alterations

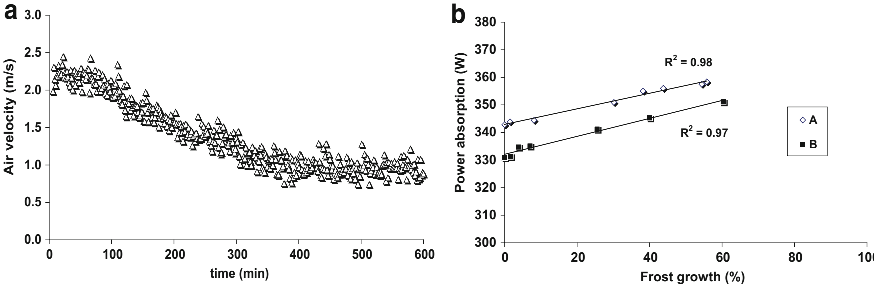

Fig. 2 Frost on the exchanger surface decreased air velocity through the air cooler (**a**) and caused an increase of fan power absorption (**b**) around 7 % from the beginning to the end of the test

include elevation of carbon dioxide (CO_2) level, reduction of oxygen (O_2) tension, or both. Whereas the term CA storage generally implies precise control of O_2 and CO_2 concentrations in the atmosphere, the term MA storage is broader and may indicate any synthetic atmosphere, arising intentionally or unintentionally, in which the composition of its constituent gases cannot be closely controlled. Carbon dioxide is the only gas used inducing a significant level of antimicrobial activity and survival on the produce. These induced environmental conditions have a marked effect on product physiology, starting from altered primary metabolism and respiratory pathways, and involve changes in gene expression, protein accumulation, and metabolite concentrations (Kanellis et al. 2009). During long storage, application of low concentration of O_2 is able to delay the decay on cherries, blueberries, raspberries, strawberries, figs, and pomegranates. While storage under CA (12 % O_2 + 12 % CO_2) for up to 8 weeks controlled significantly postharvest disease and maintained the quality of organic table grapes, storage under CO_2 at high concentration (90 % or more) is used in order to quickly remove astringency from kaki (or Japanese persimmon), a high nutritional fruit very popular in the Mediterranean area. Di Renzo et al. (2013) carried out a simultaneous CO_2/ethylene gas treatment of persimmon, as opposed to the common sequential application of ethylene following CO_2. The influence of both treatments on the fruit quality was evaluated in terms of weight loss, color index, firmness, total soluble solids, tannin content, and juice titratable acidity, immediately after the treatment, after 7 and 21 days, to simulate the shelf life period (fruits were stored at 6 °C and 85–95 % RH). Results showed the efficacy of the simultaneous CO_2/ethylene treatment that within 7 days after the treatment allows picking up immature persimmons to complete the simultaneous treatment within 24 h to have ready to eat fruits for market, optimizing the chain of such a short-season produce.

Modified atmosphere packaging is a nontoxic method for keeping quality and extending shelf life of fruits and vegetables (Kader et al. 1989), by reducing respiratory activity, delaying softening and ripening, and reducing the incidence of various physiological disorders and pathogenic infestations (Caleb et al. 2013) due mainly to the relatively low oxygen and high carbon dioxide levels inside the package.

Ultraviolet-C (UV-C) irradiation light is part of the electromagnetic spectrum, with wavelengths between 200 and 280 nm; due to its antimicrobial effect and low cost, this treatment is attractive to the food industry (Shim et al. 2012). The effectiveness of this treatment for microbial inactivation depends mainly on radiation dose and the structure and topography of the surface of the product.

Heat treatment has been recognized as a feasible postharvest treatment for fruits and vegetables with potential to delay ripening and decay, since it is easily applied, leaves no chemical residues, and can reduce the initial population of microorganisms. These effects include changes in tissue respiration, hormone production, particularly ethylene and enzyme activities, and other changes that impact on fruit and vegetable quality. Heat treatments include hot water dips, hot water brushing, and hot air treatments (vapor heat and forced air). The type of high-temperature treatment and its duration affects fruit or vegetable ripening or senescence as well as nutritional and quality attributes.

4 Isolation of Natural Preparations from Plants[1]

A very interesting and profitable area is the isolation of pure natural substances using plant materials for pharmaceutical, cosmetic, and food companies. The natural products are used as food ingredients, as cosmetics, and as components of pharmaceutical preparations (for example for antitumor, sedative, and UV-protection drugs). Several species are very interesting for the isolation of extracts and manufacture of the preparations for example grape marc, olive pomace, citrus pulp poppy (*Papaver somniferum* L.), milk thistle (*Silybum marianum* L.), henna (*Lawsonia inermis* L.), horse chestnut (*Aesculus hippocastanum* L.), and leuzea (*Rhaponticum carthamoides*/*Willd*./*Iljin*).

Herbal substances are all mainly whole, fragmented, or cut plants, plant parts in an unprocessed usually dried form but sometimes fresh. Herbal substances are precisely defined by the plant part used and the botanical name according to the binomial system (genus, species, variety, and author). Herbal preparations are obtained by subjecting herbal substances to treatments such as distillation, extraction, and freeze-drying.

Essential oils are odorous products, usually of complex composition, obtained from a botanically defined plant raw material by steam distillation, dry distillation, or a suitable mechanical process without heating. Essential oils are usually separated from the aqueous phase by a physical process that does not significantly affect their composition.

The large-scale technology of essential oil distillation generally consists of a main distillatory apparatus (funnel shaped, thermal isolated), a steam condenser, and an additional apparatus (steam boiler and apparatus for improving of a used water). An inside screw plate is driven by an electric engine, which is installed on the apparatus. This screw plate works as an excellent stirrer. With reference to this system, the container has a mixing apparatus, which is not a usual feature in many other types of commercial equipment. This is extremely useful for a complete distillation procedure in order to obtain high yield of essential oil. The source of steam flow is a boiler (heated by oil, gas, or electricity), and the flow is controlled mechanically, according to the plant mass and cooling requirement. The length of distillation depends on medicinal plant species, which are used to the isolation of essential oils (Salamon 2014; Bucko and Šalamon 2007).

[1] Part of the described research about the isolation of components by lyophilization was supported by the Ministry of Education, Science, Research and Sport, Slovak Republic, in the project The Isolation of Plant Natural Components by Lyophilization Process and Modification of their Qualitative-Quantitative Properties (No. 00162-0001 /MŠ SR-3634/2010-11/).

The essential oil is produced by the passage of steam through the plant raw material in a suitable apparatus. The steam is introduced from an external source or generated by boiling water. At last steam and oil vapors are condensed, and the water/essential oil mixture is separated by decantation.

Extracts are preparations of liquid (liquid extracts and tinctures) and solid (dry extracts) consistency, obtained from herbal drugs, which are usually in a dry state.

Liquid extracts (*extracta fluida*) are liquid preparations in which, generally, one part by mass or volume is equivalent to one part by mass of the dried herbal and animal matter. These preparations are adjusted, if necessary, so they satisfy the requirements in terms of residual solvent content and, where applicable, of constituents. Liquid extracts are prepared by using ethanol in a proper concentration or water to extract the herbal drug or by dissolving a soft or dry extract (which has been produced using the same strength of extraction solvent as is used in preparing the liquid extract by direct extraction) or the herbal drug in either ethanol or water. Liquid extract may be filtered, if necessary. A slight sediment may form on standing, which is acceptable as long as the composition of the liquid extract does not change significantly. Dry extracts are solid preparations obtained by evaporation of the solvent used for their production. Dry extracts usually have a loss on drying or a water content not greater than 5 % m/m.

Tinctures (*tincturae*) are liquid preparations usually obtained using one part of herbal drug or animal matter and ten parts of extraction solvent or one part of herbal drug or animal matter and five parts of extraction solvent. Tinctures are prepared by maceration or percolation using only ethanol for extraction or by dissolving a soft or dry extract of the herbal drug or animal matter in ethanol. Tinctures are usually clear and are filtered, if necessary. A slight sediment may form on standing, which is acceptable as long as the composition of tincture does not change significantly.

Lyophilization (freeze-drying) is carried out using the simple principle of physics called sublimation. This technology is important in pharmaceutical, food, and cosmetic industries (Salamon et al. 2015). The process of freeze-drying consists of freezing at atmospheric pressure and sublimation at reduced pressure. On a larger scale, the process is usually done using a freeze-drying machine. In this step, it is important to cool the material below its triple point (the lowest temperature at which the solid and liquid phases of the material coexist). This ensures that sublimation, rather than melting, will occur in the subsequent step. Due to the fact that larger crystals are easier to freeze-dry, it's fundamental, in order to produce larger crystals, to freeze product slowly (for example cycling temperature up and down).

Primary drying means the sublimation of ice to water vapor and its dissipation from space of lyophilization. *Secondary drying* is the process of removing residual moisture and is carried out at increased temperatures.

After the freeze-drying process is complete, the vacuum is usually broken with an inert gas, such as nitrogen, before the material is sealed. At the end of the operation, the final residual water content in the product is extremely low, around 1–4 %. The work on optimizing the lyophilization usually consists of two parts: (1) optimization of sample dilution, due to the fact that, after evaporation of solvents, extracts from plants become viscous, and (2) optimization of lyophilization program.

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Geophysical Techniques for Plant, Soil, and Root Research Related to Sustainability

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Abstract The sustainable management of human activities, from production to waste disposal and the cycling of finite resources, is one of the great challenges of research for the coming decades, stemming from societal needs and the growing awareness of environmental mechanisms.

Research on geophysical methods provides an interdisciplinary approach to such challenges by addressing the need for techniques to assist in designing and monitoring strategies for sustainability in agriculture and other environment-related sciences.

In the past few decades, technological advances have produced new tools or have improved existing techniques for near-surface geophysical investigation in a robust, cost-effective, and noninvasive way. Experimental results have proved that soil physical properties thus detected and mapped can be used as a proxy of physical, chemical, and biological features relevant for the appropriate management of soils, based on their behavior, spatial variability, and time dynamics.

This chapter reviews principles of the techniques and reports selected research results on environmental and agronomic research.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_23

1 Introduction

Research in the coming decades faces challenges stemming from the most urgent needs of society, from a growing population to the reduced availability of important resources and problems in cycling of renewable ones. Among them pursuing sustainability plays a key role and requires the knowledge of environmental mechanisms and the ability to monitor the impact of strategy implementation. The concept of "sustainable agriculture" well identifies the relationship between agriculture and environment, with the specific challenge to produce sufficient food and fiber, as well as raw materials for "green chemistry" with acceptable environmental costs and to manage difficult environments while preserving and enhancing the amount and quality of environmental resources. The integration of the environmental concerns into agricultural policy is the key strategy for enhancing the sustainability of agro-ecosystems (EEA Report 2013). This relationship is more evident if we consider the increasing frequency of the climate-related hazards and the role of the agriculture in the climate adaptation strategies (see IPCC Report 2014 by Field et al. 2014).

The arena where agricultural land use and environmental processes meet is the soil: the thin upper part of Earth Crust (Earth Skin) represents one of the more complex systems in which lithosphere, hydrosphere, and biosphere interact and are strongly linked. The thickness of the zone beneath the Earth surface that is of interest for the agriculture science is within the range 0–2 m. There is a growing demand of near-surface observing technologies for studying a wide spectrum of phenomena in the soil having implications on agriculture and environment, from the analysis of time-dependent change of water content to the detection of pollutants and from the analysis of soil salinization and fertility to the study of soil–root plant interactions (Allred et al 2008; Vereecken et al. 2006).

Geophysics addressed these challenging themes with novel observing technologies based on completely innovative sensors (i.e., optical fibers, electromagnetic devices), advanced algorithms for 2D and 3D tomographic imaging, and new technologies for field surveying (i.e., drones and Land Unmanned Vehicles). To date, geophysics provides a set of robust, cost-effective, and completely noninvasive or minimally invasive technologies for near-surface investigations able to estimate the physical properties of the shallow layers of soil and subsoil.

Such technologies are used in a range of applications, from archaeology to hydrology or precision agriculture, and allow to acquire information that can be directly used for the description and monitoring of relevant features or can guide strategies for sampling (Rossi et al. 2011).

Research on geophysical applications in agriculture and the environment has been conducted in Basilicata in the past decade, and this chapter provides an introduction to the techniques and an overview of selected results obtained within this context.

2 Principles of Geophysical Techniques for Agriculture and the Environment

Sheriff (1991) has defined “applied geophysics” as: “making and interpreting measurements of physical properties of the earth to determine subsurface conditions, usually with an economic objective, e.g., discovery of fuel or mineral depositions.” By working at different scales, geophysical methods may be applied to a wide range of investigations. The geophysical exploration methods or geophysical surveying measurements within geographically restricted areas are used to determine the distributions of physical properties at depths that reflect the local subsurface geology.

There is a broad division of geophysical surveying methods into those that make use of natural fields of the Earth and those that require the input into the ground of artificially generated energy. The natural field methods utilize the gravitational, magnetic, electrical, and electromagnetic fields of the Earth, searching for local perturbations that may be caused by concealed subsurface features. Artificial source methods involve the generation of local electrical or electromagnetic fields that may be used like natural fields or, in the most important single group of geophysical surveying methods, the generation of seismic waves whose propagation velocities and transmission paths through the subsurface are mapped to provide information on the distribution of geological boundaries at depth. Generally, natural field methods can provide information on Earth properties at greater depths and are logistically more simple to carry out than artificial source methods.

The basic physical principles are quite simple: an energizing source, generally located on the surface, sends a primary signal (i.e., elastic waves, electromagnetic pulse) into the ground and a receiving system detects a secondary signal generated by the interaction between the soil and the primary signal. The analysis of the geophysical signals measured by means of the receiving system allows us to reconstruct the spatial pattern of the physical properties of the subsoil (i.e., density, electrical resistivity, electrical permittivity). In absence of an artificially generated signal, the geophysical methods are identified as passive and the sensors can only detect the fluctuations of the natural geophysical field (magnetic, electric, gravimetric). The investigation depth and the spatial resolution of the geophysical methods are strictly connected to the frequency of the energizing signal and to the electrodic distance between the transmitting and receiving sensors (Steeples 2001).

As the range of applications of geophysical methods has increased, the subdiscipline of “environmental geophysics” has been defined as follows: “The application of geophysical methods to the investigation of near-surface physicochemical phenomena which are likely to have (significant) implications for the management to the local environment” (Greenhouse 1991; Steeples 1991).

A wide range of geophysical surveying methods applied to environmental problems exists, for each of which there is an “operative” physical property to which the method is sensitive. Methods are listed in Table 1.

Table 1 Geophysical methods

Method	Measured parameter	Operative physical property
Seismic	Travel times reflected/refracted seismic waves	Density and elastic moduli, which determine the propagation velocity of seismic waves
Gravity	Spatial variations in the strength of the gravitational field of the earth	Density
Magnetic (Mag)	Spatial variations in the strength and of the geomagnetic field	Magnetic susceptibility
Electrical resistivity	Earth resistance	Electrical resistivity ρ Electrical conductivity (EC)
Induced polarization	Polarization voltages or frequency-dependent ground resistance	Electrical capacitance
Self-potential (SP)	Electrical potentials	Electrical conductivity (EC)
Electromagnetic	Response to electromagnetic	Electrical conductivity (EC) and inductance
Radar	Travel times of reflected radar pulses	Dielectric constant

Geophysical methods are often used in combination because in the phase of interpretation the ambiguity arising from the results of one survey method may often be resolved based on results from another method. The main fields of application of geophysical surveying and the most appropriate surveying methods are listed in Table 2.

Geophysical imaging techniques offer high spatiotemporal resolution combined with a noninvasive character and are a very attractive tool for soil characterization without disturbance (Michot et al. 2003; Samouelian et al.. 2003; al Hagrey 2007; Besson et al. 2010).

Among the numerous techniques, electrical and electromagnetic methods are most often used, and we will describe some of them, with emphasis on methods which have been used in case studies from research teams in Basilicata.

Self-Potential and Magnetometry are passive methods based on measurements of electrical and magnetic natural fields carried at the earth surface. They are the oldest geophysical methods and have been first applied using purely qualitative approaches. Nowadays, thanks to novel algorithms for tomographic data inversion, these old methods are becoming modern tools for innovative application in hydrogeophysics and environmental sciences (Chianese and Lapenna 2007; Soueid Ahmed et al. 2013). The SP method is a very promising tool for studying the water–plant root interactions, while the Mag method is suitable for mapping the presence of heavy metal in soil.

Electrical conductivity (ECa) or its inverse resistivity (ER) is one of the most utilized variable to indirectly assess soil spatial variability in agricultural fields (Corwin and Plant 2005).

Table 2 Main fields of application and relevant methods of geophysical survey

Application	Appropriate survey methods*
Exploration for fossil fuels (oil, gas, coal)	S, G, M, (EM)
Exploration for metalliferous mineral deposits	M, EM, E, SP, IP, R
Exploration for bulk mineral deposits (sand and gravel)	S, (E), (G)
Exploration for underground water supplies	E, S, (G), (Rd)
Engineering/construction site investigation	E, S, Rd. (G), (M)
Archaeological investigations	Rd, E, EM, M, (S)
Agriculture	G, M, S, EM, E, SP, IP, R, Rd

G gravity, *M* magnetic, *S* seismic, *E* electrical resistivity, *SP* self-potential, *IP* induced polarization, *EM* electromagnetic, *R* radiometric, *Rd* ground-penetrating radar. Subsidiary methods in brackets.
Source: Kearey et al. (2002)—An introduction to geophysical exploration (modified)

The techniques commonly used to measure the ECa variation within the root zone at field scale are essentially two: Electrical resistivity (ER) and Electromagnetic induction (EMI).

EMI methods use dual coil systems in which a transmitter coil is used to generate a primary electromagnetic field. When this electromagnetic field travels through the soil, eddy currents are generated as a function of soil conductivity, and this produces a secondary magnetic field which is detected by the receiving coil together with the primary magnetic field.

Electrical conductivity is then calculated as a function of the difference between the primary and the secondary magnetic fields. The explored soil volume is function of: the distance between transmitting and receiving coils, coils' operating frequency, coils' orientation, and distance from the soil.

The first applications in agriculture were on soil water (Edlefsen and Anderson 1941) and salinity (Rhoades and Ingvalson 1971), but a major diffusion of the technique in the 1980s is linked to the development of precision agriculture, based on optimization of agricultural management within a field. Technologically, this was also made possible by the growing availability of GPS which allowed the use in dynamic mode. Electromagnetic tools are easy to carry in the field and do not require contact with soil, therefore horizontal variations are easily mapped even in harsh environments (frozen/dry soil), during the cropping season by lifting the instruments above the canopy or with crop residues covering the soil surface (Brevik et al. 2003). Characterizing electrical conductivity in the soil profile, though, is not simple, given the nonlinear relation between EC and depth (with few exceptions). This requires complex processing of data (Corwin and Lesch 2005). Furthermore, calibration is not easy; it is time consuming and needs to be repeated in case of lengthy measurements, since readings are affected by air temperature (Dabas and Tabbagh 2003). Also, metals interfere with magnetic fields, and metallic objects in measurement areas may totally prevent a campaign.

DC Electrical Resistivity (ER) methods are widely used in agricultural and environmental sciences and allow to overcome some of the limitations of other methods as far as calibration and profile characterization are concerned<Q>.

The most appropriate methods for obtaining information on the variability of the electrical resistivity of the subsoil are the Electrical Resistivity Tomography (ERT) and the Automated Resistivity Profiling (ARP). The ERT methods are able to describe the resistivity pattern at different levels of depth in subsoil, while the ARP is an optimal tool for the fast resistivity surveying of large areas.

The working principle of the ERT is the injection of a known DC electric current into the subsurface through an array of transmitting electrodes and in the subsequent measurement of the voltage difference with an array of receiving potential electrodes. In this way, ERT is able to provide information about the spatial distribution of the electrical resistivity (i.e., the electrical conductivity) in the subsoil.

The electrical resistivity tomography of subsurface investigation is based on the variability of resistance to the conductance of electrical current, in subsurface materials, depending on variations in moisture content, density, and chemical composition. In electrical resistivity investigation, an electrical current [I (mA)] is applied through two current electrodes, and the potential difference [ΔV (mV)] between two or more potential electrodes is measured to detect the resistivity of the material at depth. In order to reduce electrode polarization effects, which could affect the accuracy of the measure, the injected current is modulated as a low-frequency square or sinusoidal wave. There are several possible electrode arrangements, and Fig. 1 depicts the most used ones, which are the Wenner, Schlumberger, and dipole–dipole arrays.

Whichever the used array, the ERT is based on the measure of the ground electrical potential while the current is injected. In this way, it is possible to calculate the apparent resistivity (ρa):

$$\rho a = K\left(\frac{\Delta V}{I}\right)$$

where ρa is expressed in Ωm and K is a geometrical factor depending on the adopted array configuration (Fig. 1). The spatial arrangement of measured soil volumes depends on the position of the electrodes at the surface and on the used array configuration (Edwards 1977).

The choice of the array configuration depends on the site features as well as on depth, size, and composition of the target as well as on the desired signal/noise ratio. Details about array configurations and their sensitivity functions are reported in Loke (2001). Modern georesistivimeters have multielectrode systems able to acquire a large number of data by automatically switching quadrupoles for each array, which is composed of a consistent number of electrodes properly fitted on the ground. All possible quadrupole spacings along the line are used for measurements, from the lowest—corresponding to adjacent electrodes—to maximum spacing, determined by the total array length.

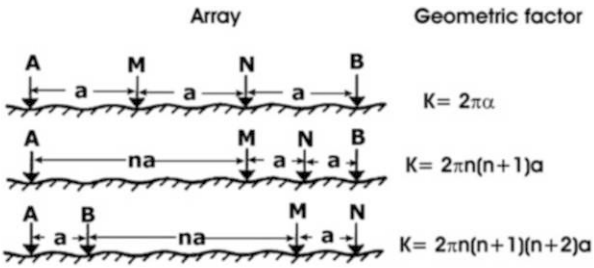

Fig. 1 Some common collinear electrode configurations for resistivity studies. A–B: current electrodes; M–N: potential electrodes; a: electrode spacing; k: geometric factor; n: ratio of the distance between the A–M electrodes and the A–B dipole spacing

Processing of data with numerical methods then allows to reconstruct the heterogeneous spatial distribution of resistivity in the subsurface. This distribution can be represented as 2D or 3D tomograms (Loke and Barker 1996) (Fig. 2).

The continuous or automatic profiling of resistivity is an extremely fast and cost-effective tool for mapping the horizontal spatial variability of the apparent resistivity in large areas. Two devices have been developed for applications in agriculture: the ARP (ARP ©, Geocarta, Paris) in France and Veris 3100 (Veris Technologies, Salina, KS) in the USA.

The ARP (Automatic Resistivity Profiling—Fig. 3) is an evolution of the Mucep (Panissod et al. 1997), developed in France by CNRS and the University of Paris IV since 1979. It is a multielectrode system which measures at three soil levels simultaneously 0–50, 0–100, 0–200 cm from the soil surface. The system is designed to be used on-the-go, towed in the field, and has a V-shaped 2D geometry (defined "vol-de-canard" by Panissod et al. 1997) where rolling electrodes are teethed wheels. A doppler radar is coupled with a GPS and positioned on the device to provide precise positioning.

The spatial information collected by the ARP system is used for positioning measurements but also for computing a DEM (Digital Elevation Model) providing topographic attributes such as slope and position that facilitate the interpretation of resistivity variation and the definition of management zones (Rossi et al. 2013a).

The Veris system uses a linear geometry with a Wenner array and explores two soil layers: 0–30 and 0–90 cm from the soil surface. Electrodes are metal discs.

The ground-penetrating radar (GPR) is an active electromagnetic technique and nondestructive for physical detection, which utilizes similar principles to the reflection seismic method.

An electromagnetic pulse in the range of 10 MHz to 1 GHz is radiated by a transmitting antenna and propagates through the soil to be investigated, and a receiving antenna gathers the backscattered signal engendered by hidden targets, i.e., anomalies arising into the electromagnetic features of the surveyed medium. The result of a single GPR measurement is a trace where the amplitude of the backscattered field is represented along the two-way-travel time (Fig. 4).

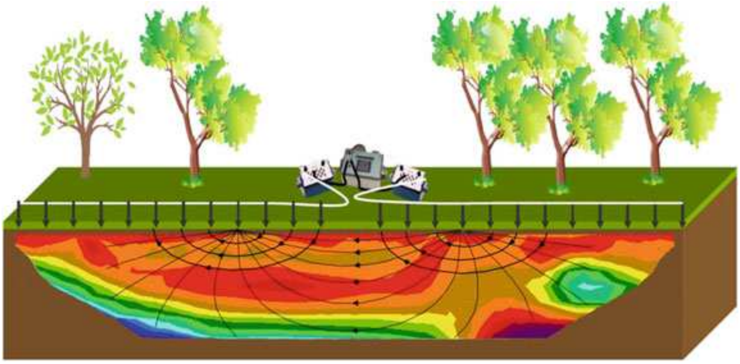

Fig. 2 Representation of a 2D section of soil resistivity obtained after data inversion with numerical modeling

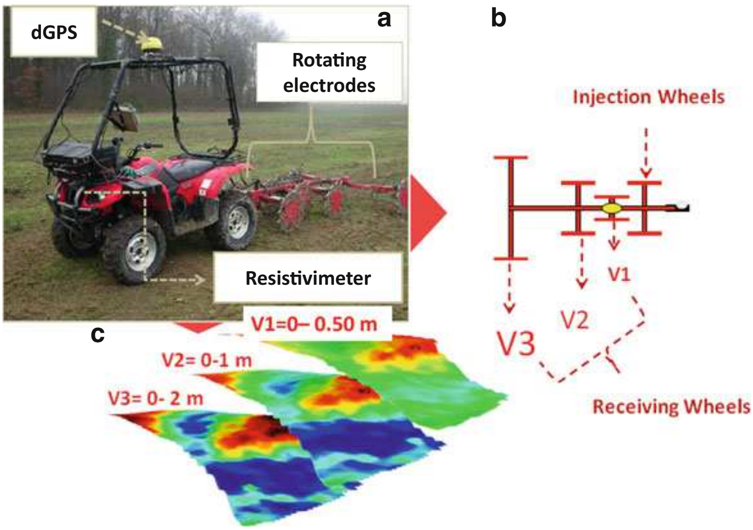

Fig. 3 (**a**) Picture of the on-the-go resistivity meter (ARP ©, Automatic Resistivity Profiling, Geocarta, Paris, France) trained by a filed vehicle; (**b**) schematic representation of the multiple rotating electrode system; and (**c**) maps of soil electrical resistivity distribution at the three consecutive exploration depths ($V1 = 0$–0.5 m; $V2 = 0$–1 m; $V3 = 0$–2 m)

Accordingly, the outcome of the GPR survey is a radargram built as the superposition of the time traces collected at the single measurement points (Daniels 2004)

The velocity at which the EM energy travels in the ground depends on the material. If the velocity of the propagated EM wave was known, then the depth of wave reflection can be obtained as:

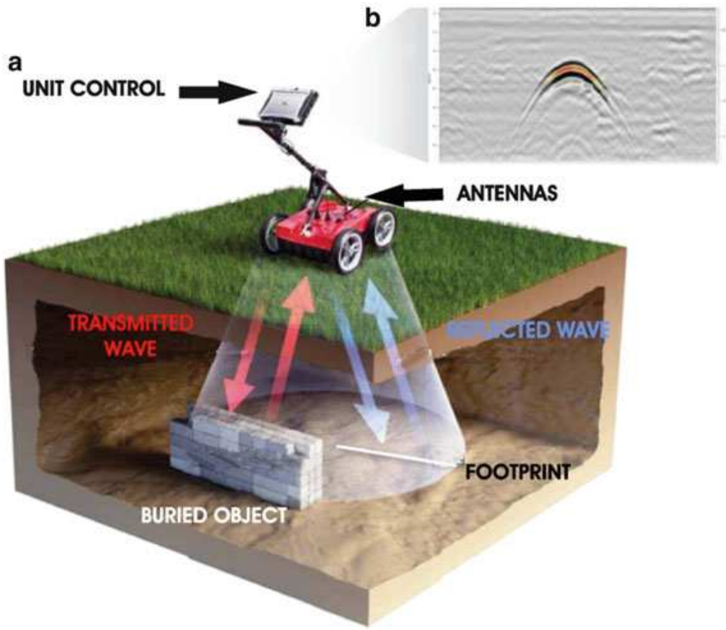

Fig. 4 Schematic representation of the GPR working principle (**a**) manual data acquisition system; (**b**) raw-data radargram

$$d_{\mathrm{r}} = \frac{Vt_{\mathrm{r}}}{2}$$

where d_{r} = depth of wave reflection; V = velocity of EM wave; and t_{r} = time range of the wave propagating path and reflecting path, and V denotes the velocity of electromagnetic signal into the probed medium. Such a velocity depends on the relative dielectric permittivity (ε_{r}) of the surveyed medium:

$$V = \frac{c}{\sqrt{\varepsilon_{\mathrm{r}}}}$$

c being the speed of light in vacuum, which can be approximated to 0.3 m/ns. The relative dielectric permittivity can be estimated by using direct or indirect methods (Conyers and Goodman 1997; Daniels 2002), and its values for several materials encountered in geological surveys are given in Table 3.

Data can be collected along arrays by dragging antennas on the ground.

In recent years, research efforts have been done for implementing advanced data processing based on addressing GPR data processing as an inverse electromagnetic scattering problem. This gives better results in determining target location and geometric features (Soldovieri et al. 2011).

Table 3 Relative dielectric permittivity of geologic materials measured at 100 MHz

Material	Relative dielectric permittivity (ε_r)	Material	Relative dielectric permittivity (ε_r)
Air	1	Shale	5–15
Dry sand	3–5	Clay	5–40
Dry silt	3–30	Concrete	6
Ice	3–4	Saturated silt	10–40
Asphalt	3–5	Dry sandy coastal land	10
Volcanic ash/pumice	4–7	Average organic-rich surface soil	12
Limestone	4–8	Marsh or forested land	12
Granite	4–6	Organic-rich agricultural land	15
Permafrost	4–5	Saturated sand	20–30
Coal	4–5	Freshwater	80

3 Applications and Case Studies in Agriculture and the Environment

The EM and ERT methods have been largely applied in agriculture and environmental studies, from monitoring of saltwater intrusion in coastal areas to the diffusion of pollutants in groundwater; the time-dependent change of soil water content; the surveying of plant root biomass (Amato et al. 2008); the analysis of water–soil–root plant interactions and many other significant applications (Werban et al. 2008; Calamita et al. 2012).

The ARP is increasingly used in precision farming (viticulture) giving contributes for improving the management strategies aimed to improve and enhance the quality of the crop production (Rossi et al. 2013a).

The GPR method can be applied to a wide range of agriculture and environmental problems such as the detection of pollutant leakage in groundwater, the mapping of the root–plant geometry, and the rapid mapping of soil water content. Recently, novel applications in precision farming have been carried out using advanced system of semi-automatic vehicles for GPR data acquisition (Hubbard et al. 2002; Rubin 2006).

A case study where a combination of techniques was used in an agricultural field to highlight variation at different scales regards a study in a wheat field located at Gaudiano-Lavello—Basilicata (41° 6′ 6″ N, 15° 50′ 55″ E), managed by ALSIA (Agenzia Lucana di Sviluppo ed Innovazione in Agricoltura). The field subjected to two tillage management (conventional tillage at 35 cm and sod seeding) from 3 years.

On-the-go multi-depth resistivity meter (ARP ©, Geocarta, Paris) (Rossi et al. 2013a) was used to measure simultaneously at three different depths that correspond to the distance between receiving wheels ($V1 = 0.50$ m, $V2 = 1$ m, $V3 = 2$ m). Data were real time referenced by DGPS. Data were collected on

2.16 ha along parallel transects 4 m distant between each other. A total number of 59,376 measurements were taken. The entire area was surveyed in about 40 min at an average speed of 3.76 m/s.

A 2D resistivity survey was conducted with a Syscal R2 (Iris Instruments, Orleans, France) resistivity meter with a Wenner–Schlumberger array with 48 electrodes lined up on the soil surface for a total length of 47 m and with an electrode spacing of 1.0 m.

A GPR survey was also carried out on the same survey lines by using an acquisition module GSSI SIR 2000 equipped with a 400 MHz antenna and having survey cart and encoder.

In 2D ERT sections (Fig. 5), resistivity ranged between 30 and 400 Ωm, up to a depth of about 5 m. The highest resistivity values (from 80 to 400 Ωm) can be associated to the presence of resistive structures with values above 100 Ωm. Conversely, the lowest resistivity values (from 30 to 80 Ωm) could be attributed to a higher water and/or clay content. In addition, at about 3.0 m depth, the 2D tomogram shows a low-resistivity feature than can be ascribed to the groundwater table with overlying capillary fringe.

The radargram corresponding to the ERT profile shows a higher attenuation of the signal in the right side, and this can be associated to increased soil water. Conversely, the left side of the radargram shows a continuous series of reflectors and can be related to the presence of discontinuities like stones or compacted soil.

The three maps of resistivity from ARP (Fig. 6) show that resistive areas are mostly concentrated in southern part of the field, while an area of low resistivity is discernible in the north-eastern area of the field. Summary statistics of soil electrical resistivity measured at the three consecutive depths are reported in Table 4.

Buvat and coauthors (2014) used the multi-depth resistivity dataset to develop a "geophysical taxonomy" based on the vertical succession of the three apparent resistivity values. They found that the resistivity-based clusters well matched soil pedological profiles and were consistent with soil unit boundaries. Following an approach similar to these authors, we used the vertical succession of resistivity values to map soil layering, based on the difference between the resistivity measured in the first ($V1$) and in the second layer ($V2$) values, which were grouped into three classes: D (decreasing values), C (constant values), and I (increasing values). The geophysical taxa show distinct clusters following a north-south gradient. ER increased with depth predominantly in the southern half of the field while it decreases in the northern corner (Fig. 7).

At the adopted imaging resolution and at this time of the year (about 6 months after tillage) we didn't distinguish any spatial pattern related to tillage type, which splits the field longitudinally in two blocks; instead the presence of a structured spatial pattern underlies the necessity of accounting for soil spatial variability in evaluating tillage effects. ER varied from 18 to peak values of about 200 Ωm; highest values were found in the third layer. This range of values can be attributed to different soil features (Samouelian et al. 2005) hence, as in all geophysical exploration, map interpretation requires ground-truth calibration.

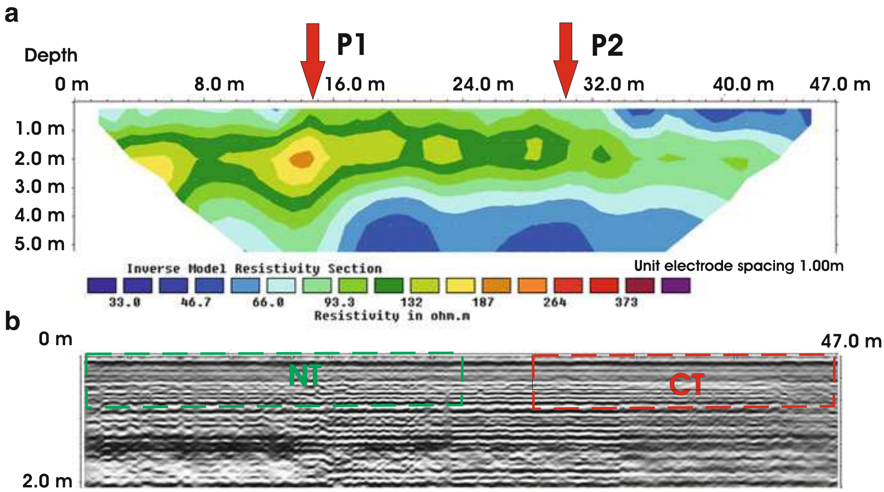

Fig. 5 (**a**) 2D tomogram of electrical resistivity measured in the experimental field, P1 and P2 arrows point the management systems, respectively, P1 = No Tillage and P2 conventional tillage. (**b**) GPR Radargram carried out in the same direction of resistivity profile in the two management systems (*NT* no tillage and *CT* conventional tillage)

Other studies where a combination of geophysical techniques have been applied are related to coastal areas as shown in the work of Nowroozi et al. (1999), Abdul Nassir et al. (2000), Choudhury and Saha (2004), Sherif et al. (2006), Khalil (2006), Cimino et al. (2008). In the characterization of the coastal saltwater intrusion in the Metapontum forest reserve, Satriani et al. (2012a) used ER tomography alone to highlight the spatial distribution of saline water in the pine forest (Fig. 8)

Geophysical prospecting has an important field of application in archaeology. Loperte et al. (2011) used an integrated geophysical approach based on magnetic, Ground-Penetrating Radar, and geoelectrical survey to investigate a construction work site in the Greek and Roman settlement of Paestum, southern Italy (Fig. 9). The survey showed features that could be ascribed to archaeological remains, as was confirmed by subsequent excavations where walls, canals, and tombs were found.

The high potential of geophysical survey in agriculture has been now recognized; over the last decade geophysical sensors based on the nondestructive measurement of soil electrical conductivity (or its inverse resistivity) have been extensively used in precision agriculture, alone or coupled with terrain information, to help delineating uniform management zones (Peralta et al. 2013; Moral et al. 2010; Kitchen et al. 2005). Using such techniques, we are able to visualize soil features related to their electrical behavior; as current flux in soil is mostly electrolytic, resistivity is very sensitive to the two components that are mainly involved in charge transfer: the degree of pore water saturation and salinity (Lesch 2005) and the specific surfaces associated to the presence of clay particles (Tabbagh et al. 2000). Resistivity is even sensitive to the microstructure of clays,

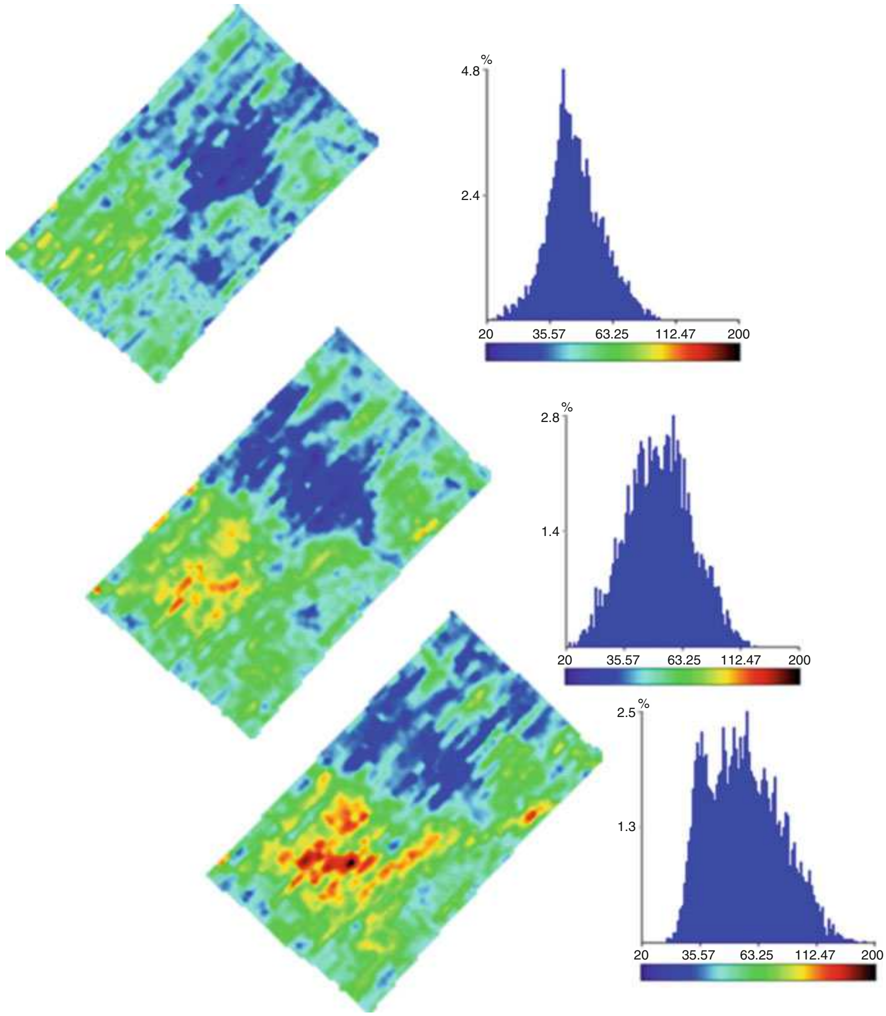

Fig. 6 ARP multi-depth apparent resistivity maps and relative frequency distribution (*red shade* indicate high values and *blue shade* depict low values): *top* $V1 = 0\text{–}0.5$ m layer, *middle* $V2 = 0\text{–}0.1$ m layer, *bottom* $V3 = 0\text{–}2$ m layer

based on lab measurements of worldwide collected clay samples; a first database of clays resistivity was compiled by Giao and coauthors (Giao et al. 2003). A soil conductivity survey conducted across different soils showed strong and consistent correlations with clay (Sudduth et al. 2005). This sensitivity is very useful in agricultural soil mapping, since many relevant properties are heavily influenced by and covariate with clay content, such as: water holding capacity, organic matter content, soil structure, temperature, and cation exchange capacity. For the opposite reason resistivity readings can also be used to localize resistive features, that act as

Table 4 Descriptive statistic of the multi-depth apparent resistivity layers

	*V*1	*V*2	*V*3
Mean	45.24	52.43	57.80
Median	42.87	49.21	51.96
Standard deviation	12.25	17.80	23.25
Kurtosis	1.68	0.81	2.12
Skeweness	1.07	0.91	1.30
Minimum	18.34	18.22	23.10
Maximum	110.46	134.54	201.84
Number of observations	54,997	54,997	54,997

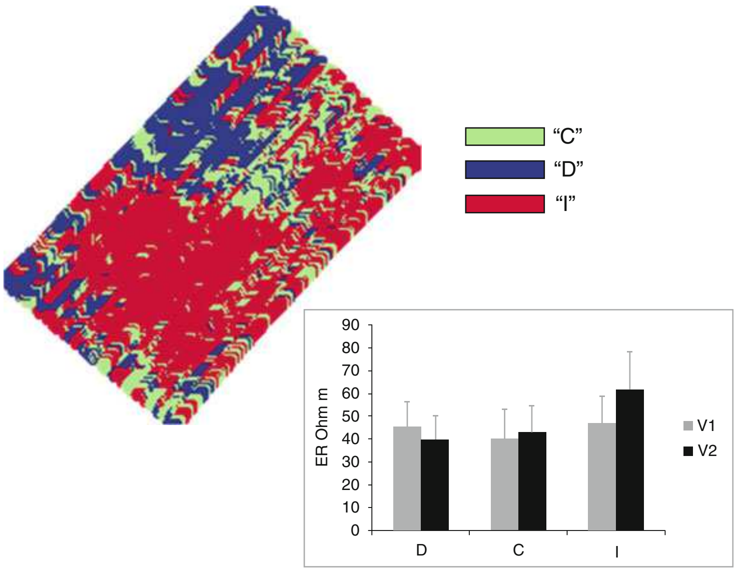

Fig. 7 *Bottom left*: map of apparent resistivity taxa, based on the difference between the resistivity measured in the first (*V*1) and in the second layer (*V*2) values were grouped in three classes: D (decreasing values = blue), C (constant values = green), and I (increasing values = red). *Bottom right*: bar plot of *V*1 (*solid gray bar*) and *V*2 (*solid black bar*) resistivity average values (and relative standard error bars) of the three geophysical taxa (D, C, I)

barriers to current flux, such as gravel lenses (Tetegan et al. 2012; Rossi et al. 2013b); this is of great value, because of the strong influence that rock fragments exert on soil hydrology, workability, thermal regime, and nutrients pools (Poesen and Lavee 1994) but also because these techniques help filling the well-known methodological gap of quantitative research in stony soils (Eriksson and Holmgren 1996). This extraordinary sensitivity of the technique to the presence of insulating materials constituted the base for the use of the technique for imaging woody plant root system (Amato et al. 2008; Rossi et al. 2011). Plant roots are the key component of plant survivorship and ecology but at the same time are

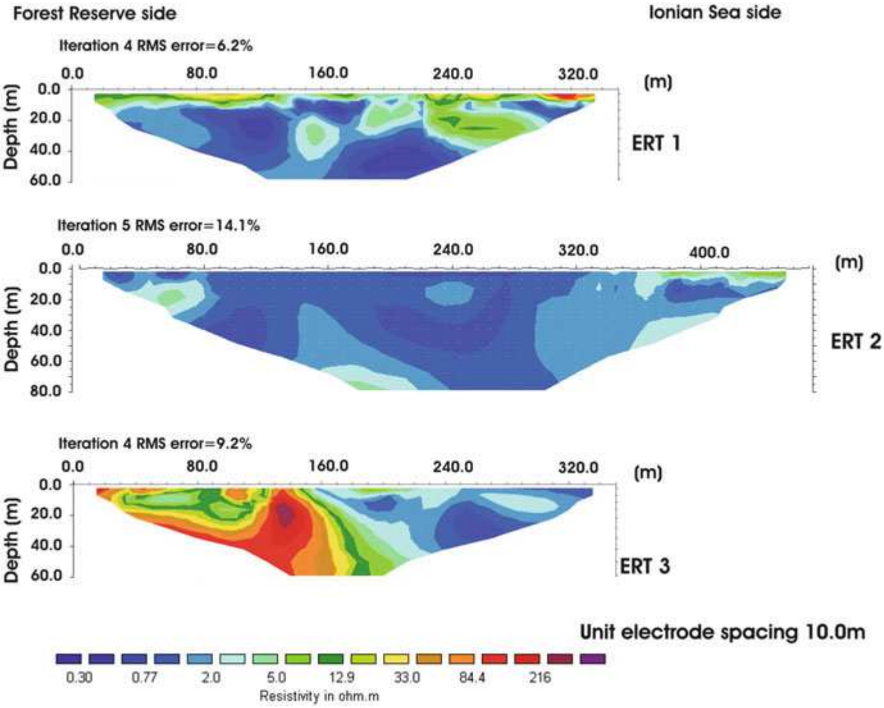

Fig. 8 Electrical resistivity tomograms from the Metapontum forest reserve

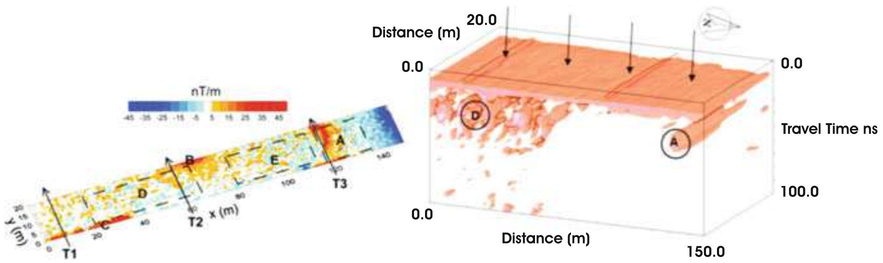

Fig. 9 Map of processed magnetometric results (*left*) and 3D visualization of GPR prospecting (*right*) at a construction work site in Paestum (SA). The main electromagnetic anomalies are marked by *capital letters* while the *black arrows* indicate the travertine bank

considered the most elusive aspect of belowground studies; this is mainly related to the lack of methodologies to study root systems at the appropriate spatiotemporal scale without interfering with their growth and development (Amato 2004). Quantitative research on the use of resistivity tomography for mapping root system spatial variability has shown that lignified coarse plant roots exhibit a strong electrical response, that rooted soil resistivity can increase several hundred Ohm meter (Amato et al. 2008), and that their effect can be dominating in agricultural soil (Rossi et al. 2011). First research on herbaceous roots (Amato et al., 2009) has shown that even at very low density they increase resistivity, but that their resistivity values overlap those of other common soil materials; thus fine roots could only be discerned and quantified keeping the other sources of variability low and unstructured.

A combination of Ground-Penetrating Radar (GPR) and Electrical Resistivity Tomography (ERT) has been used by Satriani et al. (2010) to produce high resolution images that were obtained in laboratory measurements, and they have clearly shown the presence of soil volumes with a high density of fine and woody roots.

Several research reports have shown that resistivity could be used to map permanent soil properties at farm scale (André et al. 2012; Buvat et al. 2014). In some cases, soil texture can dominate the resistivity pattern overshadowing soil structure and water-related properties (Banton et al. 1997). For a given texture, though, soil structural state variation, by altering the proportions between water and air filled porosity, can exert a strong effect on resistivity; this is at the base of the successful use of high resolution resistivity tomography for mapping soil alterations induced by tillage (Besson et al. 2004; Basso et al. 2010). Basso and coauthors (2010) found that resistivity mapping allowed to discern between tilled, freshly tilled, and untilled soils better than penetrometry. Time lapsed resistivity tomography was later used to evaluate soil structural recovery after compaction (Besson et al. 2013). Satriani et al. (2012b) monitored water content and distribution in drybean using resistivity tomography and time-domain reflectometry in two different irrigation treatments with applications for the reduction of water use without reducing yield.

Repeated resistivity measures were also used to infer within-field spatiotemporal organization of soil water, discounting this way the effect of soil texture (Besson et al. 2010). Whether resistivity is going to be used to discern permanent or transient soil properties, some baseline conditions must be satisfied: the target soil property variation must be large enough and must have a sufficient degree of contrast with the surrounding matrix (Banton et al. 1997), and of course the scale of measurements must be proportional to the target. Once these prerequisites are met, map interpretation requires ground-truth calibration, since several soil constituents show overlapping resistivity ranges (Samouelian et al 2005) or offsetting resistive behavior (i.e., rock fragments coated in clay; sandy saline layers) which can lead to ambiguous interpretation. The choice of the sampling strategy is crucial since the high costs of destructive sampling can rapidly counterweight the benefits of using a low-cost ancillary information instead of traditional expensive and labor-demanding soil survey methods. The issue of geophysical sensor data ground-truth sampling schemes has been addressed by Lesch (2005) that suggests the use of a model-based sampling strategy as an alternative to probability-based sampling. Model-based or directed sampling instead of relying on randomization principle is focused toward the estimation of a regression model; hence sampling locations are explicitly chosen to cover the full range of the target variable (feature space). Directed sampling strategies typically allow to reduce the number of samples for an efficient model parameter estimation (Fitzgerald et al. 2006). Additional spatial optimization criteria can be included to maximize the spread of data to minimize the autocorrelation between observations (Lesch 2005), to reduce the costs of measurements (Minasny and McBratney 2006), or to intensify the number of samples where the variation is large (Minasny et al. 2007).

Acknowledgments This work was partly financed by the Project psr BASILICATA 2007–2013. MISURA 124 "Approcci innovativi per il miglioramento delle performances ambientali e produttive dei sistemi cerealicoli no-Tillage BIO-TILLAGE" CUP C32I14000080006.

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Satellite Technologies to Support the Sustainability of Agricultural Production

P D'Antonio, C D'Antonio, V Doddato, and M Mangano

Abstract Precision farming is a form of multidisciplinary and technologically advanced agriculture, which recourses to machines equipped with "intelligent systems," able to dose the productive factors (fertilizers, pesticides, etc.) according to the real needs of the homogeneous areas constituent to the plot (Verhagen and Bouma, Modeling soil variability. In: Pierce FJ, Sadler EJ (eds) The state of site specific management for agriculture. ASA Publications, 1997).

Experimental trials have been conducted in order to compare two satellite-guidance devices and two correction systems of the GPS signal: the EZ-Steer/RTK and Autopilot/EGNOS. The machines used in the tests were the tractor New Holland T7060, the rotary harrow Alpego DG-400, and the burier Forigo DG-45, to determine which of the two systems ensured the best quality of work. The results obtained showed that the EZ-Steer/RTK system guaranteed a lower stability of the theoretical trajectory than the Autopilot/EGNOS system, above 1.69 %. From the elaboration of data of the two guidance systems behavior to manage the only width of transposition, it is observed that the EZ-Steer/RTK system is able to guarantee a better hold of the line compared to the Autopilot/EGNOS system, which provides a mistake of 176 cm on the total width of transposition and 2 cm on the mean value. In the matter of the normalized transposition surfaces, the Autopilot/EGNOS system ensures a better work quality.

1 Introduction

Precision farming (PF) is a management philosophy or approach to the farm and is not a definable prescriptive system (Dawson 1997). It identifies the critical factors where yield is limited by controllable factors and determines intrinsic spatial variability. It is an essentially more precise farm management made possible by modern technology (Mandal and Ghosh 2000). The variations occurring in crop or soil properties within a field are noted and mapped and then management actions are taken as a consequence of continued assessment of the spatial variability within

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_24

that field. The development of geomatics technology in the later part of the twentieth century has aided in the adoption of site-specific management systems using remote sensing (RS), GPS, and geographical information system (GIS).

This approach is called PF or site-specific management (Brisco et al. 1998; Carr et al. 1991; Palmer 1996).

The farming tends to manage every factor of production in varying measures, treating small areas inside the lot as separate surfaces. By doing so, the economic margin of crops can be increased, reducing the input of the technical means. Furthermore, the environmental impact and the quantity of the production factors used, such as pesticides and fertilizers, are significantly reduced. Therefore, the precision farming aims to adapt the contributions in a point manner, taking into account the local variability of the physical, chemical, and biological characteristics of the field and the timing of implant (Pierce and Sadler 1997). At the same time, also the soil preparation work must be performed accurately, in order to avoid overlap, which would cause an increase of the costs. For this aim, a detailed mapping of the physical, chemical, and biological properties of the field has been used, so that they can be managed by the control computer of the cultivation operations, placed beside the machines. Therefore, the implementation of the actions demands an automatic positioning system (GPS, global positioning system), which allows the machine to recognize the exact location on the map, differentiating the agricultural operation to carry out. A group of 24 satellites in orbit around the Earth forms the GPS. With three satellites and a receiver and through the three-dimensional triangulation, the receiver will indicate its position on the Earth. That is done through the analysis of the high-frequency signals that the satellites send to the receiver, which calculates how long it takes to receive the signal and its position is displayed on a screen. In addition, it reduces the environmental damage and the risks in agriculture. During the crop production, the uncertainty of the yield may be reduced and the safety of the farmers' incomes can be increased if the technological elements are used and combined correctly (Auernhammer 2001; Gandonou et al. 2004; Chavas 2008).

Precision agriculture is a systems approach to farming. To be viable, both economic and environmental benefits must be considered, as well as the practical questions of field-level management and the needed alliances to provide the infrastructure for technologies.

That study was conducted to investigate the convenience in the use of two normally used system of guidance, examining their reliability and the opportunity of reducing production costs, and therefore also have a fuel saving, with clear environmental benefit.

2 Materials and Methods

The experimental trials were conducted on two satellite-guidance devices using two different correction systems of the GPS signal:

Fig. 1 Motorized roll

- The EZ-Steer, with RTK precision system
- The Autopilot, with EGNOS precision system

The EZ-Steer is an assisted guidance system, wherein the management of the tractor direction happens by a motorized roll, placed beside the steering, which is operated by the control unit positioned in the tractor cabin (Fig. 1).

This system doesn't overcome the value of 90 points (on a scale that ranges from 50 to 150), because of a non-instantaneous reaction of the starter to the course correction pulses issued by the control unit and because of the roll slipping light on the wheel; it was observed that, using a precision RTK and setting a value more than 90 points.

The Autopilot, instead, is an integrated system, which uses the hydrostatic guidance system for the management of the tractor through a hydraulic control unit (Fig. 2), which communicates with the control unit, placed in the control room.

In that case, the control unit communicates, both, with the GPS antenna and with the sensors proximal to the wheels, which indicate how the feed axis diverts respect to the orthogonal of the tractor. The Autopilot's hydraulic circuit, differently from the EZ-Steer, allows to work with a value up to 135 points before going in overcorrection, which means it has a remarkable ability to maintain the correct trajectory also on land which is full of holes and/or soft. The GPS with EGNOS error correction can obtain a positioning accuracy, which is a precision between consecutive passes, of 20 cm, and a repeatability year after year of 90 cm (it's a free service); the RTK, instead, is a high-precision technology, with an accuracy between consecutive passes of 2.5 cm and a repeatability year after year of 2.5 cm. The RTK is able to provide an elevation accuracy of 5 cm, with an improvement of almost two orders of height compared to the GPS standard (DGPS), since this system is able to extract the additional information, examining the carrier wave of the GPS signal (Tyler et al. 1997). The RTK system's disadvantages are a higher cost, the need to establish a local base station, and a significant decrease compared to the GPS standard methods. A light-bar provides information of the visual guide to the operator, who may make some corrections of manual steering.

Fig. 2 Hydraulic control unit

During the trials in the field, the tractor New Holland T7060 was used, while as operating machines the following have been used:

- The rotary harrow, Alpego DG-400
- The burier, Forigo DG-45
- The rotary tiller, MASCHIO Pantera 420
- The plow scrambler, SILVER 66/15

It was decided to carry out investigations on flat surfaces and, in any event, not surrounded by mountains in the circumstances, so that the rover and the eventual RTK antenna could be served by the largest number of satellites; 8 plots away from trees, power lines, and farms were chosen as areas of experimental interest for the same reason, because these elements could create interferences between the receiver and the satellite.

To carry out the measurement, a tape measure to 20 m, a measuring tape from 3 m steel rods for reinforcement, and a line from carpentry, squaring surveyor have been used. The distance between each pair of pickets has been detected, obtaining the so-called length of transposition, except that, by connecting the two pegs with a fishing line, in order to detect the maximum distance, taken perpendicularly to the line, between the latter and the margin of transposition, identifying the width of transposition. The measurements were carried out over several days of the campaign and developed over a distance of 6,200 m for each of the systems examined. With regard to the eight plots, the measures that characterize them are summarized in Table 1 (Fig. 1).

The data collected for each of the two systems is not concordant; in fact, while for the EZ-Steer/RTK, 80 observations were carried out, for the Autopilot/EGNOS system, 75 observations were performed. But it is an obvious consequence, since the two systems are independent, while what makes them comparable is the fact that they have been tested on a common route of 6,200 m. So for the analysis of variance (ANOVA), it is necessary to standardize the number of measured data.

Table 1 Size of 8 plots

	EZ-Steer/RTK				Autopilot/EGNOS			
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8
Greater side (m)	120	125	110	115	120	140	130	125
Smaller side (m)	90	80	95	90	85	75	80	85
Surface (ha)	1.08	1.00	1.06	1.04	1.02	1.05	1.04	1.06

3 Results

The experiments were performed over several days in the countryside on a route of 13,000 m and 80 observations for each plot. The basic parameters that have characterized the two trials are summarized in Table 2 and in Table 3 are the machine operating data.

The surveys have been performed on pairs of contiguous swaths, to identify areas where an overlap or some variations happen, so that even the measure results reasonable.

For each transposition, then, the apparent area has been calculated, multiplying the transposition length for its width. Obviously, since in the analysis of variance for one factor (ANOVA) it is necessary to standardize the number of the detected data, to the nonexistent data, a value of 0 has been assigned and the average was calculated considering these terms.

Thanks to the elaboration of data in relation to the behavior of the two satellite-guidance systems that manage the only direction of tractor advancement, we have obtained the following results in Table 4.

On the basis of these results, you gather that the EZ-Steer/RTK system ensures a lower capacity of the theoretical path; in fact, the total of the traveled route shows an error of 229.42 m and with respect to the Autopilot/EGNOS system above 3.806 %. From the elaboration of data relating to the behavior of the two guidance systems in managing only the transposition width, we have obtained the following results in Table 5.

Regarding to longitudinal measures, the quality of work is given by the optimal length of transposition anything, from a comparison of the data shows how complex the EZ-Steer/RTK, despite surgical correction of the accuracy of the satellite signal ensured by RTK, ensures a lower seal of the theoretical trajectory, in fact, the total of the journey performed, shows a longitudinal transposition of 229.42 m more than the Autopilot/EGNOS system, equal to 3.806 % of 6,200 m paths. It follows that, between the two systems, the Autopilot/EGNOS is able to correct before and better the deviation from the theoretical trajectory.

Each system consists of two devices, each of which has a different ability to correct the accuracy, the RTK and the EGNOS, and to manage the accuracy, EZ-Steer and Autopilot. EZ-Steer is a guidance system of the type witnessed soothe control of direction of the tractor is the case for action on the steering board of a roll

Table 2 Basic nominal geometric parameters

	EZ-Steer/RTK	Autopilot/EGNOS
A swath average length(m)	118	130
Total number of passes made	52	48
Meters traveled (m)	6,136	6,240
Contiguous passes' number	26	24
Single pass width (m)	4.07	4.07
Two contiguous passes' width (m)	8.15	8.15
Swath total width (m)	211.5	194.65
Two contiguous passes' surface (m^2)	961.7	1,059.5
Σ of work surface (m^2)	24,957	25,304.5

Table 3 Operative data of the machines

	Forigo DG-45 New H. T7060	Alpego DG-400 New H. T7060	Zappatrice MASCHIO Pantera 420 New H. T7061	Aratro rimescolatore SILVER 66/15 New H. T7062
Average speed (km/h) (m/min)	3.6; 60	4.0; 66.7	3.8; 60	6.0; 69.7
Work front width (m)	3.8	4.00	4.20	4.30
Processing depth (m)	0.2	0.1	0.29	0.25
Fuel con-sumption (l/h)	15.4	15.8	16.10	15.80

Table 4 Transposition length results

	EZ-Steer/ RTK	Autopilot/ EGNOS	Variation
Average length of a swath (m)	118	130	−2
Total route traveled (m)	6,136	6,240	−104
Total transposition length (m)	998.64	769.22	229.42
Transposition average length (m)	12.493	9.6153	2.877
Transposition length of total traveled route (%)	16.275	12.469	3.806
Minimum transposition length (m)	1.3	2.45	−1.15
Maximum transposition length (m)	28.7	17.1	11.6

motor, the management of which, in turn, is assigned to the control unit accommodated in the tractor cabin; it is such an architecture that focuses on the limit of the EZ-Steer system to allow the tractor to emphasize the theoretical path, and because the motor cannot handle the multiple pulse course correction issued by the control unit, it shows a very ready reaction to them, except that, roll films are observed with

Table 5 Transposition width results

	EZ-Steer/RTK	Autopilot/EGNOS	Variation
Width of the work front (m)	4.075	4.075	0
Width of two contiguous wipes (m)	8.15	8.15	0
Swaths' total width (m)	**52.875**	**48.6625**	**4.2125**
Total transposition width (m)	**11.6**	**13.237**	**1.64**
Average transposition width (m)	**0.145**	**0.165**	**0.02**
Minimum transposition width (m)	0.05	0.08	0.03
Maximum transposition width (m)	0.355	0.375	0.02

slight shifts on the steering wheel, which reduce the sensitivity of the system. All these elements are summarized by the aggressiveness parameter, which explains the ability of the system to follow a rectilinear profile and faithful to the trajectory theoretical.

There is, however, a limit, called overcorrection and is proportional to the architecture of the system. The EZ-Steer system, however, is implemented by an RTK correction, with an experimental aim to compensate greatly reduced aggression and, therefore, to significantly reduce the length of implementation, even bringing it below what would have been possible with an Autopilot/EGNOS system. In the EZ-Steer/RTK, the transposition length equals to 998.64 m, while for the Autopilot/EGNOS system, transposition length equals to 769.22 m. Apparently, the ability to control the actual trajectory on the racing line and therefore the aggressiveness of the two drive systems, the EZ-Steer and Autopilot, are likely to prevail on the correction accuracy of the satellite signal carried by the devices and RTK EGNOS.

The results on the widths of transposition, instead, in a sense, stressing the different correction capabilities of precision, were made by the RTK mode and the EGNOS mode, in fact, whereas with the Autopilot/EGNOS system, it has an average width of transposition equal to 16.5 cm, with the EZ-Steer/RTK an average width of transposition of 14.5 cm. For all EZ-Steer/RTK, 14.5 cm is, however, a result that does not respect the potential of 2.5 cm RTK correction, while the complex Autopilot/EGNOS is fully integrated in the range of 20 cm guaranteed by the EGNOS correction. The reason, also in this case, is attributable to the aggressiveness of the two different driving systems, satellite; this is because the aggressiveness of 90 points induces the tractor to be moved further from the ideal trajectory, unlike what happens with the high aggressiveness of 135 points obtained on the Autopilot.

With regard to operating machines, the Autopilot/EGNOS and the EZ-Steer/RTK showed a homogeneous regularity of work due to the ability of stabilizing active suspension of the tractor New Holland T7060, except that the regularity of the surfaces were the backdrop to the trials and machinery.

An analysis of variance (ANOVA) on the lengths of transposition is that the calculated F (F) is greater than the critical value of F (Fcrit), except that as the value of significance (p value) is less than the value of reliability ($\alpha = 0.05$), we reject the null hypothesis (H0), which suggests that there is no significant difference between the means, and accept the alternative hypothesis (H1), which emphasizes, however, that there is a significant difference between the means; therefore, this means that the values of length of transposition collected in the field for the EZ-Steer system/RTK and Autopilot/EGNOS deviate significantly from the average. With regard to the widths of transposition and similarly the length of implementation, the analysis of variance showed that the calculated F (F) is greater than the critical value of F (Fcrit); we reject the null hypothesis (H0), which suggests that there is no significant difference between the means, and accept the alternative hypothesis (H1), which tells us that the means are significantly different from each other. Therefore, from what the analysis of variance shows, the values of transposition length collected in the field for the two systems differ significantly from the average.

In the analysis of variance on the standard surfaces, differently from what happens with the length and width of a transposition, it appears that the calculated F (F) is less critical than the F (Fcrit) and the significance value (p value) is greater than the value of reliability ($\alpha = 0.05$); we accept the null hypothesis (H0), which suggests that there are significant differences between the means, and reject the alternative hypothesis (H1), which tells us that the means are significantly different from each other. The analysis of variance on standard surfaces, so that the values obtained for the EZ-Steer/RTK and the Autopilot/EGNOS do not differ significantly from the average.

Relating to the data collected about the transposition width and the total width of the work front, the results are summarized in Table 6.

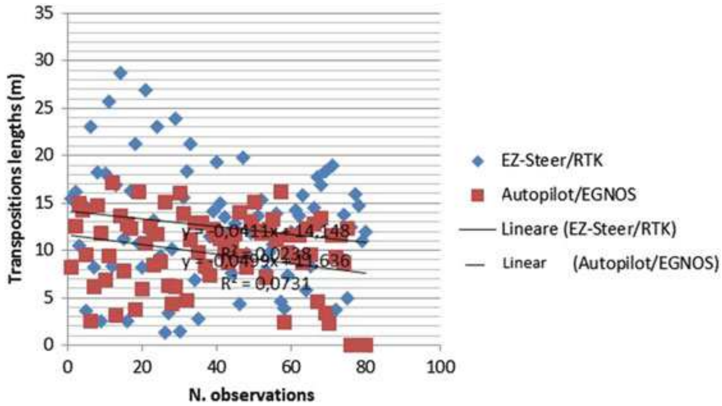
The collected data showed that the Autopilot/EGNOS system is useful ensuring a better quality of work than the EZ-Steer/RTK system; in fact, it provides a precision on the transposition total area, approximately 6,200 m^2. The area of transposition, therefore, is the parameter that most of all allows to compare the two combinations of guidance systems, as it is a datum that merges the longitudinal behavior of transposition with the latitudinal one. As for the transposition width also for the surface of transposition, the proportion (%) of the transposed area is not considered with respect to the total worked area, in that with increasing the work front and, therefore, the surface unitarily worked and the surface transposed being equal, it follows its reduction if we consider it in percentage terms.

The average depth of work respects the operating nominal depth when the tractor is supported either by the EZ-Steer/RTK system or by the Autopilot/EGNOS system. The analysis of variance (ANOVA) affected parameters such as transposition length, transposition width, and normalized areas. For the calculation of the variance of the transposition length, we have analyzed the data obtained, which have reported in the graph relative to the transposition lengths provided by the two guidance systems (Graph 1).

The results obtained showed that the values of transposition length surveyed in the field for the EZ-Steer/RTK and the Autopilot/EGNOS systems one deviate significantly from the average. Like to the calculation of the variance of the transposition width, the data collected have been analyzed which have shown in

Table 6 Results on the surface of transposition

	EZ-Steer/RTK	Autopilot/EGNOS	Variation
Area of two contiguous wipes (m^2)	3,847	4,238	−391
Total worked area (m^2)	24,957	25,305	−348
Total transposition area (m^2)	**11,484.36**	**10,182.17**	**1,302.19**
Transposition average area (m^2)	**1.81**	**1.59**	**0.22**
Minimum transposition area (m^2)	**0.065**	**0.196**	**−0.131**
Maximum transposition area (m^2)	10.19	6.5	3.69



Graph 1 Transposition lengths provided by the two guidance systems

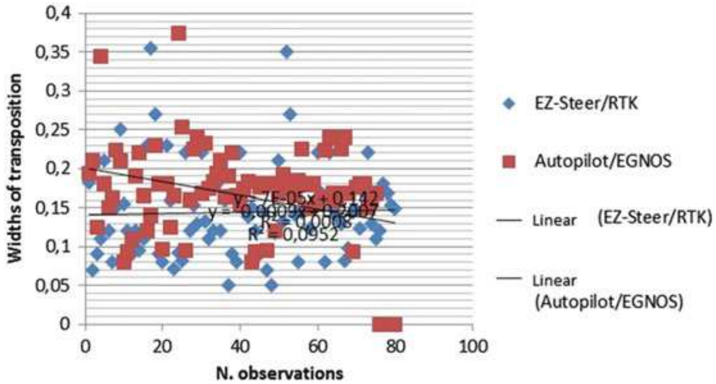
the graph of the transposition widths provided by the two guidance systems (Graph 2).

For the calculation of the variance of the transposition normalized areas, obtained by multiplying for each survey the transposition length for its width, we have analyzed the collected data which have shown in Graph 3.

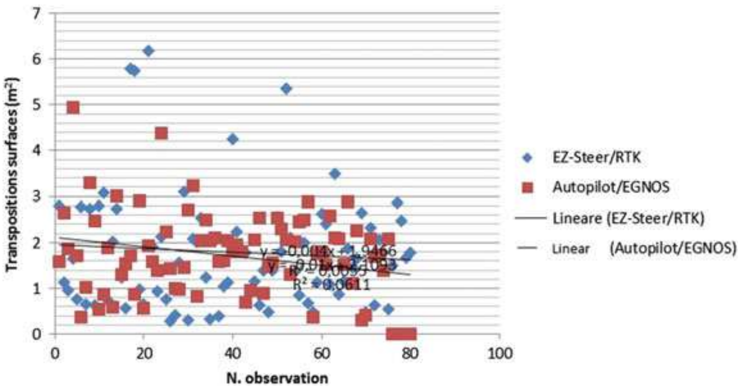
The analysis of variance on the normalized areas shows that the values obtained from the systems EZ-Steer/RTK and Autopilot/EGNOS do not deviate significantly from the average.

The survey results are summarized in Table 7 to deduce the behavior of the two systems and draw conclusions.

In longitudinal terms, a good work quality is given by the null transposition length. It’s clear from the comparison with the data that the EZ-Steer/RTK system provides a lower capacity of the theoretical trajectory. In fact, the total of the route that has been carried out shows a longitudinal transposition of 229.42 m more than the Autopilot/EGNOS system, equal to 3.806 % of 13,000 m routes. It follows that, between the two systems, the Autopilot/EGNOS is able to correct before and better the deviation from the theoretical route.



Graph 2 Comparison between the transposition widths provided by the two guidance systems



Graph 3 Comparison between the transposition normalized surfaces provided by two guidance systems

Table 7 Results about the two guidance systems

	EZ-Steer/ RTK	Autopilot/ EGNOS	Variation
Total transposition length (m)	**998.64**	769.22	229.42
Average transposition length (m)	**12.483**	9.6153	2.87
Variance – average transposition length	**38.3352**	18.3766	19.96
Percentage of the transposition length on the total of traveled route (%)	**16.275**	12.469	3.806
Total transposition width (m)	11.6	**13.237**	−1.64
Average transposition width (m)	0.145	**0.165**	−0.02
Variance – transposition average width	0.0037	**0.0043**	0.00
Total transposition area (m^2)	**11,484.36**	10,182.17	1,302.19
Average transposition area (m^2)	**1.81**	1.59	0.22
Variance – average transposition area	**1.5861**	0.888	0.70

4 Conclusions

Experimentation has shown that the two satellite-guidance systems examined had no significant differences in the quality of work, although the complex autopilot/ EGNOS has a higher reliability on the length of transposition. It follows that the two combinations of satellite guidance, in view of the similar amount of latitudinal transposition, make it suitable for all those jobs which tolerate such an error, such as plant protection treatments, fertilizing, harrowing, mowing, harvesting, etc., while for jobs requiring great precision, e.g., sowing, weeding, planting, and processing of files, there is the need to use a combination that guarantees maximum precision and, therefore, to optimize the system supporting it with the Autopilot RTK correction. The maximum precision that results, however, also involves the greatest savings on the factors of production; therefore, this solution would be desirable to also increase their procurement costs and increase with firm size.

Otherwise, that study wanted to check the accuracy of only the devices RTK and EGNOS, and this would have raised the need to follow a different approach to the findings; in fact, it would be necessary to use a single device driving, such as Autopilot, except that it would be necessary detecting the precision of the real trajectory in relation to time.

The precision between consecutive passes measures the relative accuracy of 15 min intervals, e.g., a receiver with precision between consecutive passes of 2.5 cm allows to work for 95 % of the time with an offset or overlap less than 2.5 cm. Also, the precision year after year is a measure of repeatability over the time of the accuracy or the ability of the same rows after 1 day, 1 week, 1 month, or 1 year.

At the actual level of technology there are many perspectives of full automation in agriculture, thanks to the use of robots and of internet, which would improve the transfer of data even thousands of miles away. This change, although it has its economic value, may also represent the input to give importance to agricultural systems, to date, the common feeling, less attention apparently more powerful than loans qualifying, and also seeking new employment prospects, requiring more and more people able to open your mind multidisciplinary interaction. In conclusion, a snapshot of the distribution of the solutions of precision agriculture in Italy, if taken today, allows to highlight how in recent years the development of this sector has been slow due to the reorganization of the company structure, reducing the number of operators and increasing the size and strength of the business of some figures between farms and agromechanical.

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Electrolysed Water in the Food Industry as Supporting of Environmental Sustainability

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Abstract Food safety is a priority for the food industry and to achieve this result a correct plant sanitation programme is of the utmost importance. Among various disinfection techniques, an emerging one is represented by the use of electrolysed water (EW) as the disinfecting agent. The use of EW is compliant with the desire to find alternatives to chlorination and heat treatments, representing a green cleaning alternative to toxic disinfectants. EW is an activated liquid, obtained by passing a diluted saline solution (NaCl, KCl or $MgCl_2$) through an electrolytic cell, thus causing the production from the anode side of electrolysed oxidising water, containing high dissolved oxygen, free chlorine and characterised by a low pH (2.3–2.7) and a high oxidation–reduction potential (ORP $>$ 1,000 mV). At the same time from the cathode side electrolysed reduced water is produced, with high pH (10.0–11.5), high dissolved hydrogen and low ORP (-800 to -900 mV). Unlike other chemical disinfectants, EW is not harmful for skin and mucous membranes and is quite easy to handle. Furthermore, the use of EW is relatively inexpensive and, above all, is a sustainable technique. Currently used sanitisers (e.g. glutaraldehyde, formaldehyde, etc.) are effective, but their adverse effects on the environment are well known. Differently from these chemicals, the use of EW has a reduced impact on the environment and because of its properties, it may find several applications in the food industry. In this work, the characteristics and some EW applications as sustainable sanitation technique applied in the food industry are reported and discussed.

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A. Vastola (ed.), *The Sustainability of Agro-Food and Natural Resource Systems in the Mediterranean Basin*, DOI 10.1007/978-3-319-16357-4_25

1 Introduction

Chlorine is commonly used as a disinfectant in food processing industries. However, the continuing outbreaks of food infection raise concerns and doubts about food safety. A large part of the food industry uses hypochlorite as disinfectant, but it is not often used under optimum conditions compromising its effectiveness. The excessive use of this disinfectant involves the presence of undesirable by-product residues on food (Gil et al. 2009). In addition, the chlorine-based disinfectants are a risk for human health and the environment (Ölmez and Kretzschmar 2009). In fact, it is known that from the reaction of chlorine with organic matter are generated carcinogenic halogenated by-products (DBP), for example trihalomethanes (THMs) and halogenated acids (HAAs) (Gil et al. 2009; Singer 1994). Moreover, the use of chlorine allows the production of large amounts of wastewater with high levels of biological oxygen demand (BOD). Chlorine dioxide, ozone, organic acids, peroxyacetic acid, hydrogen peroxide and EW are the main alternative sanitising agents that arouse interest (Ölmez and Kretzschmar 2009). In particular, EW represents a good alternative to chlorination and heat treatments, representing a green cleaning alternative to toxic disinfectants. Unlike other chemical disinfectants, EW is not harmful for skin and mucous membranes and is quite easy to handle. Furthermore, the use of EW is relatively inexpensive and, above all, is a sustainable technique. The cost of use is relatively low; the highest cost is the purchase of an electrolytic unit, but, after the initial investment, the costs are very low, requires only water, salt and electricity (Huang et al. 2008). Another important aspect is the low environmental impact which involves the use of EW. When the EW is in contact with the organic matter or is diluted with ordinary tap water by reverse osmosis, water becomes again "normal". As a result, the impact on the environment is much less negative compared to the use of chemical disinfectants, the use of which is also linked to the difficulties of transporting and storing potentially hazardous chemicals (Nakagawara et al. 1998; Tanaka et al. 1999). On the other hand, the main disadvantage is that EW rapidly loses its antimicrobial activity. The solutions REW and OEW maintain for a limited time their properties (12–21 days), if they are stored away from light and heat. Between the two solutions, the OEW loses its effectiveness more quickly, because the chlorine present in gaseous form is dispersed rapidly by volatilisation, so decays the bactericidal power (Kiura et al. 2002). This sustainable technology is already applied in various countries. Since 2002 in Japan EW is enclosed in the list of permitted food additives; moreover, in the USA the EPA (Environmental Protection Agency) has approved the use of electrolysed water in the food industry (Venturini 2013).

2 Electrolysed Water

EW is an activated liquid, obtained by passing a diluted saline solution (NaCl, KCl or $MgCl_2$) through an electrolytic cell, thus causing the production from the anode side of electrolysed oxidising water (OEW), containing high dissolved oxygen, free chlorine and characterised by a low pH (2.3–2.7) and a high oxidation–reduction potential (ORP > 1,000 mV). At the same time from the cathode side electrolysed reducing water is produced (REW), with high pH (10.0–11.5), high dissolved hydrogen and low ORP (−800 to −900 mV) (Huang et al. 2008; Venturini 2013; Rui et al. 2011). Of the two solutions, one, the acidic and oxidiser solution, contains hypochlorous acid (HOCl), hydrogen chloride (HCl) and free gas (O_2 and Cl_2); the other, the basic and the reductant solution, contains sodium hydroxide (NaOH), and, from this, H_2 gas is liberated. In Fig. 1, the electrolytic cell for the production of electrolysed water is schematically shown. Using a bath electrolysis without separation baffle, a solution with a pH close to neutral (6.2–6.5), with a low concentration of free chlorine (NEW), is obtained (Venturini 2013).

Due to its properties, and particularly for its bactericidal effect, EW may find several applications in the agriculture and food industry. The disinfectant action is due to several factors that act synergistically: pH; ORP; presence of free chlorine (the disinfecting action is mainly due to the presence of hypochlorous acid) (Venturini 2013). Additionally, the high redox potential induces the modification of the metabolic flows and influences the ATP production, probably due to the variation of the flow of electrons in the cell (McPherson 1993). HOCl, the most

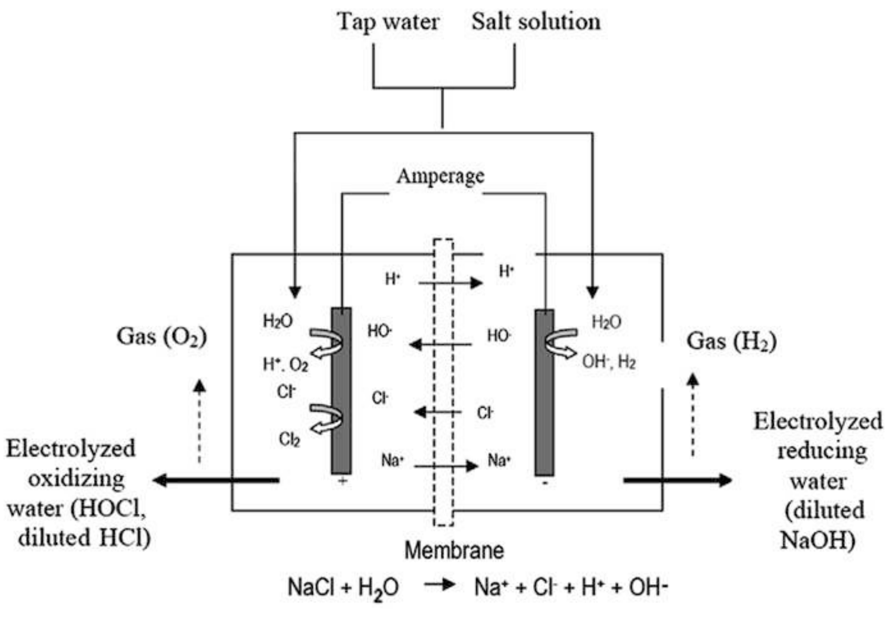

Fig. 1 Scheme of the electrolytic cell for electrolysed water (Venturini 2013)

active of the compounds of chlorine, seems to be the main responsible for the death of the microbial cell, inhibiting the oxidation of glucose, due to the oxidation of the sulfhydryl groups of enzymes involved in carbohydrate metabolism (Marriott and Gravani 2006).

3 Application of EW as Surface Disinfectant

EW has been successfully utilised as surface disinfectant, for example for cutting surfaces made with different materials (glass, steel, glazed ceramic tiles). OEW can be used to reduce bacterial contamination on teflon, stainless steel and ceramic using short treatments (5 min) (Serraino et al. 2010; Park et al. 2002). However, the bactericidal efficacy of EW depends on the amount of organic matter present on the surfaces. In fact, many disinfectants, including hypochlorite, have a reduced effectiveness in presence of a large amount of organic substance (Bach et al. 2006; Liu et al. 2006). This effect can be reduced using the alkaline EW before application of the acidic solution. Alkaline water contains high concentrations of sodium hydroxide, which exerts a detergent action dissolving fats, proteins and polymeric compounds outside the bacterial membranes. In this manner the action of the acid solution will be greater (Ayebah et al. 2005). Møretrø et al. (2012) reported the effectiveness of EW for the disinfection of surfaces contaminated with *Salmonella*, even in the presence of biofilm. Bartolomé et al. (2011a) used EW for cleaning and disinfecting a circuit milking and cooling tank in a herd of dairy cattle by comparing its effectiveness with traditional cleaning chemicals. In this study, EW has been used as a replacement to a chlorinated alkaline detergent with phosphates and an acid descaling. The obtained results suggested that the EW not only preserves the integrity of the milking systems but also ensures a greater degree of sanitisation, compared to the traditional chemical products, besides being a clean and environmentally friendly system.

4 EW on Fruits and Vegetables

The use of EW could be useful also for the treatments of fruits and vegetables, in pre and post-harvest. In fact, in the various studies (Guentzel et al. 2010; Vandekinderen et al. 2009; Tomás-Callejas et al. 2011) is reported that the use of EW, NEW and OEW does not leave significant residues of chlorine and does not affect quality the sensory and nutritional of the fruits and vegetables. In pre-harvest, EW can be used for irrigation inhibiting the microbial growth in water (*Phytophthora* spp., *Fusarium* spp., *Algae*). The OEW can be used to protect products from deterioration post-harvest caused by fungal species, such as *Aspergillus*, *Cladosporium*, *Penicillium*, and from the presence of mycotoxins produced by these fungal species. OEW, diluted with water in a 1:4 ratio, is effective to prevent the gray rot of peaches due to the germination of *Botrytis cinerea* (Venturini 2013). Guentzel et al. (2010) reported about the use of near-neutral EW (pH 6.3–6.5) on surfaces of peaches and grapes to inactivate pure cultures of *B. cinerea* and *Monilinia fructicola* responsible of gray mould and brown rot on fruits surfaces. From the study resulted that the dipping and daily spraying treatments prevent the microbial growth better than dipping alone. Moreover, EW is effective for washing and disinfection of fresh-cut fruits and vegetables. The water can represent a vehicle of cross-contamination; for this reason chlorine is usually added to the washing water but EW represents a valid alternative to this practice (Graça et al. 2010; Yudin et al. 2010). Yang et al. (2003) reported that a reduction of *Salmonella typhimurium*, *Escherichia coli* O157:H7 and *Listeria monocytogenes* of 2 log CFU/g can be obtained by plunging fresh-cut lettuce in EW at pH 7, containing 300 mg/L of free chlorine, for 5 min. Also Abadías et al. (2008) indicated that diluted NEW (50 mg/L free chlorine) has a bactericidal power against *E. coli*, *Salmonella*, *Listeria innocua* and *Erwinia carotovara* on fresh-cut lettuce, carrot, endive, corn salad and Four season salad. In addition, the result obtained showed that the NEW has an efficacy comparable with NaClO (120 mg/L free chlorine). Tomás-Callejas et al. (2011) used neutral and acidic electrolysed water (AEW) for fresh-cut mizuna baby leaves. The results of the study suggests that EW has a disinfecting power equal to NaClO. Furthermore, NEW has a higher effect against enterobacteria and mesophilic bacteria, while AEW against psychrotrophic and lactic acid bacteria. In another study (Graça et al. 2010) NEW and AEW were used to inactivate food-borne pathogens on the surface of fresh-cut apples, pears and oranges. From this study emerged that both solutions (NEW and AEW) are able to reduce the microbial population, but AEW has a higher efficacy. Deza et al. (2003) reported that the neutral solution had the same or greater efficacy than AEW on the surface of tomatoes. Koide et al. (2009) reported about the use of slightly acidic EW (pH 6, 1.20 mg/L available chlorine) on fresh cut cabbage. This study showed that slightly acidic EW has a disinfectant efficacy equivalent or higher than NaClO. Gómez-López et al. (2013) investigated about the production of trihalomethanes in baby spinach washed with EW. According to this study, although the EW contains a certain amount of chlorine, it is not involved in the production of dangerous levels of THMs. Even in the washing and cleaning of mushrooms (*Pleurotus ostreatus*), EW has been useful for the purpose of removing *E. coli* O157:H7, *Listeria*, *S. typhimurium* and *Bacillus cereus*, which hardly were eliminated with normal washing procedures (Venturini 2013). Ding et al. (2011) also reported about the use of EW with a neutral pH (6.2–6.5) value and low concentration of free chlorine (5 mg/L) on oyster mushroom to eliminate food-borne pathogens. The study showed that the EW with neutral pH and low concentration of free chlorine allows to obtain the same results of using strong acid electrolysed water (pH 2.5–2.7, 50 mg/L available chlorine), with less dangers for human health. Pangloli and Hung (2013) reported that EW with 30 mg/L of free chlorine can be successfully used to wash blueberries reducing the population of *E. coli* O157:H7 that may be present. Nimitkeatkai and Kim (2009) observed the effect of EW on washing apples. For the test were used strong acidic EW (pH 2.8) and weak acidic EW (pH 6.5). The authors assessed the efficacy of the two sanitising solutions, and the better choice is to wash apple with weak acidic EW (either 2 or 5 min) or strong acidic EW for 2 min to preserve sensory quality of apples. Liu et al. (2013) used EW during the production of germinated brown rice (GBR). In fact, although the production of GBR is quite simple, the growth of contaminating microorganisms may constitute a problem. The EW (with different parameters) was used to wash the brown rice. The study showed that the acidic EW promotes the accumulation of gamma-aminobutyric acid (GABA) during the germination of brown rice. The accumulation of GABA is positive because it has many beneficial properties for human health (Liu et al. 2013). Moreover, both strong acidic EW and slightly acidic EW were more effective in inhibiting microbial growth during germination and also promoted the growth of GBR compared with alkaline EW. This aspect has been confirmed in a previous study in which the alkaline EW inhibited the growth of mung bean sprouts; on the contrary, strong acidic EW promoted the growth of mung bean sprouts (Liu et al. 2011). In addition, Rui et al. (2011) studied the application of EW for the washing of mung bean sprouts. The use of EW as washing water, but also of irrigation, was effective for the reduction of populations of *Salmonella* and *E. coli*. Issa-Zacharia et al. (2011) used slightly acidic EW (pH 5.6–5.8) on Chinese celery, lettuce and daikon sprouts. The efficacy of the electrolysed solution was compared to sodium hypochlorite solution. It was found that slightly acidic EW is efficacy, as much as the sodium hypochlorite, to reduce the population of indigenous aerobic mesophilic bacteria.

5 EW on Animal Products

EW is also effective on animal products against pathogenic microorganisms. For example, the EW can be used to reduce the concentration of *E. coli* O157:H7, *Salmonella* spp., *L. monocytogenes* and *Yersinia enterocolitica,* conveyed through the faeces, on shell eggs. Normally, prior to incubation, the eggs are subjected to a disinfection treatment that involves the use of formaldehyde, glutaraldehyde or hydrogen peroxide. Although effective, these treatments may have toxic effects, not only on the operator who uses them but also on the chick. The EW achieves the same results in terms of disinfection without toxicity (Favier et al. 2000; Ni et al. 2013; Cao et al. 2009). The washing with EW of chicken carcasses before plucking and evisceration was useful to reduce the risk of cross-contamination and to remove *Campylobacter jejuni* from the surface of carcasses (Park et al. 2002; Fabrizio and Cutter 2004). Rahman et al. (2012) used both slightly acidic EW (pH 6.2–6.5, 10 mg/L of available chlorine) and strong acidic EW (pH 2.5–2.7, 50 mg/L of available chlorine) for dipping treatment of fresh chicken breast meat. The results showed that the two solutions have similar antimicrobial activity and not affect negatively the overall sensory quality of meat. On the contrary, EW treatment improved sensory attributes of meat (freshness, texture, odour) and extended the shelf life of the product. Azad et al. (2013) also reported about the use of EW, as drinking water, to reduce the oxidative damage to skeletal muscle of broiler chickens exposed to heat stress. The oxidative damage is due to the production of ROS (reactive oxygen species). From the study resulted that the chickens treated with EW water and exposed to a temperature of 34 °C for 5 days showed higher feed consumption, considerable improved growth performance and lower ROS production compared with the control with normal drinking water. Moreover, Bartolomé et al. (2011b) evaluated the possibility of using EW as drinking water of dairy cattle, and the effects on the quality of milk produced. In milk from cows that had ingested EW, there was a significant reduction in the number of somatic cells and the concentration of coagulase-positive microorganisms. The use of EW for the washing of fresh meat was also investigated. Bosilevac et al. (2005), Fabrizio and Cutter (2004) and Fabrizio et al. (2002) compared the effectiveness of EW with the chlorinated water, ozonated water, acetic acid and trisodium phosphate in reducing the bacterial population on fresh meat. From the studies resulted that the low pH of acidic EW allows a greater reduction, compared to the common chlorinated water, of the phenomenon of cross-contamination due to the sequential washes of carcasses. The EW is also effective to inactivate the bacteria present on fish and seafoods. In fact, it is the efficacy to reduce the population of *E. coli* O157:H7 on salmon raw or to prolong the shelf life of yellow fin tuna during chilled and frozen storage (Huang et al. 2006). Phuvasate and Su (2010) also evaluated the possibility of using EW and EW ice to minimise the growth of histamine-producing bacteria on fish skin and food contact surface. High levels of histamine cause scombroid syndrome, a common illness due to consumption of highly contaminated fish. From this study it resulted that soaking fish skin inoculated with histamine-producing bacteria in EOW (50 ppm) for 120 min can be obtained a reduction of bacteria slightly higher compared with distilled water treatment, but using EW containing 100 ppm of chlorine resulted in a better reduction of bacteria. The treatment with EW ice (100 ppm) was very effective to reduce bacteria on fish skin. This result suggested that EW ice treatment, reducing microbial load on fish skin, can reduce the possibility of cross-contamination when fish fillet is prepared. In the same study, EW containing 50 ppm of chlorine resulted in a good sanitiser to eliminate histamine-producing bacteria on food-contact surface. Feliciano et al. (2010) evaluated the efficacy of sanitised ice in reducing bacterial load on fish fillet and in the water collected from the melted ice. The results of this study showed that the sanitised ice allows to reduce the microbial load on raw fish fillet and minimise the microbial growth in water collected from the melted ice. In fact, melting ice may be a reason of cross-contamination if not discarded properly. Furthermore, according to Doi (2002), using a non-diaphragm cell can be produced sterile seawater by filtered seawater and adding HCl solution. The sterile solution obtained in this manner can be used for the treatment of fish and seafood without affecting taste and smell. In the study of Lin et al. (2014), shrimps were stored under acidic EW ice. From the observations, it appeared that the shrimps in EW ice maintained longer, compared to the sample under traditional ice, their initial characteristics. Particularly, a delay in colour change, a slight variation in the pH, a lower production of volatile basic nitrogen, and no negative effect on the texture of the product have been observed. In addition, Wang et al. (2014) reported that using acidic EW ice in dark condition can be obtained a stronger bactericidal effect compared with light condition; in fact, in light condition acidic EW had the highest chlorine loss rate. In this condition, acidic EW ice caused a lower change of pH compared with the control treated with tap water ice, lower accumulation of alkaline compounds and nitrogenous materials.

6 Combined Treatments

In order to increase the efficacy of EW has been proposed its use in combination with other treatments on different foods, without damaging the eco-friendly character of the treatments. Martínez-Hernández et al. (2015) investigated about the use of NEW combined with ultraviolet C light (UV-C) and with superatmospheric O_2 packaging (HO) to reduce *Salmonella enteritidis* and *E. coli* on fresh-cut kalian-hybrid broccoli. The results showed that NEW + UV-C or NEW + OH is more effective in reducing pathogens compared with NaClO or NEW and UV-C alone. On the contrary, the use of triple combination (NEW + UV-C + OH) did not improve the bacteriostatic effect of double combination. Liu et al. (2013) attested that EW in combination with ultrasound has better antimicrobial properties than EW alone. Zhou et al. (2011) used EW in combination with chitosan or carboxymethyl chitosan (CMC) to preserve the characteristics of the puffer fish (*Takifugu obscurus*) during refrigerated storage. On the product treated with EW + chitosan and EW + CMC was detected a microbial load significantly lower than control (untreated) or than the sample treated with EW alone. However, the combination of EW with chitosan showed better antimicrobial efficacy than the combination of EW with CMC. Rahman et al. (2011) investigated about the combination treatment of alkaline EW and citric acid with mild heat to ensure microbial safety and sensory quality of shredded carrots. The results showed that the dipping in sanitiser solution for 3 min at 50 °C is effective to reduce the microbial count but did not influence the tissue, pH and surface colour of shredded carrots, compared to the untreated control. Similar results were obtained on cabbage, in which the combination of alkaline EW with 1 % of citric acid for 5 min of dipping at 50 °C has a strong sanitising effect on total count on cabbage (Rahman et al. 2010). Zhou et al. (2012) indicated that the immersion of Nanhui peaches in EW or in EW and 1-methylcyclopropene (MCP) contributes to maintain the colour of peach flesh during storage. In fact, peaches treated with EW or EW-MCP showed lower flesh colour changes, lower production of ethylene, lower changes in polyphenol oxidase and peroxidase activity, compared with untreated fruits. Therefore, was also detected a lower production of malondialdehyde, one of the compounds resulting from oxidation processes. In Table 1 are summarised the main applications of EW on different foods.

Table 1 Main applications of EW on different foods

Food	Results of treatment	Combined treatment	References
Fresh-cut fruit and vegetables	EW with different parameters was used for washing or dipping treatment. It was found that EW is a good sanitiser and did not affect the sensory and nutritional quality of products.	For fresh cut broccoli was used EW combined with UV-C (ultraviolet C light) and HO (superatmospheric O_2 packaging). The combined treatment was more effective in reducing pathogens compared with single treatment.	Vandekinderen et al. (2009), Tomás-Callejas et al. (2011), Graça et al. (2010), Yang et al. (2003), Abadías et al. (2008), Deza et al. (2003), Koide et al. (2009), Martínez-Hernández et al. (2015)
Germinated brown rice (GBR) Mung bean sprouts	EW with different parameters was used as washing water but also for irrigation. It resulted that AEW was more effective in inhibiting microbial growth during germination and promoted the growth of GBR and mung bean sprouts.	On GBR EW in combination with ultrasound had better antimicrobial properties than EW alone.	Rui et al. (2011), Liu et al. (2011, 2013)
Shredded carrots and cabbage		EW + citric acid is effective to reduce the microbial count but did not influence the tissue, pH and colour, compared to untreated control.	Rahman et al. (2010, 2011)
Peaches and grapes blueberries apples	The washing treatment with EW was effective to preserve the overall quality of the products and reduce the population of microorganism that cause loss in quality.	EW + MCP (1-methylcyclopropene) was used for washing of Nanhui peaches. It was observed lower flesh colour changes and lower production of ethylene and peroxidase activity, compared with untreated fruits.	Guentzel et al. (2010), Pangloli and Hung (2013), Nimitkeatkai and Kim (2009), Issa-Zacharia et al. (2011), Zhou et al. (2012)
Chinese celery, lettuce, daikon sprouts	The slightly AEW was effective, as much as the sodium hypochlorite, to reduce the population of indigenous aerobic mesophilic bacteria.		Issa-Zacharia et al. (2011)
Baby spinach	The EW is not involved in the production of dangerous levels of THM.		Gómez-López et al. (2013)

(continued)

Table 1 (continued)

Food	Results of treatment	Combined treatment	References
Oyster mushroom	EW with a neutral pH (6.2–6.5) was used to wash mushroom. The treatment had the same disinfectant efficacy of strong acidic EW.		Graça et al. (2010)
Eggs	The EW gave good results in terms of disinfection without toxicity for chick compared to the treatment with formaldehyde, glutaraldehyde or hydrogen peroxide.		Favier et al. (2000), Ni et al. (2013)
Meat	Reduction of microorganisms from the surface of carcasses. The treatment did not affect the overall sensory quality, compared with the common chlorinated water.		Fabrizio and Cutter (2004), Rahman et al. (2012), Bosilevac et al. (2005), Fabrizio et al. (2002)
Milk and poultry	EW was used as drinking water for cows and broiler chickens. The treatment positively affected the quality of milk from cows that had ingested EW and the growth of chickens.		Azad et al. (2013), Bartolomé et al. (2011b)
Fish and seafoods	The EW ice was effective to reduce the histamine-producing bacteria on fish skin and to preserve the quality of seafood flesh.	The combined treatment of EW + Chitosan was better than EW + CMC (carboxymethyl chitosan) for reducing microbial load and improving the overall quality of puffer fish.	Huang et al. (2006), Phuvasate and Su (2010), Feliciano et al. (2010), Lin et al. (2014), Wang et al. (2014), Zhou et al. (2011)

7 Conclusions

From the reported studies, it is evident that the EW represents a sanitising technique as supporting of environmental sustainability. It can be used as disinfectant surface but also for the treatment of food products. In particular, from the cited studies, it resulted that AEW has a better antimicrobial activity compared with NEW. However, in order to preserve the sensory and nutritional quality of food, it is advantageous to use the NEW or slightly AEW. In any case, the effects of EW used in different conditions have to be further investigated depending on the type of food.

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