AARHUS
UNIVERSITY
DEPARTMENT OF BIOSCIENCE

Effects of agricultural system and treatments on density and diversity of plant seeds, ground-living arthropods, and birds.

Master thesis
60 ECTS
Julie Marie Søby
201405607

Data sheet

Project	Master thesis
Extent	60 ECTS
Education	MSc in biology
Place of education	Aarhus University Department of Bioscience Ny Munkegade 114-116 8000 Aarhus C
Title	Effects of agricultural system and treatments on density and diversity of plant seeds, ground-living arthropods, and birds
Author	Julie Marie Søby
Student number	201405607
Supervisors	Jørgen Aagaard Axelsen Beate Strandberg
Handed in	15/9 2020
Total number of pages	92
Number of appendix pages	11
Photos	All by author

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Acknowledgements

First and foremost, I would like to express my gratitude to the 15 farmers who gave me permission to carry out fieldwork in their land and who were all helpful and friendly. A special thanks goes to Tina Houlborg Jørgensen who provided initial contacts to farmers, and for her tips on fieldwork. I would also like to thank several course administrators in Agroecology for recommending literature.

My sincerest gratitude goes to my supervisors Jørgen Aagaard Axelsen and Beate Strandberg. The many discussions, their continuous supervision during a global pandemic, and their continuous support, enthusiasm and encouragement of my project and ambitious ideas, were invaluable. I would like to extend my gratitude to the lab technicians at the Department of Bioscience, especially Lise Lauridsen for technical assistance in the greenhouse and for finishing the seedling identification and freezing treatments due to covid-19 restrictions. A special thanks goes to Anne Mette Lykke for excellent statistical guidance.

I would also like to thank my fellow master students, Bjarke Giil Clausen, Rune Ruby Flejsborg and Michael Kirk Jespersen for the many hours of lunch and car discussions on our respective projects. My gratitude is also extended to my uncle Birger Søby, for proofreading my thesis.

Finally, I would like to thank my family and friends for their love and support, and especially my partner Emil Andreasen Klahn for his endless support, and encouragement throughout this entire process.

Preface

This thesis is the conclusion of my MSc studies in Biology, at the faculty of Technical Sciences, Aarhus University. I was motivated to carry out an independent project with agriculture as a theme, and to obtain new knowledge, and identification skills of plants, arthropods and birds. My priority was to get a broad understanding of agriculture, a subject I was curious about but had little previous knowledge on from my biology background. My aim was to understand and evaluate effects of agricultural systems and main agricultural treatments on selected groups of organisms inhabiting farmland. These groups consisted of plant seeds, ground-living arthropods and birds. I also wanted to gain experience working with planning and conducting fieldwork, using multivariate statistics, and collaboration with farmers.

In this project, I collaborated with 15 farmers who were all curious of my project and agreed to be a part of it. They helped me a great deal in gaining basic knowledge of agriculture. These farmers will receive this thesis, and a summary of my results.

I am aware, that classic biology and agriculture, in some cases, are viewed as opposing forces. This thesis aims to review and understand the effects of agriculture on biodiversity – objectively, without taking side.

For the first chapter, the sections 1.1.1-1.1.3 will provide an overall introduction to seeds, ground-living arthropods and birds. The effects of agricultural treatments and agricultural systems on these groups will be reviewed in the sections 1.2 and 1.3 respectively. Landscape effects will be mentioned in the last part of the introduction.

Abstract

This master thesis aims to compare density and diversity of weed seeds from the topsoil, ground-living arthropods, and birds within the cultivated field, across three agricultural systems: organic, conventional and conservation agriculture (CA). It has been solidified that organic farming, in general, provides a better support for farmland biodiversity than conventional agriculture. Resent Danish studies on ground-living arthropods and birds suggest, that CA could provide better support for these groups compared to conventional fields. Only few studies, and none in Denmark, have compared the organic and CA systems, or all three systems, with respect to biodiversity. Using data from fifteen fields, five from each agricultural system, this project includes 23357 seeds, 2823 arthropods and 484 birds, belonging to 88, 54 and 17 species respectively, across the three systems. Data collection was carried out in fields sown with winter wheat in 2019 before and after the event of sowing and tillage. Results obtained through multivariate statistics on thirteen predictors of agricultural treatments, fields and landscape information show that agricultural system had a consistent effect on seeds, ground-living arthropods and birds, and explained a staggering 52% of the variation in these groups. Furthermore, CA fields had significantly higher arthropod and bird densities than organic and conventional fields. In the autumn, after the sowing and tillage event, CA and organic fields had comparable topsoil seed densities. In this study, tillage was identified as the most important treatment with detrimental effects on all three farmland groups. Landscape heterogeneity was also identified as a significant predictor for farmland birds. These studies suggest that less usage or absence of, tillage can have positive effects on farmland biodiversity and provide support through the availability of lasting in-field habitats and food items.

Dansk resume

Dette specialeprojekt havde til formål at sammenligne tæthed og diversitet af ukrudtsfrø fra overfladejorden, jordlevende leddyr og fugle i marken mellem tre driftsformer i landbruget: økologisk, konventionelt og conservation agriculture (CA). Det er kendt, at økologisk dyrkning generelt understøtter biodiversitet i agerlandet bedre end konventionel dyrkning. Nye studier fra Danmark om jordlevende leddyr og fugle antyder, at CA marker også kan understøtte disse grupper bedre sammenlignet med konventionelle marker. Kun få studier, og ingen i Danmark, har sammenlignet hvordan biodiversitet i økologisk og CA-dyrkning, eller alle tre driftsformer, forholder sig til hinanden. Med data fra femten marker, fem fra hver af de tre driftsformer, inkluderer dette studie 23357 kimplanter, 2823 leddyr og 484 fugle, fordelt på 88, 54 og 17 arter på tværs af de tre systemer. Data blev indsamlet i marker af vinterhvede i efteråret 2019 før og efter såning og jordbearbejdning. Resultater opnået med multivariat statistik på 13 forklarende variable bestående af landbrugsbehandlinger samt mark- og landskabsinformation, viste, at driftsform havde en konsekvent effekt på ukrudtsfrø, jordlevende leddyr og fugle i marken, og kunne endda forklare hele 52% af variationen i disse grupper. Derudover havde CA-marker signifikant højere tætheder af leddyr og fugle end økologiske og konventionelle marker. I efteråret, efter såning og jordbearbejdning, havde CA-marker og økologiske marker sammenlignelige tætheder af ukrudtsfrø i overfladejorden. Jordbearbejdning blev identificeret som den vigtigste behandling i dette studie, med tydeligt skadelige effekter. Landskabsheterogenitet blev også identificeret som havende en signifikant effekt på agerlandets fugle. Disse resultater antyder at mindre brug, eller fravær, af jordbearbejdning kan have gavnlige effekter på biodiversiteten i agerlandet ved at understøtte tilgængelighed af blivende habitater og føderessourcer i marken.

1 Introduction

1.1 Farmland species

Natural ecosystems and agroecosystems are fundamentally different. In practice, agroecosystems are fields, farms and/or a group of farms, all including the uncultivated habitats around and in between them. Agroecosystems are artificial, deliberately simple and have a high degree of human interference. The main aim of agroecosystems is to deliver provisioning services through crops and livestock, and consequently, inputs and treatments to the systems are delivered to increase this production. Fields are characterized by frequent and intense disturbances through repeated cycles of harvest and sowing, and from other treatments such as tillage and pesticide application. Few crops and livestock species dominate the agroecosystems, and these populations are carefully regulated by the farmers (Gliessman 2015).

Traditionally, biodiversity is defined as ‘the variety of species, ecosystems and genes’, whereas agrobiodiversity covers the variety utilized by agriculture (FAO 2005). As a result, agrobiodiversity can be described as the “planned” or the deliberately introduced biodiversity such as crops, cover crops and livestock, and “associated” biodiversity encompass all the naturally occurring species in the agroecosystems such as poppies, hares and skylarks (Costanzo and Bàrberi 2014). All these associated species in farmland are often loosely referred to as farmland species, and they will be the focus in this study.

Many species call the agricultural landscape their home; it is in fact estimated, that “(…)50% of all species in Europe depend fully or partly on agricultural habitats.” (BISE, chap. Cropland and grassland), and some even when grassland habitats are available (Robinson et al. 2001). In the newest edition of the Danish Red List of Threatened Species, 41.6 % of the evaluated species were categorized as threatened, and it was evident that farmland was the third most important habitat for red listed species (Moeslund et al. 2019). This is important because habitats other than the pristine (or little intervened), have traditionally not received much attention for their importance in conservation of biodiversity (Tscharntke et al. 2005).

1.1.1 Plants

Crops are the main characters in the agricultural field, and besides them, few or no plant species are wanted. Often, side characters such as cover or catch crops play smaller parts in supporting the main crop. Some farmers plant flower strips to support pollinators or natural enemies for biocontrol, or for ornamental purposes. All these plants are in the field intentionally.

Unwanted, and therefore trespassing, plant species in a field can be referred to as weeds; commonly defined as "(…) plants growing in the wrong place at the wrong time"(Boelt et al. 2011). Primarily, weeds in agriculture are plants harmful to the crops through competition for nutrients, light, water, and space. However, weeds are also plants causing complications during harvest, or increased costs when separating grain and weed seeds, as it is the case with the seeds of scentless chamomile (*Tripleurospermum perforatum*) (Boelt et al. 2011). In wheat, loss potential to pests can be a staggering 50%, where weeds are the most important pests compared to pathogens, viruses and animal pests. For these reasons, weed control is of great importance to farmers in order to mitigate loss (Oerke 2006). In section 1.2, some methods for weed control will be presented. Weeds, however, have been shown to become more tolerated by farmers, when economic losses are insignificant (Andreasen and Stryhn 2008).

Most weeds in a field germinate from seeds already present in the soil – i.e. from the seedbank. One of the reasons why weeds are difficult to remove completely has to do with dormant seeds in the seedbank. Some seeds will lie dormant in the seedbank for a long time, which is often the case of seeds from fat-hen (*Chenopodium album)*, and they will germinate when dormancy is broken by events like changes in temperature or soil turnover. Conditions inducing and breaking seed dormancy vary and for this reason, weeds can emerge continuously (Boelt et al. 2011). According to Melander et al (2011) there are approximately 200 commonly occurring weed species in Denmark, with 20-30 of them being the most common and tortious ones (Boelt et al. 2011 chap. 3). Two of the most common species are chickweed (*Stellaria media*) and annual meadow grass (*Poa annua)*, which are harmful because they form dense carpets (Boelt et al. 2011). For annual meadow grass, this happens particularly in autumn in moist soil after winter crops are sown and the soil is undisturbed (Andreasen and Stryhn 2008).

Three linked studies illustrate the development of flora in Danish fields. Andreasen et al. (1996) compared surveys from 1967-70 with 1987-89 and found a decline in weed flora frequency in Danish fields. Hereafter, Andreasen and Stryhn (2008) used data from 2001-2004 and compared it to the previous findings. They found a drastic decline in arable flora frequency since the last survey, and the same species were dominant. In the time between the first two studies, the area with spring crops decreased, and winter wheat increased (68%) and became the most dominant crop (Andreasen and Stryhn 2008). The third, and most recent study by Andreasen et al (2018) used new data from 2014 and compared it to the previous data. Here, they found an increase in the arable seed bank, and concluded that the seedbank had returned to its previous level. However, a large change in the species composition had occurred. Besides from the overall decline, other species now made up around half of the recorded species (Andreasen et al. 2018). These results solidify how the arable weed communities are still experiencing massive changes.

As the very base of the agroecosystem, plants are the drivers of biodiversity in the field. Animals and microorganisms in the field depend on the availability of resources provided by living plants and plant material. Plant root exudates are a food-source for microorganism, whereas seeds, plants and litter are food for many animals. Habitats for fauna are provided through overall soil protection, shade and water retention (Neher 1999). Specific plant families and species are particularly important to invertebrates and granivorous birds. Marshall et al. (2003) reviewed associations between selected weed species, insect species/families and granivorous birds using a UK database. The arable weeds most important to field biodiversity and for more than 26 species of granivorous birds were: chickweed (*Stellaria media*) with 71 insect associations, knotweed (*Polygonum aviculare*) with 61 associated insect species and fat-hen *(Chenopodium album*) with 31 insect associations. Of importance to 11-25 granivorous bird species were; duckleaf (*Rumex obtusifolius)* with 79 associated insect species, annual meadow grass (*Poa annua*) with 53 associated insect species, and groundsel (*Senecio vulgaris*) with 46 insect species.

1.1.2 Ground-living arthropods

In this section, the basis of the soil food web will be covered, but soil and the interaction between soil and organisms will be covered in section 1.2.1.

The soil food web is particularly supported by plant material, and it consists of microflora (e.g. algae, fungi and bacteria), microfauna (e.g. protozoans), mesofauna (e.g. collembola, nematodes, and mites), macrofauna (insects) and soil megafauna (earthworms) (Neher 1999). Bacteria and fungi that colonize organic matter are concentrated in plant litter, and around roots. They also act as important decomposers (Ingram et al. 2000). Micro- and mesofauna live in the soil pores and microfauna depend on soil moisture for reproduction and movement (Lavelle et al. 1995). Mesofauna feed primarily on microorganisms, such as collembola consuming fungal hyphae below and above the soil surface, but some are omnivorous and thus also feed on other mesofauna. Densities of soil organisms are inversely proportional to the trophic levels they represent (Neher 1999), and up to 118 000 collembola pr. m^2 were recorded in a field experiment on green manure (Axelsen and Kristensen 2000). Collembola are a particularly important group as they are prey to generalist predators in fields (Bilde et al. 2000). A field experiment of a forest detritus-based soil food web found considerable evidence of bottom-up regulation of the soil food web (Chen and Wise 1999). In that study, experimental plots with detritus addition exhibited three times more Collembola and doubled or several more predators after 3 months, compared to the control plots with no addition. Such responses in predators are important in matters of biocontrol.

Controlling animal pests is a priority to the farmer, as pest species such as aphids can cause severe damage to the crop. In conservation biocontrol, which is of particular interest in fields, the main focus is to support and protect the natural enemies (NE) of pests already present in the system. Support can be done through ensuring refugia, favorable habitats and microclimates; and food availability in the agroecosystem (Lövei and Sunderland 1996, Hajek 2004). Providing food such as high quantities of Collembola, can play an important role in retaining and mobilizing macrofauna generalist predators in the field, in order for them to act as pest control agents when the pest species arrive (Agustí et al. 2003). If the prey densities are too low, predator populations could decrease (Lövei and Sunderland 1996), and the efficiency of the biocontrol agents could be lost.

Common generalist predators already present in the soil food web in the field are ground beetles (Coleoptera: carabidae) and spiders (Lövei and Sunderland 1996, Agustí et al. 2003, Holland et al. 2006). Carabids are mostly present on the soil surface, such as the common species *Bembidion* *lampros* and *Notiophilus biugattus,* and they feed primarily on Collembola and Diptera. Carabids are mostly polyphagous, and they are predators on potential pests such as aphids (Sunderland 1975), but some species also eat seeds. There are studies suggesting carabids as control of weed seeds, e.g. Bàrberi et al. (2010), and seed predation by carabids can in some weed species account for up to 50% of the predation (Kromp 1999). However, studies on carabids as pest control agents rely on laboratory experiments, and not on open field studies. Average numbers of carabids in mid-fields have great fluctuations from 1-96, but they average at 32 pr. m^2 and are all caught using pitfall traps. Carabid densities in field boundaries are generally much higher with an average of 233 pr. m^2 (Kromp 1999).

Spiders are key predators in fields (Agustí et al. 2003), especially when groups of species are assembled. With several species of spiders, there is very little “enemy-free space” for prey species, due to spiders being positioned in all dimensions e.g. vertically in straw (Sunderland 1999) and wolf spiders patrolling the ground (Ingram et al. 2000). To cement this point, webs from linyphiid spiders covered 50% of the ground surface in a field of winter wheat in 1981 (Sunderland et al. 1986). Linyphiid spiders are even known to locate their webs in close proximity to high densities of Collembola (Agustí et al. 2003).

Ground dwelling organisms experience several challenges in agricultural fields: scarcity of food and low quality of it, compacted, dried up or waterlogged soil (Lavelle et al. 1995) and impactful agricultural treatments make for harsh living conditions. Widespread decline in arthropods are reported (Seibold et al. 2019), and these declines are also evident in farmland. A British study using invertebrate data collected from approximately 100 cereal fields pr. year over a time period of 42 years (1970-2011) reported a decreasing abundance of spiders, ground beetles, parasitoid wasps (Braconidae), leafminer flies (Agromyzidae), spearwinged flies (Lonchopteridae) and fungal feeding beetles (Lathridiidae and Cryptophagidae) (Ewald et al. 2015). Additionally, a new Danish study showed 80% decline in flying insects in farmland in the period from 1997 to 2017, using windscreens samples from cars, sweep nests, sticky tape and feeding rates of barn swallows (Møller 2019). Thus, there are strong indications that overall decline is also happening in Denmark. These declines are important in terms of services provided to the agroecosystems by invertebrates, but also due to their importance as food for birds.

1.1.3 Birds

Many birds are linked to farmland, but some can be described specifically as farmland birds because of their farmland habitat preferences. Depending on habitat preference distinctions, Newton (2017) defined up to 158 farmland bird species in Britain in the breeding season, and up to 168 in the winter (Newton 2017). In Denmark, Heldbjerg et al. (2018) used habitat preference to calculate a Relative Habitat Use (RHU) index for 104 species in the common bird monitoring from 2014. Based on this, they defined 41 farmland species with an RHU index value above one. Of these species, 16 were high use habitat specialists (HiU) with an RHU index value above two, and 25 were intermediate use habitat specialists (IU) with an RHU index value below two but above one. Additionally, for the 41 species, RHU indices were calculated for arable land (fields, fallow land, smaller elements like hedgerows and orchards) and grassland habitats (meadows, marches, dry grassland, grassland without trees/shrubs) in order to determine their habitat type preference. The Danish Ornithological Union (DOF) report 23 birds as farmland species (Eskildsen et al. 2020), and the difference from Heldbjerg et al. (2018) can roughly be attributed to the exclusion of marsh and meadow species as farmland species. The list of farmland birds used in this thesis is a summary of the species defined by Heldbjerg et al. (2018) and Eskildsen et al. (2020) with a total of 45 species, all listed for completeness, in Table 1. In this thesis, focus will mainly be on the farmland species with arable land preferences (RHU>1 for arable land). Not surprisingly, several species commonly referred to as "farmland specialists", had a high use habitat preference (RHU>2) for the arable land. These were corn bunting, skylark, lapwing, grey partridge, yellow wagtail, kestrel and barn swallow.

Weeds, cereal grain and arthropods are very important food items for birds in the farmland (Newton 2017 chap. 7). Wilson et al. (1999) reviewed food items for 26 granivorous birds. Of these 26 birds, 13[1] are also Danish farmland birds. Holland et al. (2006) reviewed 22 farmland birds, also of which 13[2] were Danish farmland birds. They both listed food items as important groups, if they were of dietary importance during some part of the year or constituted 5% of the diet. The seeds of the plant families Asteraceae, Brassicaceae, Caryophyllaceae Chenopodiaceae, Fabaceae, Poaceae, Polygonaceae and Urticaceae were common in the diet of granivorous farmland birds, (Wilson et al. 1999), such as skylark, corn bunting and grey partridge. For plant species, chickweeds (Caryophyllaceae*: Stellaria media*) fat-hen (Caryophyllaceae: *Chenopodium album*) and knotweed (Polygonum: *Polygonum aviculare*) were some of the most important to birds (Marshall et al. 2003). Cereal grains, shoots and grass seeds are generally important foods for farmland birds (Newton 2017 chap. 6) at all times of the year (Holland et al. 2006). However, a study of skylarks in France found, contrary to earlier studies, no cereal grains present in their winter diet and as a result, weed seeds were the sole dietary contribution (Eraud et al. 2015).

Grey partridges feed nestlings and chicks with insects and other invertebrates, and this is also the case for other granivorous farmland birds, such as sparrows (house sparrow, wood sparrow, meadow pipit and wagtails) (Newton 2017, chap. 7). Some farmland birds are more strictly insectivorous, such as yellow wagtails (Holland et al. 2006) and swallows. To these birds, some important arthropod groups are Arachnida, Coleoptera, Diptera (especially Daddy-longlegs (Tipulids) (Newton 2017, chap. 14)), Hemiptera, Hymenoptera and Lepidoptera (Wilson et al. 1999, Holland et al. 2006). Thus, high densities of these food components are especially important during the breeding season to feed chicks and nestlings. Many birds shift food item preferences over the year, and the overall tendency is that in winter, a larger proportion of the food intake is weed seeds and cereal grains compared to insects. An example of this is the tree sparrow who eat 4% plant material in the breeding season and 60% in the nonbreeding season (Holland et al. 2006). Earthworms are also a major food component for lapwings, corvids, gulls, snipes, buzzards and a minor food group for many other farmland birds (Newton 2017, chap. 5).

On a European level, farmland birds have declined 57% from 1980 to 2016 (Moshøj et al. 2019), and in Denmark farmland birds are also in significant decline (Eskildsen et al. 2020). Farmland birds, both high use and intermediate use specialists, had stronger long-term population decline, than specialist species in other habitats (Heldbjerg et al. 2018). The once very common skylark had a significant population drop during the period from 1976 to 1985, and there has been a further decline of -10% since the last Red List evaluation in 2010.

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[1] Grey partridge, wood pigeon, skylark, magpie, jackdaw, rook, carrion crow, house sparrow, tree sparrow, linnet, goldfinch, yellowhammer, reed bunting and corn buntling.

[2] All as above, except yellow wagtail and lapwing replacing magpie and carrion crow.

Table 1 Farmland species sorted by RHU index value, applied by Heldbjerg et al. (2018). (I) Farmland specialist (II) Intermediate farmland specialists and (III) Farmland species only defined by DOF. RHU values marked in red are HiU for arable land and/or grassland. The 23 species in bold are classified as farmland species by Eskildsen et al. (2020). Breeding and winter population trends applied by Eskildsen et al. (2020). Farmland birds "0" are stable, "+" increase with less than 5% pr. year, "++" increase with more than 5% pr. year, "-" decline with less than 5% pr. year, "--" decline with more than 5% decline pr. year, and NA is no information, also applied from Eskildsen et al. (2020). The column on Danish Red List evaluations is applied from Moeslund et al. (2019), and in this column "" indicate progression from LC in 2010 to the specified status from 2019. Ground nesting and diet of some birds are included.*

Latin name	Common name	Danish name	Breeding population trend in DK 20010-2019	Winter population trend in DK 2009/10-2018-19	Danish Redlist evaluation in 2019	RHU index farmland	RHU Arable land/Grassland	Ground nesting	Diet
I. Farmland specialists (RHU > 2)									
Emberiza calandra	**Corn bunting**	**Bomlærke**	-	-	NT*	11.3	11.0/0.6	X	GR
Alauda arvensis	**Skylark**	**Sanglærke**	-	-	NT*	5.9	5.6/1.0	X	GR
Perdix perdix	**Grey partridge**	**Agerhøne**	-	--	VU*	5.2	4.2/1.6	X	GR
Vanellus vanellus	**Lapwing**	**Vibe**	-	NA	VU*	5.2	2.6/3.8	X	INS
Motacilla flava	**Yellow wagtail**	**Gul vipstjert**	0	NA	LC	3.7	2.0/3.4	X	INS
Anthus pratensis	**Meadow pipit**	**Engpiber**	0	++	LC	3.1	0.7/8.3		
Haematopus ostralegus	Oystercatcher	Strandskade	0	NA	LC	3.1	0.7/8.6	X	
Falco tinnunculus	**Kestrel**	**Tårnfalk**	0	+	LC	2.8	2.1/2.1		
Hirundo rustica	**Barn swallow**	**Landsvale**	-	NA	LC	2.8	2.5/1.6		
Saxicola rubetra	**Whinchat**	**Bynkefugl**	0	NA	LC	2.8	1.2/4.8	X	
Tringa totanus	Redshank	Rødben	-	+	NT*	2.6	0.5/9.0		
Circus aeruginosus	Marsh harrier	Rørhøg	+	NA	LC	2.5	1.7/2.6		
Sturnus vulgaris	Starling	Stær	-	+	VU*	2.3	1.8/1.9		
Larus canus	Common gull	Stormmåge	-	+	LC	2.3	2.0/1.8		
Sylvia communis	**White throat**	**Tornsanger**	-	NA	LC	2.1	1.9/1.6		
Acrocephalus palustris	Marsh warbler	Kærsanger	0	NA	LC	2.0	1.3/2.9		
II. Intermediate farmland specialists (2 >RHU >1)									
Linaria cannabina	**Linnet**	**Tornirisk**	0	NA	LC	1.9	1.9/1.1		GR
Carduelis carduelis	**Goldfinch**	**Stillits**	0	++	LC	1.8	1.8/1.2		GR
Chroicocephalus ridibundus	Black-headed gull	Hættemåge	-	-	EN*	1.8	1.5/1.8		
Tadorna tadorna	Shelduck	Gravand	-	NA	VU*	1.8	1.4/2.2		

Delichon urbicum	House martin	Bysvale	-	NA	LC	1.8	1.6/1.4		
Corvus frugilegus	**Rook**	**Råge**	0	0	LC	1.7	1.7/1.1		GR
Gallinago gallinago	**Common snipe**	**Dobbelt-bekkasin**	NA	NA	LC	1.7	0.5/5.6		
Motacilla alba	**Pied wagtail**	**Hvid vipstjert**	-	NA	LC	1.7	1.7/1.2		
Anser anser	Greylag goose	Grågås	++	+	LC	1.7	0.5/6.0		
Larus argentatus	Herring gull	Sølvmåge	-	-	LC	1.7	1.1/2.8		
Corvus cornix	**Hooded crow**	**Gråkrage**	-	-	LC	1.6	1.5/1.3		GR
Corvus corone	**Carrion crow**	**Sortkrage**	NA	NA	LC	1.6	1.5/1.3		GR
Passer montanus	**Tree sparrow**	**Skovspurv**	-	-	LC	1.6	1.9/0.5		GR
Hippolais icterina	Icterine Warbler	Gulbug	-	NA	VU*	1.6	1.6/1.1		
Pica pica	Magpie	Husskade	-	-	LC	1.5	1.5/1.1		GR
Riparia riparia	Sand martin	Digesvale	-	NA	NT*	1.5	1.1/2.1		
Emberiza citrinella	**Yellow hammer**	**Gulspurv**	--	-	VU*	1.4	1.5/1.0	X	GR
Luscinia luscinia	Thrush Nightingale	Nattergal	-	0	VU	1.4	1.2/1.6		
Emberiza schoeniclus	Reed Bunting	Rørspurv	0	-	NT*	1.4	0.6/3.9		GR
Buteo buteo	Common buzzard	Musvåge	-	-	LC	1.2	1.1/1.4		
Ardea cinerea	Grey heron	Fiskehejre	+	++	LC	1.2	0.8/2.3		
Acrocephalus schoenobaenus	Sedge Warbler	Sivsanger	0	-	LC	1.2	0.4/4.3		
Cuculus canorus	Cuckoo	Gøg	-	NA	NT*	1.1	1.0/1.3		
Coloeus monedula	Jackdaw	Allike	0	-	LC	1.0	1.1/0.8		GR
Columba palumbus	Common wood pigeon	Ringdue	-	--	LC	1.0	1.1/0.9		GR
Passer domesticus	House sparrow	Gråspurv	-	0	LC	1.0	1.3/0.4		GR
III Farmland species (1>RHU) classified by DOF									
Oenanthe oenanthe	**Northern wheatear**	**Stenpikker**	-	NA	VU*			X	
Sylvia curruca	**Lesser whitethroat**	**Gærde-sanger**	+	NA	LC				
Turdus pilaris	**Fieldfare**	**Sjagger**	?	0	LC				
Lanius collurio	**Red-backed shrike**	**Rødrygget tornskade**	0	NA	LC				

This tendency is even worse for grey partridge, yellowhammer, lapwing and northern wheatear, all classified as vulnerable (VU), who all had a 30% population drop over 10 years (Moeslund et al. 2019). These five species are ground nesting birds, and Heldbjerg et al. (2018) specifically reported that among the 41 farmland species, ground nesting birds had significantly greater decline compared to non-ground nesting species. Compared to the previous Danish Red List evaluation in 2010, 14 of the 45 farmland birds have progressed from least concern (LC) to either near threatened (NT) or vulnerable (VU), in the newest Danish Red List evaluation. Farmland bird species are declining, and there are strong suggestions that this decline can be attributed to changes in agricultural systems, landscape changes and overall intensification (Chamberlain et al. 2000, Donald et al. 2001).

1.2 Agricultural treatments

In this thesis, the term "treatments" will be used, as opposed to "practices". I have found that practices are often used as an umbrella term, covering everything from inputs, treatments, specific agricultural farming systems and more specific farm variables such as row distance and crop rotation, or only one of the three. To minimize confusion, the term treatments are used in this thesis as independent applications to the field, as described below.

Treatments are applied to fields to optimize production. Ignited by new high-yielding crop varieties, agrochemicals (chemical fertilizers and pesticides), efficient irrigation, and increased mechanization (Matson et al. 1997), production accelerated during the Green Revolution in the 1960'ties (Donald et al. 2001). Agricultural treatments such as tillage, and the application of pesticides and fertilizer (these two are also called inputs) are used to provide optimal conditions for the crop and to combat pests (McLaughlin and Mineau 1995). These applied treatments can affect species inhabiting the agroecosystems.

Soil is the stage where the act of farming plays out. Agricultural treatments are applied to increase soil fertility, as fertile soil is the very foundation of farming. Soil fertility can be described as the ability to sustain growth of crops and can be evaluated based on several parameters. One of these parameters is soil organic matter (SOM), consisting of live and dead organic matter. It contains soil organic carbon (SOC) along with important plant nutrients such as nitrogen. Assembled by fungal hyphae and microorganisms, SOM is integrated in soil micro- and macroaggregates (clusters of different sizes). These aggregates are very important in agriculture; which is why the stability of soil aggregates is another measure of soil quality. A loose "crumblike" structure of aggregates is accompanied by higher porosity leading to high aeration and better capacity for water storage and drainage in the soil. Plant roots can effortlessly grow in these conditions (Gliessman 2015, chap. 8). The crumb structure of the soil is also important to soil fauna, as mesofauna live in the pore space, and soil fauna can even modify the structure of the soil.

As decomposers, earthworms feed on SOM, from the soil surface (Neher 1999), and here they act as ecosystem engineers by increasing soil porosity, when they dig and drag organic matter into the soil (Kladivko 2001). There are different types of earthworms; some live in the upper soil layers and some can bury several meters into the soil (Ingram et al. 2000). The passages created by movements of earthworms aid water infiltration, provide homes for other microorganisms, aerate the soil and give space for plant roots to grow (Kladivko 2001).

1.2.1 Tillage

Soil with good crumb structure is easy to till, but in turn, tillage can alter the soil structure. With tillage, aggregates are broken up, the soil is compressed from the heavy machinery, and pores are destroyed. This can lead to compacted soils with low porosity, all which can compromise the water retention and drainage ability of the soil. End results of intensive tillage can, in the worst case of scenario, be more extreme soil conditions such as drought and waterlogging (Gliessman 2015, chap. 8). With tillage, microbial activity is increased in the upper soil layers (with aeration) and SOM breakdown is accelerated (Beare et al. 1994). Anaerobic conditions for longer periods can cause loss of microbial organisms, and this is generally associated with waterlogged and compacted soils (Ingram et al. 2000).

Tillage as a treatment in agriculture is very common. In Denmark, 93% of the farmland is being tilled annually (Holstrup et al. 2017). Tillage has effective and important uses, where the most important ones are the mechanical destruction of weeds, the mixing of crop residue into the soil and for the loosening of topsoils to prepare for sowing.

Tillage turn over the soil to destroy the roots of weeds and to bury seeds and sprouts. When battling weeds, deep tillage (10-20 cm) buries up to 95% of the weed seeds and sprouts below the top 5 cm. When seeds are buried, seed dormancy is induced, and many seeds die. Some weed seeds, like poppies and fat-hen, can survive in the seedbank for long, and during the next tillage, seeds from the seedbank are transferred to the topsoil and brought to light where germination is induced (Boelt et al. 2011). Thus, new seeds are also brought up during tillage. Depending on the tillage system, some species are favored over others. Annual meadow grass (*Poa annua*) is favored in compacted soils (Andreasen and Stryhn 2008), whereas stickyweed (*Galium aparine*) and sow thistles (*Sonchus avensis*) can dominate in no-till systems (Boelt et al. 2011).

Tillage also affects the small-scale world of interconnected soil fauna and microbes. As soil is turned, soil fauna are killed and habitats altered. Kladivko (2001) reviewed how some groups of soil fauna are more vulnerable to tillage than others, but the overall picture is that meso and macrofauna are vulnerable to tillage. Studies on Collembola show moderately to mild inhibition by tillage (Kladivko 2001), and recent results from Denmark showed significantly higher densities of Collembola in no-tillage fields compared to conventional fields (Jørgensen 2017). Jørgensen (2017) also found significantly higher densities of spiders in no-tillage fields compared to conventional tillage, and these results are consistent with Samu et al. (1999). During mechanical crop treatment, spiders suffer from high mortality rates, even in reduced tillage and simple grass cutting. This could very well be because spiders are more affected by habitat destruction as they have more permanent homes, and because they have more delicate bodies compared to carabids and other beetles (Thorbeck and Bilde 2004). Beetles are not necessarily killed by tillage, and some manage to dig their way to the surface after burial. However, carabid densities and species are generally higher in no-tillage systems (Kromp 1999). This was also supported by Jørgensen (2017) who also found significantly higher densities of carabids in no-tillage fields compared to conventional tillage.

With tillage, seeds and invertebrates are buried, and this lower food availability impact farmland birds (Holland 2004). Compared to conventional tillage, more granivorous birds are reported in non-inversion tillage in the winter in the UK (Cunningham et al. 2005), especially in non-inversion cereal fields (Cunningham 2004). Ground nesting birds are extremely sensitive to tillage, as nests are destroyed, and because nestlings and adult birds can be killed or injured during the disturbances of tillage. Nest numbers in no-tillage systems are up to 12 times higher (McLaughlin and Mineau 1995), and these systems have intrinsically better cover, e.g. for nests, as stubbles are not integrated into the soil (Holland 2004). Because even light harrowing can destroy nests and eggs, reduced tillage fields can potentially act as a traps to ground nesting birds (Cunningham et al. 2004).

1.2.2 Mulch and fertilizer

Compared to a natural ecosystem, agroecosystems have a high degree of nutrient flow in and out of the system. Nutrient inputs to a field can derive from inorganic fertilizer, organic fertilizer and mulches.

Mulching is the process of adding crop residue on the soil surface and it is primarily performed to supply the soil with carbon rich organic matter to increase soil fertility. The mulch can be left on the surface or tilled into the soil; the latter is a common organic treatment, whereas it is left on the soil surface in no-tillage systems. Mulch can also be living plants, and this “live mulch” is referred to as “cover- “or “catch crops”. The benefits of live mulch are the same as dead mulch, with a few additions. Nitrogen can be supplied to the soil if nitrogen-fixating catch crops, such as legumes, are used. Cover crops can also suppress weeds through direct competition, and when the live mulch die back and is decomposed, it acts as “green manure” to the soil (Axelsen and Kristensen 2000). A study on mulch and tillage effects on wheat production found that mulch used in conventional tillage increased soil porosity, which was correlated with increased yields (Głab and Kulig 2008). Mulch has more parts to play, other than being a potent carbon fertilizer. When left on the surface, mulch cover the soil, and act as a form of insulation by mitigating drying and freezing of the soil (Kladivko 2001). Furthermore, weeds can be controlled through mulching, as a layer of crop residue suppress regrowth of seeds (Ramakrishna et al. 2006), and because live mulch competes with weeds for water, space, light and nutrients.

Mulch, live or dead, have strong bottom up effects on the soil food web. A study showed, that the biomass of microorganisms (fungi and bacteria) were enhanced in sawdust mulch, and this increased supply of organic matter, provided a bottom up effect where arthropods were more numerous in mulch than without (Wardle et al. 1999). Similar results were also found by Axelsen and Kristensen (2000), where very high densities of Collembola and mites were found in experimental plots with catch crops, compared to the control without. As it was also suggested by Wardle et al. (1999), mulch support arthropod diversity through provision of structural complexity, and the derived microhabitats are beneficial to spiders (Samu et al. 1999) and other arthropods. Therefore, mulch can be assets in biocontrol through the derived microhabitats (Hajek 2004). Barré et al. (2018) suggest that benefits of mulch can also be extended to birds, because a significant increase in bird abundance were a possible response to increased arthropod diversity and density as a result of mulch.

As reviewed by Kromp (1999), effects of mulch and fertilizer on carabids are varied and can be difficult to separate. This could be due to the fact, that when studies add organic fertilizer, the carbon supply and structural heterogeneity effects are similar to those of mulch. However, on a species level, *Bembidion lampros*, can be more numerous in plots with organic fertilizer, and carabids tend to avoid plots with inorganic fertilizer (Kromp 1999). Organic fertilizer has shown to increase carabids in some cases, and this could be due to increased prey availability as effects of manure are evident on microorganisms, detritivores and earthworms (Holland and Luff 2000).

There is no doubt, that extensive use of fertilizers, has led to increasing homogenization of weed flora species in the arable setting where only light and water are the limiting growth factors (Storkey et al. 2012), as seen over a 50-year period in Germany (Baessler and Klotz 2006). Because some species are very competitive in nutrient rich soil, weed communities change with these inputs. This must affect the agroecosystem from the bottom up, impacting arthropod and bird communities.

1.2.3 Pesticides

Pesticides are efficiently used to protect crops against unwanted pathogens, animal or plant pests. For this reason, they can alter density and diversity of farmland species in fields. Herbicides are game changers when combatting weeds (Oerke 2006), and they can reduce densities of weeds in a conventional field with two thirds after treatment (Hald 1999). Herbicides can affect plants on various life cycle stages, where decrease in seed production, disrupted growth and flowering depend on type, dose and timing of the herbicide application (Boutin et al. 2014). Three important plants families to arthropods and birds, Brassicaceae, Chenopodiaceae and Fabaceae, were particularly sensitive to herbicides in cereal fields (Hald 1999), and this was also the case for the important family Polygonaceae (knotgrasses and sorrels) (Wilson et al. 1999). Thus, application of herbicides (and fertilizer) generally induce lower species diversity and density.

Application of pesticides and their implications on other organisms are complex, but non-target effects are obvious wildcards. Herbicides applied in the field can have spillover effects to non-targeted plants in the field margins (Boutin et al. 2014), and the reduction and removal of weeds, through the use of herbicides, can seriously affect insects in fields (Marshall et al. 2003). Results of a 42-year study in the UK with widespread invertebrate decline (mentioned in 1.1.2) used climate and pesticide data and found, through model selections, that the decline in Araneae and Carabidae were driven only by pesticides. In the same study, a combination of weather and pesticides drove the decline of other Coleoptera (Ewald et al. 2015). Wilson et al. (1999) also found that insecticides have detrimental effects on the Coleoptera families ground beetles, rove-beetles, weevils, leaf beetles and click beetles, and negative effects of insecticides and herbicides on spiders were also reported. These findings are supported in the following field studies on carabids and spiders. From a field study in Denmark, dry mass of carabids increased by 25% (Navntoft et al. 2006) when pesticides were reduced to one fourth of the normal application rate. An explanation of this could be, that carabids are affected by herbicides and fungicides through habitat modification and loss of food resources (Holland and Luff 2000). Similar results and suggestions are found for spiders; significant density declines after insecticide application was reported for spiders, and linyphiids were especially sensitive (Everts et al. 1989). In a study on field margins, spider abundance had a delayed decreasing response to one annual herbicide (glyphosate) application, and it was suggested that this delay was due to a decrease in prey species responding to reduced vegetation and the reduction of plant structural complexity (Baines et al. 1998). For these reasons, pesticides affect arthropods in fields with direct mortality and indirectly through altered habitats and prey densities.

Even though pesticides are not applied to target birds, effects of pesticides on birds are substantial both directly and indirectly (Newton 2017 chap. 8). The recognitions of DDT accumulation impact on eggshells in raptors, affected reproduction directly (Ratcliffe 1970), but breeding success can also be affected indirectly. For example, Boatman et al. (2004) found some evidence of indirect effects of pesticides on a farmland bird, as breeding performance of yellowhammers were negatively associated with foraging in areas sprayed with insecticides.

Pesticide applications to combat weeds and pest species, have indirect effects through the food availability for birds; insecticides affect arthropods directly whereas herbicides both affect plants directly and arthropods indirectly. However, pesticides can also have direct lethal, and sub-lethal effects on birds upon ingestion of pesticide coated seeds, and Newton (2017) suggest these effects are likely underestimated. It is fair to assume that pesticide use, as part of changes in, and intensification of, farmland are at least indirect drivers of farmland bird losses (Chamberlain et al. 2000).

Finally, Geiger et al. (2010) conducted a study on number of plants, carabids, ground-nesting farmland birds and biocontrol potential across Europe in nine areas. They applied 13 agricultural intensity variables, such as ploughing regime, use of pesticides and fertilizer and eight landscape variables. Pesticides had the most consistent, significant, and negative effects on all four groups.

1.3 Agricultural systems

The Danish term ”driftsform” has many translations in English, and they are used inconsequently in the literature I reviewed. Some of the translations are: agricultural practice, farming practice, agricultural system, farming system, cropping system, farm management system and agricultural management system. All these listed terms are used to describe a well-defined set of inputs and treatments used (or not used) in farming. The term *agricultural system*, also used by Food and Agriculture Organization of United Nations (FAO), or just *system* is applied in this thesis. Here, the three systems, conventional, organic and conservation agriculture (hereafter CA) are in question.

Conventional agriculture is by far the most common agricultural system in Denmark. Of the 2.634.879 ha of agricultural land and 30.762 farms in Denmark, organic farming account for 12.11% of the production area (319.000 ha) and 13.06% of farms (4016 farms) in 2020 (Danmarks statistik 2020). This is a doubling of 2007 numbers (Landbrugsstyrelsen 2019). Corresponding numbers are not available for CA in Denmark. However, 357.590 ha and 3635 farms had reduced tillage in 2018, whereas numbers for 2019 and 2020 are not available (Danmarks statistik 2020). Using the 2018 numbers of 2.632.453 ha of agricultural land and 32.652 farms, reduced tillage accounted for 13.58% of the production area and 11.13% of the farms. As it is evident in Table 2, non-inversion tillage (also called minimum tillage) is the largest proportion of reduced tillage, whereas no-tillage is a much smaller part. It is assumed, that all CA area and farms are denounced as a part of the no-tillage group, but not all no-tillage area and farms are likely to be CA because this system also include other treatments than the absence of tillage. Thus, CA fields in Denmark is likely to cover less than 1.47% of the production area, and less than 3.01% of farms. Even though organic production covers more area than CA, global numbers report significant increase in land under both CA and organic production (Kassam et al. 2019, FiBL and IFOAM 2020).

Table 2 Production in numbers. Organic are 2020 numbers, whereas the other three are 2018 numbers. Applied from AFG5,* Danmarks statistik (2020)

Systems	Area		Farms	
Organic*	319.000	12.11%	4016	13.06%
Reduced tillage	357.590	13.58%	3635	11.13%
Non-inversion tillage	319.006	12.12%	3364	10.30%
No-tillage	38.585	1.47%	984	3.01%

Organic and CA are both alternatives to conventional farming, and there are main differences between the three agricultural systems, which will be reviewed in detail in pairs of organic/conventional and CA/conventional in the following two sections. Conventional farming is not reviewed alone but in comparison to the alternatives, because the literature on the field I reviewed, is based on comparisons between systems and treatments.

To give an overview of treatments, conventional agriculture utilizes both tillage and pesticides to combat pests, whereas organic utilize tillage, and CA utilizes pesticides. With less tools to combat pests, organic and CA have a higher dependency on other treatments to avoid substantial losses to pests. In both systems, mulch or cover crops are often applied, and much attention is paid to crop rotations.

Table 3 Overview of treatments used by the three agricultural systems.

Treatments	**Conventional**	**Organic**	**CA**
Tillage	+	+	-
Pesticides	+	-	+
Fertilizer	Organic/Inorganic	Organic	Organic/Inorganic
Cover		Mulch/cover crops	Mulch/cover crops
Crop rotations		+	+

1.3.1 Organic farming

An organic agricultural system is defined by FAO 1999 as *“(…) a holistic production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles, and soil biological activity, (…) This is accomplished by using, where possible, agronomic, biological, and mechanical methods, as opposed to using synthetic materials, to fulfil any specific function within the system.*”. Thus, organic agricultural systems avoid synthetic inputs such as pesticides and inorganic fertilizers, and the system focus on “soil building” crop rotations (FAO/WHO 1999). As reviewed in 1.2.3 (on pesticides), the use of pesticides has detrimental effects on plants/seeds, arthropods and birds. Even though organic systems adopt advantages known from the absence of pesticides, and that they are often representatives of no-pesticide use, the system comprises of more than absence of pesticides. Crop rotations, organic fertilizer, mulch and/or cover crops, and sometimes grazing are commonly integrated. For this reason, the findings in this section are attributed to effects of the entire organic system and not just the absence of pesticides alone.

It has been established that organic farming increase biodiversity when compared to conventional farming. A recent meta-analysis found that average species richness in organic systems was 30% higher than in conventional systems (Tuck et al. 2014), even though effects vary between taxonomic groups (Bengtsson et al. 2005, Hole et al. 2005, Tuck et al. 2014).

Without the use of pesticides, substantial differences in weeds are evident when comparing the organic and conventional systems. Higher biomass and more species of weeds are consistent results in organic fields. This was the case in a Danish study by Hald and Reddersen (1990) who compared food availability for birds in pairs of organic and conventional fields. In that study they found higher weed biomass and more species in organic fields, and some species like shepherds’ purse (*Capsella bursa-pastoris)* were more frequent in the organic fields. Food availability for birds were also investigated by Moreby and Sotherton (1997) in the UK, where they compared 28 and 31 pairs of organic and conventional fields in 1990 and 1991, respectively. Their results revealed significant differences, with three times more weed species and a greater cover from board-leafed species, in organic fields. In Denmark, Hald (1999a) also compared pairs of organic and conventional fields - 21 pairs in 1987, and 17 pairs in 1988. Here, more important weed species for arthropods, a five times higher weed biomass were found in organic fields. Additionally, conventional fields were more similar to organic fields before herbicide application in the spring than in the summer after application (Hald 1999). Results from the REFUGIA project in Denmark, on the effects of organic agriculture systems, showed results of higher biomass of weeds and much higher species numbers in organic fields compared to conventional fields (Andersen et al. 2014). Given the many associations between weeds and arthropods (Marshall et al. 2003) it can be reasonable to assume that at least herbivorous arthropods dependent on weeds, are better supported in organic compared to conventional fields.

For arthropods, the results in organic fields are a slightly less consistent than for weeds, however arthropods tend to be more numerous here (Bengtsson et al. 2005). Moreby and Sotherton (1997) found more spiders in organic fields, but more ground beetles and flies in conventional fields. These results for ground beetles seem to be less representative, as Kromp (1999) reviewed higher species richness and higher abundance in organic fields. Hald and Reddersen (1990) found higher abundance of most examined groups of arthropods in organic fields, and only a few groups with higher abundance in conventional fields. Furthermore, they found higher arthropod biomass and more species, especially herbivores, in organic fields. In Switzerland, Pfiffner and Niggli (1996) compared organic, biodynamic and conventional fields of winter wheat, and they found almost twice as many rove beetles, ground beetles and spiders in organic compared to conventional fields as well as more species. Hald and Reddersen (1990) found higher densities of bird food items in organic fields compared to conventional and concluded that the difference between available food items in organic and conventional fields, were more prominent in midfield compared to field margins. This is important because birds such as the skylark forage almost exclusively in the mid-field.

Hole et al. (2005) found more birds in organic fields compared to conventional fields in a review of comparative studies comparing the two systems. In 31 pairs of organic and conventional Danish fields, Braae et al. (1988) counted birds from 1984 to 1987. They found 36 bird species who were significantly more frequent in organic fields compared to conventional fields, and only three species were more frequent in conventional fields (oystercatcher, thrush nightingale and reed warbler). Consistently and significantly higher mean bird abundance and species richness were also found in organic fields in the USA, with similar trends for granivorous, omnivorous and insectivorous birds (Beecher et al. 2002). That study also included edge landscape in the 30 matching pairs of conventional and organic fields. Wilson et al. (1997) also accounted for landscape edge effects (in pairs of organic and conventional fields in the UK), and found significantly higher densities of skylarks in organic fields in the breeding season. Furthermore, they argue, that based on vegetation height and density preferences, organic fields can support higher breeding success due to more variation in crops rotation and in winter or spring crops. Moreover, conventional winter crops can act as traps, because pesticide application result in unsustainable foraging opportunities (Wilson et al. 1997). Freemark and Kirk (2001) also found significantly higher species richness and total abundance on organic sites in Canada and accounted for landscape effects. Their analyses of bird yielded similar explanatory power to the local habitat and to agricultural variables comprised of treatments, inputs and farm information.

1.3.2 Conservation agriculture (CA)

Conservation agriculture (CA) is defined by the implementation of three treatments, as defined by FAO (2017) as: i) a minimum of mechanical soil disturbance through no-tillage and direct seeding, ii) permanent organic soil cover with cover crops or crop residues and iii) focus on crop species diversification through crop rotations. Stated claims by FAO (2017) are, that CA can support biodiversity, and reverse and prevent soil degradation. As reviewed in 1.2.1, effects of tillage can be detrimental on plants/seeds, arthropods and birds. CA adopts the advantages known from the no-tillage systems, but the CA system also comprises of crop rotations, mulch and/or cover crops. For these reasons, the findings in the following are attributed to effects of the entire CA system and not the absence of tillage alone.

Weed communities in the fields can undergo substantial changes as a result of the transition from annual tillage regimes to reduced or no-tillage regimes. More harmful species such as barren brome (*Anisantha sterilis*), slender meadow foxtail (*Alopecurus myosuroides*), field thistle (*Cirsium arvense*) and field sowthistle (*Sonchus arvensis*) can be dominating in reduced or no-tillage systems (Boelt et al. 2011), even though species varies between fields and regions (Buhler 1995). There is thus no consensus on whether no-tillage systems support fewer and more dominating species (Boelt et al. 2011), or if the emerged weeds and weed seedbank communities are more diverse than in conventionally tilled fields (Nichols et al. 2015). Nevertheless, seeds are accumulated in the top 0.5 cm soil top layer in reduced or no-tillage fields (Boelt et al. 2011), and on the soil surface in CA fields, because seeds are not buried after the seed rains. This is not necessarily an issue for the farmer. CA weed seed banks can be reduced considerably, because seeds on the surface are more susceptible to predation and unfavorable weather conditions (Chauhan et al. 2012, Nichols et al. 2015). Furthermore, Hobbs et al. (2008) review how CA, compared to conventional and conservation tillage systems, can reduce weeds over time by mulching and using cover crops. Derrouch et al. (2020) report that weed control is in fact a challenge in CA fields and that the management methods of weeds changed during the transition to the CA system. In a Danish context, some CA farmers report a reduction in weeds whereas others report no changes. These farmers, explain that this is a challenge because of the sparsity of knowledge on the subject (Stougaard and Filsø 2019).

The available weed seeds and structural heterogeneity from crop residues can support birds and arthropods. More arthropods are generally found in no-tillage fields compared to conventional tillage, even though results vary, as reviewed in 1.2.1. For CA fields specifically, fewer studies on arthropods (and birds) are available. In France, seed predation from carabids in plots of one CA and one conventional wheat field showed slightly higher predation in CA fields before harvest, but this reversed after harvest (Trichard et al. 2014). However, a stronger support for seed predation was found in a larger scale study in France by Petit et al. (2017) on 67 CA cereal fields. Here landscape effects in 1 km^2 were included with cover of permanent grassland, forest and the crop, and they found significant effect of landscape. Higher predation rates were found in older CA fields, who converted to CA 4-6 years prior to sampling, compared to younger fields who converted 1-3 years prior. Additionally, the landscape affected seed predation in the first year of conversion, but the effect disappeared in the older fields, indicating that the older CA fields have higher habitat quality compared to younger fields. In Denmark, Hundebøl (2020) found a significantly higher dry weight of carabids and spiders in four CA fields compared to four conventional fields. These Danish results for carabids and spiders were also supported by Jørgensen (2017), as mentioned in 1.2.1 on tillage, who also found significantly more collembola, spiders and carabids in CA fields.

In France, Barré et al. (2018) compared birds in two pairs of fields under conservation and conventional tillage. The two pairs consisted of conservation fields with cover crops (CTcc), conservation fields using herbicides (CTh) and a field using traditional tillage (T). They found higher abundance of birds in CTcc compared to T, with significant results for skylarks, corn buntlings and yellow wagtails, but lower abundance in CTh compared to T. They suggest that the effects of conventional tillage were less harmful than herbicides applications in CT fields. Hundebøl (2020) found five times more skylarks in CA fields compared to conventional field, using four field pairs of CA fields and conventional fields. Results from both studies, and the studies mentioned on birds in 1.2.1, suggest that food and/or nesting site availability for birds are enhanced in CA.

1.4 Agricultural landscape

This thesis does not have its focus on the effects of agricultural landscape on biodiversity, but it would be oblivious not to acknowledge the massive impact it has. For this reason, the landscape is mentioned here, but not to the full extent of the subject.

The agricultural landscape is a mosaic of larger and smaller agricultural habitats. The larger habitats are grazed pastures, cropping fields, fallow fields and meadows and they are divided by, bordering and containing edge habitats. Examples of edge habitats are field roads, hedges, stone fences and ditches (Ejrnæs et al. 2011). However, this mosaic landscape has experienced decrease in diversity (Meeus 1993) due to increase in farm and field size (Levin and Normander 2008, Eurostat 2018) resulting in homogenous and simplified landscapes (Emmerson et al. 2016) with less un-farmed land (Tscharntke et al. 2005), and increasing intensification. When comparing Danish orthophotos from 1954 to 2019 (Fig.1) it is clear, that homogenization of the agricultural landscape is present on a local, and landscape scale (Biodiversitetskortet).

Fig 1 Orthophoto south of Galten, 1954 and 2019 at 1:24188, showing change in the agricultural landscape. Photos received from (http://miljoegis.mim.dk/cbkort?profile=miljoegis-plangroendk).

Consolidation of farm units in Denmark, has resulted in a significant proportion of large farm units (35%), with a sizes of larger than 50 ha (Eurostat 2018). However, organic fields are generally smaller as the largest proportion of farms (18.2%) are less than 5 ha, and a total third of the farms are smaller than 10 ha (Landbrugsstyrelsen 2019). Some species have field size preferences, as skylarks who prefer fields larger than 7.5 ha (Gillings and Fuller 2001). When fields are large, the field circumference is relatively smaller, and many species depend on edge habitats. Edge habitats, like field margins, can act as refugia and dispersal corridors for weeds (Baessler and Klotz 2006). They support more plant species compared to the midfield (Hald 1999, Hole et al. 2005), thus the diversity decrease from the field margin in conventional fields (not in organic) to the midfield (Hald 1999).

We know that edge habitats become more important when the field is farmed intensively (Wilson et al. 1999), as they act as refugia to where organisms can retract. Edge vegetation are important to arthropods as refugia and overwintering sites. Field margins with wild flowers had a positive impact on spiders species (Baines et al. 1998) whereas grass margins and other non-crop habitats were important to ground beetles for overwintering (Kromp 1999, Holland and Luff 2000). Refugia for carabids are especially important, because carabids require winter habitats in order to act as pest control agents (Lövei and Sunderland 1996). Recruitment can happen from hedges, and it is common that the diversity of carabids decrease with increasing distance to the hedge (Kromp 1999). These results were consistent with Hald and Reddersen (1990) who found the overall arthropod biomass and the species density to decreases from the field margins into the middle of the field.

For birds, field margins can act as important food chambers and nesting sites. However, more mammal predators could also lurk in the vegetation in edges. Thus, the midfield is more safe for ground nesting birds and some birds avoid field edges completely, like lapwings and skylarks (Vickery et al. 2009).

Landscape effects have gained much attention for its effects on biodiversity, but mostly at the scale between farms (e.g. edge habitats) and regions. The field itself is undoubtedly the largest proportion of the farm, which is why it is significant that heterogeneity within the field itself is increasingly noted as important (Benton et al. 2003).

1.5 This study

The aim of this study is to investigate and compare effects of agricultural systems and treatments within fields on different taxa of farmland biodiversity across organic, conventional and CA fields. Therefore, density and diversity of weed seeds, ground-living arthropods and birds were used as metrics in evaluating how these groups were affected by agricultural systems and treatments. As reviewed in the previous sections, organic farming and CA provide, in pairwise comparison to conventional farming, increased support to farmland biodiversity. This is also true for several agricultural treatments such as reduced or absent tillage, not using pesticides, mulching and landscape heterogeneity. However, there has, to my knowledge, not been published any studies comparing biodiversity between organic and CA, or between all three systems. In comparing the conventional, organic and CA it is possible to test for pesticide and tillage effects, using organic and CA as controls respectively.

In this study, I evaluate the effects of systems, treatments and field information obtained from the farmers, using multivariate statistics, to understand whether the effects are results derived of individual important treatments, or the overall agricultural systems as assemblies of treatments. The study was not designed to capture landscape effects, but as acknowledgement of its contribution to farmland biodiversity, a simple proxy for landscape heterogeneity was used.

The study was carried out in 15 fields, five in each system, all planting winter wheat in the fall of 2019. As a result, this project was carried out in the autumn and winter months, and thus capture around half of the crop cycle. The effects of tillage were amongst others captured by conducting field work before and after sowing/tillage in all fields, and treatment data was collected through questionnaires. Seeds were sampled from the topsoil, in six plots of every field – as were ground-living arthropods. Seed and arthropod densities were also used as estimates of available food for birds in the crucial winter months. Birds were observed in all fields, before and after the sowing tillage event, and in February. The following are the hypotheses for this study, based on the reviewed literature:

1.5.1 Hypoteses

1. Seed density is positively correlated with arthropod and bird densities, and arthropods and bird densities are positively correlated. Diversity for all groups has the same positive correlations.
2. Highest seed densities and diversity in organic compared to CA and conventional due to absence of pesticides.
3. Highest densities of spiders in CA due to no-tillage.
4. Higher density and diversity of birds in organic and CA compared to conventional in the autumn and winter months.
5. Lowest densities and diversities of seeds, arthropods and birds in conventional fields.

2 Methods

2.1 Study site and experimental design

The field work in this study was conducted from August 2019 to February 2020 and took place in fields located in Central Jutland and West Zealand. A total of 15 fields with winter wheat sown in the autumn were used, and with five fields in each system they represented conventional, organic and CA. Fields in the three systems were located through two weeks of phone interviews in August, with farmers, consultants and their networks initiated from contracts of another project. Through careful selection, fields in one system type were clustered with fields from the other two systems to avoid spatial autocorrelation.

The field work consisted of collecting seeds in the topsoil, ground-living arthropods and counting birds in all fields before and after the event of sowing and tillage. These dates can be found in the appendix section 6.1. Seeds, arthropods and birds were all collected/observed on the same days respectively, and all farmers consented to the planned fieldwork, as well as being a part of the project.

Field work before sowing/tillage took place from the 23rd of August to the 21st of September 2019 and was conducted a minimum of two weeks after harvest of the previous crop, to avoid only capturing the effects of the harvest. For two fields, both with faba bean, it was not possible to wait two weeks after harvesting as the farmers wanted to sow the new crop in continuation of harvest of the previous crop due to weather conditions. Therefore, the sampling in these two fields before sowing were completed a few hours before harvest.

Field work after sowing/tillage took place from the 1st to the 24th of October 2019 and was conducted after minimum of two weeks after sowing/tillage to avoid only capturing initial effects of tillage and sowing. Due to the heavy rains in autumn and spring, two farmers were not able to sow in autumn as planned. One farmer continued tillage as planned, but the other was delayed until January. Thus, the fieldwork after sowing/tillage was collected as soon as possible after tillage, but after a minimum of two weeks after, resulting in one collection in October and one in February. Furthermore, a third bird count was conducted in February.

All fields were bordering pavement or gravel roads; some had windbreaks, forest and bodies of water in proximity, and some were neighbouring residential areas. For good measure, these landscape elements were registered and assigned a landscape heterogeneity score. One element, e.g. a hedgerow resulted in a score of 1, two elements e.g. waterhole and forest, resulted in a score of 2 and so forth. Examples of a hedgerow, forest and remise in three fields are shown in Fig 2.

Fig 2 Landscape elements: hedgerow, forest and remise with waterhole. Source: Google maps.

2.2 Data collection

Information on treatments and other basic information from each field were collected through a questionnaire send out in the end of January 2020. The response on the questionnaires was not always comprehensive and they were followed up on through personal communication and visits during spring as a result. One farmer did not answer the questionnaire completely, and thus some data was missing from this farmer. The variables used in the questionnaires appear in Table 4.

In this study, tillage was represented in three ways; incorporated in the study design where sampling was carried out before and after the event of tillage and sowing, included as a categorical variable of absence or presence of tillage and as a continuous variable of tillage depth in cm. Pesticides were represented as categorical variables of absence or presence of herbicides, fungicides and insecticides in this crop rotation (2019/2020) and the previous (2018/2019). Fertilizer was represented as a categorical variable of fertilizer type, a continuous variable of nitrogen application in kg/ha, and as a categorical variable of the absence or presence of mulch

Table 4 Information collected through questionnaires and personal communications in the spring 2020.

Basic information	
Agricultural system	
Field size in hectares	
Field location coordinates	
Years in agricultural system	
Years in reduced tillage	
Soil type	
Winter wheat 19/20	**Previous crop 18/19**
Tillage (y/n)	Tillage (y/n)
Tillage depth (cm)	Tillage depth (cm)
Herbicides (y/n)	Herbicides (y/n)
Fungicides (y/n)	Fungicides (y/n)
Insecticides (y/n)	Insecticides (y/n)
Fertilizer type (organic/ inorganic/ both)	Fertilizer type (organic/ inorganic/ both)
N application (pr. ha)	N application (pr. ha)
Mulch (y/n)	Mulch (y/n)

The sampling details of seeds in the topsoil, ground-living arthropods and counting of birds are reviewed in the following subsections. It was a priority, that all fieldwork was conducted in the absence of rain and storm.

For each visit, six plots were designated randomly in each field before and after sowing/tillage, where seeds and arthropods were collected. The plots were designated in the field using the roll of a dice from the edge of the field, after 20 initial steps into the field. First dice number indicated direction in field, second dice was number of steps times 10 in that direction, and third dice was additional steps away from initial starting point. Arthropods were collected first, and seeds second. A total of 180 of seeds and arthropods were collected; 6 samples for all 15 fields, before and after sowing/tillage.

2.2.1 Seeds in the topsoil

Seed samples were scrapes of the field topsoil (0.5-1 cm) in an area of 60x30 cm. Each sample was transferred to an open plastic bag and assigned field and plot ID. After a field day ended, the samples were brought to the greenhouse in Department of Bioscience, Silkeborg, Aarhus University to germinate. Here, each seed sample was transferred to greenhouse soil in a 30x30 trey with greenhouse soil. Samples were gently pressed into the greenhouse soil and watered, and ID signs were assigned to each sample. The trays were placed on watering tables and watered once a day for the first few weeks and once every other day later in the season due to colder weather and continuous removal of plants. Temperatures were set to min 5 degrees at night and min 15 degrees during the day with 18 hours of light and 6 hours of darkness. Trays changed position on the tables many times during the identification months.

Ongoing identification from September to May was carried out in accordance to Melander (2011) folio. "Bestemmelsesnøgle for ukrudt", when the seeds germinated. Plants were identified to species if possible and were removed after identification and registration. If identification was difficult, plants were left to bloom and identified in accordance to Segberg et al. (2012) and Stenberg and Mossberg (2005).

Fig 3 Sampling and identification of seeds. Left: greenhouse germination of seeds. Top right: identification. Bottom left: collection of sample in field

When germination stagnated after approximately 2-3 months, freezing treatments were initiated to break possible seed dormancy. Before freezing treatment, a few remaining unidentified plants were removed from the trays and planted in separate pots for later identification. Freezing was initiated after a minimum of 60 days in the greenhouse, and samples were dried in 6 days prior to this treatment. Before the first freezing treatment, seedbanks were cooled to 5 degrees Celsius for a day and then a freezing treatment at -5 degrees was initiated, followed by a by defrosting treatment at 5 degrees. This procedure was repeated to three freezing and defrosting cycles. After this treatment, seed samples were brought back to the greenhouse to germinate and identification continued until germination stagnated.

2.2.2 Ground-living arthropods

Each arthropod sampling plot was defined by pressing a metal ring of 52 cm in diameter and 5 cm high, with an area of 0.2123 m^2, into the field. The ring acted as a barrier and prevented animals from escaping capture. Ground search was carried out by carefully searching and removing plant material and topsoil fragments in order to collect all arthropods present above ground – also the ones hiding. If no activity was observed during the search, it was briefly paused, and often arthropods would break cover as a result. Search time was set to a maximum of 10 minutes, and the search was stopped if no animals were spotted for 1 minute. Arthropods in each plot were either collected with a pooter or with the fingers and transferred to plastic vials with plot and field ID. Larger predators were put in vials independently to avoid severe predation. All vials were kept in a cooler with cooling elements, to slow down movement and avoid predation within vials.

Upon the end of the field day, samples were transferred to a freezer in the Department of Bioscience, Silkeborg, Aarhus University and kept here until identification could be carried out. All arthropods were placed in glass vials in 70% ethanol and identified to family, genus or species.

Fig 4 Sampling and identification of arthropods. Left: sampling method, using metal ring barrier and pooter. Right: identification of arthropods.

2.2.3 Birds

Birds were observed and identified in all the 15 fields before sowing/tillage, after sowing/tillage and in February. Unfortunately, it was not a possibility to follow a consistent pattern during observations, e.g. tramlines, as naturally occurring lines in the fields varied after harvest, and no natural lines were visible after seeding or in February. The identifications and counts were carried out with binoculars, while walking the field. As it was not always a possibility to cover the whole field due to large field size above 35 ha, it was a priority to cover as much of the field as possible. The decision of how much of the field area to cover was made upon arrival due to variations, such as field topography, field shape and landscape, resulting in compromised visibility. For some fields, only a determined section was covered during bird observations.

In all observations, birds were only registered when they were foraging, resting, marking territory or hunting in the field. Thus, overflying birds, birds in windbreaks and all birds outside the field itself were ignored – unless they flew from or landed on the field.

2.3 Data treatment and analyses

All raw data on seeds, arthropods and birds were registered in Excel spreadsheets (version 1908, Microsoft Office 365 ProPlus), where most of the data treatment was carried out. All statistical analyses were carried out using JMP 14.0 (SAS Institute). Diversity and densities of seeds, arthropods and birds were the six response variables in this study. The predictor variables were 13 variables of agricultural system, agricultural treatments and landscape and field information.

Average densities (m^2) of seeds and arthropods were calculated for each field, both before and after sowing/tillage. These densities were calculated from the total counts of the six plots divided by the area of the sampling site for seeds (0.18 m^2) and the area of metal ring (0.21 m^2) for arthropods. For birds, this calculation of average densities was based on total observations of birds in each field divided by the field size, or field section covered in the count, in ha. Average densities for birds were also calculated for the observations in February. Based on these densities, average densities of seeds, arthropods and birds were calculated for each agricultural system before and after sowing/tillage, and from February for birds. Finally, differences in samplings/observations before and after sowing/tillage were calculated in percent for the three systems.

The Shannon-Wiener species diversity index (equation below) was used to calculate diversity for seeds, arthropods and birds. For seeds and arthropods, the raw data was used as this data was standardized in sampling, but densities were used for birds as this raw data was not standardized.

$$H' = -\sum_{i=1}^{R} p_i ln p_1$$

Data from farmers obtained through the questionnaires, were typed into Excel spreadsheets, and exact field location and field size was obtained through latitudinal and longitudinal coordinates, and area measurements imported from Google Maps respectively.

Some data was excluded prior to statistical analysis. In two fields, one conventional and one CA field, one of the bird observations from after sowing/tillage were removed to avoid highly skewed data. In the conventional field, approximately 400 black-headed gulls were resting on the field. In the CA field, approximately 300 wood pigeons were resting in the CA field. Seed diversity and density of one conventional farmer was removed, because the farmer used soil from a recreational park on the field and various ornamental plants germinated as a result. Therefore, the results obtained on seeds from this conventional farmer would not be representative and was excluded. Upon arrival, one CA farmer shared how he had a test plot with no application of pesticides. Samplings of seeds and arthropods were obtained from this test plot in addition to the regular samplings in the normal part of the field. The data obtained on the test field was not used in the analysis, and therefore excluded.

Distributions of all response variables (density and diversity of seeds, arthropods and birds) were checked for normality. Variables with skewness ±1 were transformed to meet the criteria of normal distributions. Seed densities, bird densities and bird diversity were Log+1 transformed, and seed density was Exp transformed. Skewness, kurtosis and the transformations for all variables are reported in the results chapter.

Pearson's pairwise correlations tests were run on the response variables and all numerical predictors to check for correlations in the data. For the numerical predictors N application, field size, tillage depth and years in agricultural system, linear regressions were run between response and predictors to test for significant relations. Biplots were created on the significant relationships.

As all six response variables were normally distributed after transformations, they met the assumptions of parametric ANOVA analysis. The ANOVA analyses test, on categorical variables, if two or more groups are significantly different. Oneway ANOVAs were carried out for all response variables in relation to categorical predictor variables. The post-hoc Tukey-Kramer HSD tests were used to carry out comparisons between groups if the ANOVA was significant. Twoway ANOVAs were run additionally for agricultural systems if the oneway test was significant, to check if the relationship between groups changed with the different sampling times, if this variable was also significant. Boxplots were created for significant and important results. In conclusion, 13 predictors were tested for each of the six response variables (density and diversity of seeds, arthropods and birds). These results were summarized in a table for an easy overview of the many tests.

In this multivariate dataset, with many significant predictors for each response, stepwise selection models were conducted to remove redundant predictors and identify the most important ones. These models were based on the significant predictors from the previously mentioned tests and selected through a forward step function. The "best" models for each response variable were selected on the basis of both the AIC_c and BIC information criterions for model selection (Burnham and Anderson 2004). Thus, significant predictors were added one at a time to check if this addition improved the model and was excluded if it did not. These conclusive models identified the most important predictors of seeds, arthropods and birds and they were used to prioritize the writing process. The models were run for five of the six response variables because one response had only one significant predictor.

Overall, ordinations are carried out to visualize multivariate(multidimensional) data in few dimensions. Principal component analysis (PCA) is based on linear combinations of original variables, so-called principle components. In the PCA, two axes represent eigenvalues that describe the percentage of the variance in the data, where the first two axis describe the most variation. In this study, the response variables were represented with a supplementary predictor variable that proved consistently significant in the abovementioned analysis.

3 Results

In chapter 3.1 the findings of this study are presented without statistics. An overview of statistical results is provided in 3.2. Separate models for the investigated predictor variables of seeds, arthropods and birds (sampling time, agricultural system, treatments and landscape information) are presented in respective sections 3.3-3.6. Finally, conclusive models identifying the most important predictors of seeds, arthropods and birds are presented in 3.7. Species densities of all collected and observed species of seeds, arthropods and birds can be found in the appendix 6.2. Information gathered from farmers through questionnaires can be found in 6.1.

3.1 Overview of biological findings

3.1.1 Abundance and densities

The total numbers of germinated seeds collected arthropods and observed birds are shown in Table 5. Organic fields had the highest numbers of germinating seeds, CA had intermediate numbers of seeds, and the lowest number were found in conventional fields. For arthropods, the highest numbers were found in CA fields whereas organic and conventional fields had similar numbers. Most birds were observed in CA fields, intermediate in conventional fields and lowest number of birds were observed in organic fields. Numbers after sowing/tillage were consistently lower than before sowing/tillage for all three groups.

Table 5 Total number of seeds, arthropods and birds identified and observed in this study. Numbers for samplings before and after sowing/tillage, respectively are in grey. "" indicate the number of seeds and arthropods, respectively, used for analyses. In total 23357 seeds germinated, but 410 were excluded in the analyses; 2823 arthropods were identified, but 362 were excluded (see methods for explanation).*

	Total individuals	Organic	Conventional	CA
Seeds	**22947***	**17341 (76%)**	**2456 (11%)**	**3150 (14%)**
Before sowing/tillage	19743	16029 (81%)	2034 (10%)	1680 (9%)
After sowing/tillage	3204	1312 (41%)	422 (13%)	1470 (46%)
Arthropods	**2461***	**649 (26%)**	**590 (24%)**	**1222 (50%)**
Before sowing/tillage	1724	537 (31%)	475 (28%)	712 (41%)
After sowing/tillage	737	112 (15%)	115 (16%)	510 (69%)
Birds	**484**	**45 (9%)**	**155 (32%)**	**284 (59%)**
Before sowing/tillage	201	35 (17%)	100 (50%)	66 (33%)
After sowing/tillage	127	4 (3%)	49 (39%)	74 (58%)
February	156	6 (4%)	6 (4%)	144 (92%)

The calculated densities for seeds, arthropods and birds are shown in Table 6. Organic fields had eight to ten times more seeds than conventional and CA fields respectively, before sowing and tillage. In organic fields, the seed and bird densities were 12 times lower after the sowing and tillage event. For conventional fields, the densities of seeds and arthropods were more than four times lower after sowing and tillage. CA fields experienced the least reduction across all three groups, from one-time lower seed density to 1.4 times lower arthropod densities and 1.2 times lower bird densities after sowing. After the sowing and tillage event, CA fields had four to five times higher arthropod densities than organic and conventional fields, respectively. CA fields had two times higher bird densities than organic and conventional fields before the event. After the sowing and tillage event, CA had two times higher bird densities than conventional fields, and 21 times higher than organic fields. In February, bird densities in CA were more than 12 times higher compared to organic, and more than 17 times higher than conventional fields.

Table 6 Average densities of seeds, arthropods and birds in the three agricultural systems, at the two sampling times: before and after sowing/tillage, respectively. For seeds and arthropods, the numbers to the left of the arrow are densities before sowing/tillage, and the numbers to the right are after sowing/tillage. For birds, the densities to the left of the arrow are before sowing/tillage, the densities after sowing/tillage are in the middle, and densities in February are to the right. Decline in percent is the difference between the samplings before and after sowing/tillage. SE is shown in parentheses in grey.

	Organic	Conventional	CA
Seeds m²	2968(764) → 243(38)	377(151) → 78(21)	311(71) → 272(53)
Difference	-92%	-79%	-13%
Arthropods m²	84(10) → 18(4)	75(24) → 16(5)	112(9) → 80(9)
Difference	-78%	-78%	-29%
Birds ha	0.98 → 0.08 →0.11	0.93 → 0.66 →0.08	2.17 → 1.74 → 1.42
Difference	-92%	-29%	-20%

3.1.2 Species richness and diversity

The total number of species of germinated seeds, collected arthropods and observed birds are shown in Table 7. The 22947 seeds belonged to 79 species. Most plant species were found in organic fields, intermediate in conventional fields and lowest in CA fields. The 2461 identified arthropods belonged to 54 species, where most species were found in CA fields, intermediate in conventional fields, and lowest in organic fields. The 484 observed birds belonged to 17 species, where most species were present in CA fields, intermediate in conventional fields and lowest in organic fields.

Table 7 Species richness of seeds, arthropods and birds identified and observed in this study. Species richness for the two in sampling times are in grey. Percentages of total species are shown in parentheses. "" for seeds indicate the actual data used for analysis. 9 species of plants were excluded, see methods. List of species and species density can be found in appendix.*

	Total species	Organic	Conventional	CA
Seeds	**79***	**58 (73%)**	**45 (57%)**	**49 (62%)**
Before sowing/tillage	60	47 (78%)	29 (48%)	39 (65%)
After sowing/tillage	60*	44 (73%)	36* (60%)	27 (45%)
Difference		-6%	24%	-31%
Arthropods	**54**	**37 (69%)**	**33 (61%)**	**45 (83%)**
Before sowing/tillage	48	35 (73%)	32 (67%)	39 (81%)
After sowing/tillage	38	20 (53%)	14 (37%)	36 (95%)
Difference		-43%	-56%	-8%
Birds	**17**	**8 (47%)**	**11 (65%)**	**14 (82%)**
Before sowing/tillage	9	4 (44%)	7 (78%)	8 (89%)
After sowing/tillage	11	2 (18%)	4 (36%)	8 (73%)
Difference (before, after)		-92%	-29%	-20%
February	10	4 (40%)	3 (30%)	8 (80%)
Difference (after, February)		44%	-88%	-19%

The calculated Shannon-Wiener based diversity for seeds, arthropods and bird are shown in Table 29 in the appendix, section 6.1.

3.1.3 Seeds in the topsoil

The five plant families most important to arthropods and birds among those found in this study are shown in Fig 5. They are Asteraceae, Brassicaceae, Caryophyllaceae, Chenopodiaceae and Poaceae. There are some differences between agricultural systems, when looking at seed density in relation to these important plant families and species for birds and arthropods. The organic system was clearly representing the highest proportion of the five families before sowing/tillage. After sowing/tillage, organic had the highest representation in two families, the carnation (Caryophyllaceae) and goosefoot family (Chenopodiaceae), whereas CA had the highest representation of the aster family (Asteraceae), the mustard family (Brassicaceae) and the grass family (Poaceae).

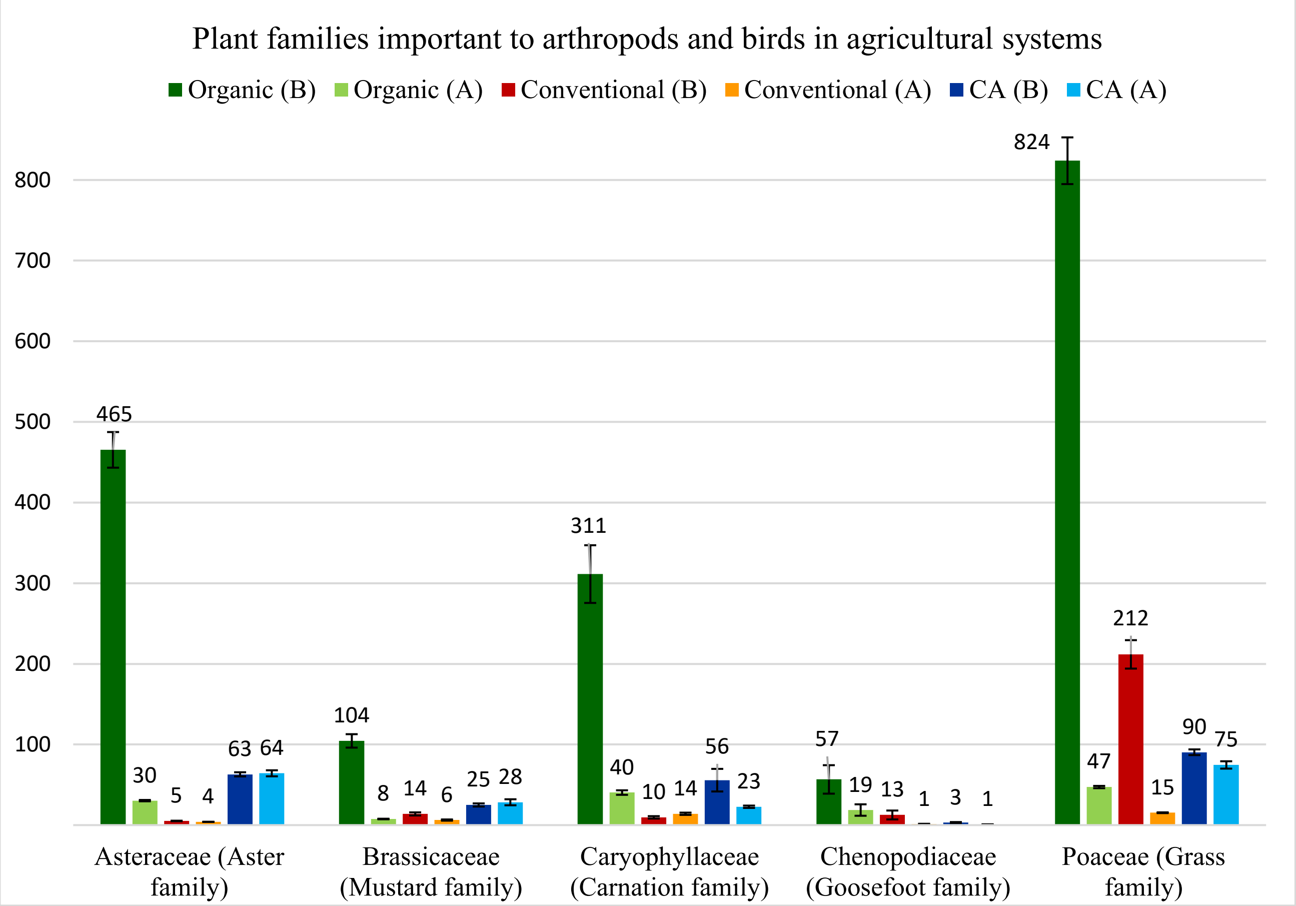


Fig 5 Densities of five plant families important to arthropods and birds. "B" is before sowing/tiillage, shown in dark colors, and "A" is after sowing/tillage shown in light colors. Lines represent SE.

On a species level, the densities for four selected species important for arthropods and birds is shown in Table 8. Here, the organic system has the overall highest representation of important seeds, however groundsel was not represented. Comparing densities of these species before and after sowing/tillage, organic and CA have similar densities of annual meadow grass and chickweeds (*Stellaria media*).

Table 8 Important plant species for arthropods and birds. (B) before sowing/tillage, (A) after sowing/tillage.

	Organic (B)	**Organic (A)**	**Conventional (B)**	**Conventional (A)**	**CA (B)**	**CA (A)**
Annual meadow grass *(Poa annua)*	802.6	42.0	195.6	14.6	58.5	59.1
Chickweed *(Stellaria media)*	310.0	33.5	9.6	9.8	55.6	22.6
Fat-hen *(Chenopodium album)*	56.5	18.1	12.6	0.9	3.1	0.6
Groundsel *(Senecio vulgaris)*					5.9	4.3

A personal observation during identification, was that several plants (often *Capsella bursa-pastoris*) from conventional and CA samples were deformed, probably due to herbicide damage. Leaves were curled inwards; stems were thickened, and capsules were misshaped. Snails and slugs (e.g. one leopard slug was found) were present in the samples in the greenhouse, probably due to the bycatch of eggs, and some herbivory was observed, but this did not affect identification. Identification was affected to some extent by aphids in the samples (a contamination from the greenhouse) but only a few plants died because of aphids.

3.1.4 Ground-living arthropods

The most caught arthropods in this study are shown in Fig 6. Springtails, spiders and beetles where the most numerous groups, and carabids were included in the figure because they accounted for most of the beetles. Surprisingly, springtails were most numerous in the conventional system before sowing/tillage, but after sowing/tillage CA had more than ten times higher springtail densities than organic, and more than 15 times higher than conventional. The organic system had higher average densities of beetles and carabids than conventional before and after sowing/tillage, but conventional had more spiders after. Densities of spiders and beetles, including carabids, were highest in CA before and after sowing/tillage. Spiders was the most represented group, and CA had more than six times higher average spider densities than conventional fields, and more than nine times higher than organic fields after sowing. Densities of carabids in CA after sowing/tillage were more than two times higher than organic and four times higher than conventional.

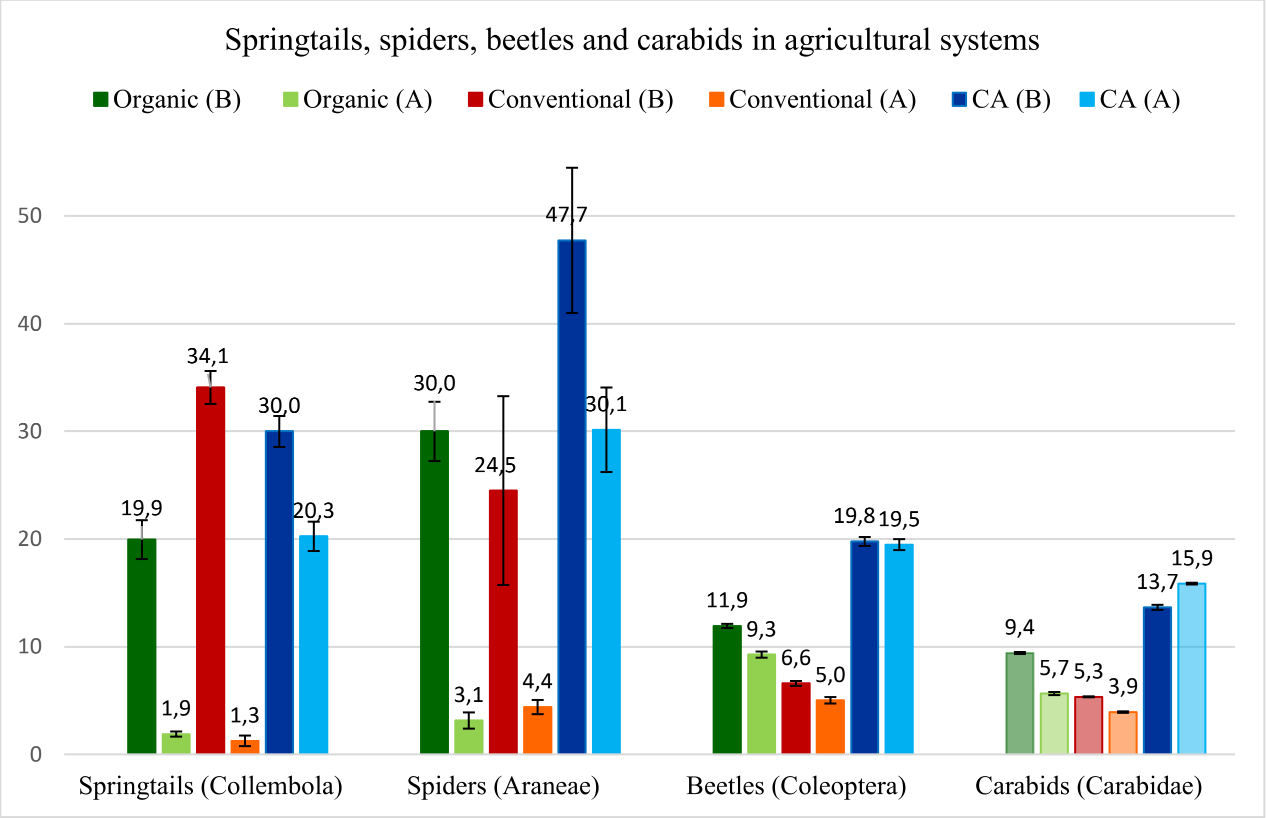


Fig 6 Average densities of carabids for agricultural systems. Carabids are nested in beetles, and thus consisted of the largest proportion of caught beetles. "B" is before sowing/tiillage, shown in dark colors, and "A" is after sowing/tillage shown in light colors. Lines represent SE.

Regarding personal observations, the search time could have been longer for some CA fields where the mulch layer was thick and dense. In many cases, springtails were seen but they were too small to collect with the pooter. Many spider webs were seen in CA fields, and after sowing/tillage webs were numerous in the crop indent. Finally, larger, and fast, spiders and beetles were observed on several occasions in CA fields fleeing the sites before it was possible to identify them or put down the metal barrier.

3.1.5 Birds

The observed bird species are shown in Table 9, and species densities of birds observed before sowing/tillage, after sowing/tillage and in February can be found in Fig 7, Fig 8 and Fig 9 respectively. Four farmland specialists, skylark, grey partridge, kestrel and barn swallow, were observed. All four were spotted in organic and conventional systems, whereas kestrel was not seen in CA. Nine of the observed species were intermediate farmland specialists: rook, hooded crow, tree sparrow/house sparrow, black-headed gull, greylag goose, magpie, jackdaw and wood pigeon. Four of them were seen in organic fields, five in conventional fields and eight in CA fields. The farmland species northern wheatear was spotted in conventional and CA field. The remaining three observed species, ring-necked pheasant, goshawk and greenfinch were not farmland species. None of them were observed in organic fields, pheasant was observed in conventional fields, and all three were observed in CA fields. The ring-necked pheasant is not considered a farmland species, most likely because it is introduced, but it is a common bird seen in farmland.

Regarding the four high farmland specialists, observations were predominantly before sowing/tillage. More skylarks were observed in organic and CA fields compared to conventional fields, and these were predominantly observed before sowing/tillage. Grey partridges' densities were about equal for organic and conventional, and lower in CA. Barn swallow densities were similar for organic and CA. Kestrel sightings were in February, and densities were very low in organic and conventional fields where it was spotted. For intermediate farmland specialists, corvids had the highest densities in CA. Tree and house sparrows were difficult to differentiate, so they were noted as a complex. The house/tree sparrows were almost exclusively seen in CA and here, they were observed from autumn to February. Greylag geese were only spotted in CA in the autumn, after sowing/tillage. Buzzards were observed in all three systems, but highest densities in CA and observations were mainly in august, before sowing/tillage. Wood pigeons were spotted only in conventional fields in august, but later in the fall after sowing and tillage, observations were mainly in CA and few in conventional fields. In the autumn in observation after sowing/tillage, a very high number of wood pigeons were seen on a CA fields; none were foraging but they were making themselves comfortable when resting in the dense layer of dry crop residue. A very high number of black-headed gulls was also seen on a conventional field, where they were resting. Both gulls and pigeons were excluded to avoid high skewness, as mentioned in the methods chapter. Wheatears were seen mainly in CA fields and pheasants in all three. The goshawk was seen in a CA field bordering a forested area, which it flew to from the field. Logging in the forest took place at the next observation in the autumn and it was not seen again. Greenfinches were seen in a CA field, flying from the crop into a shrubby wildlife area within the field.

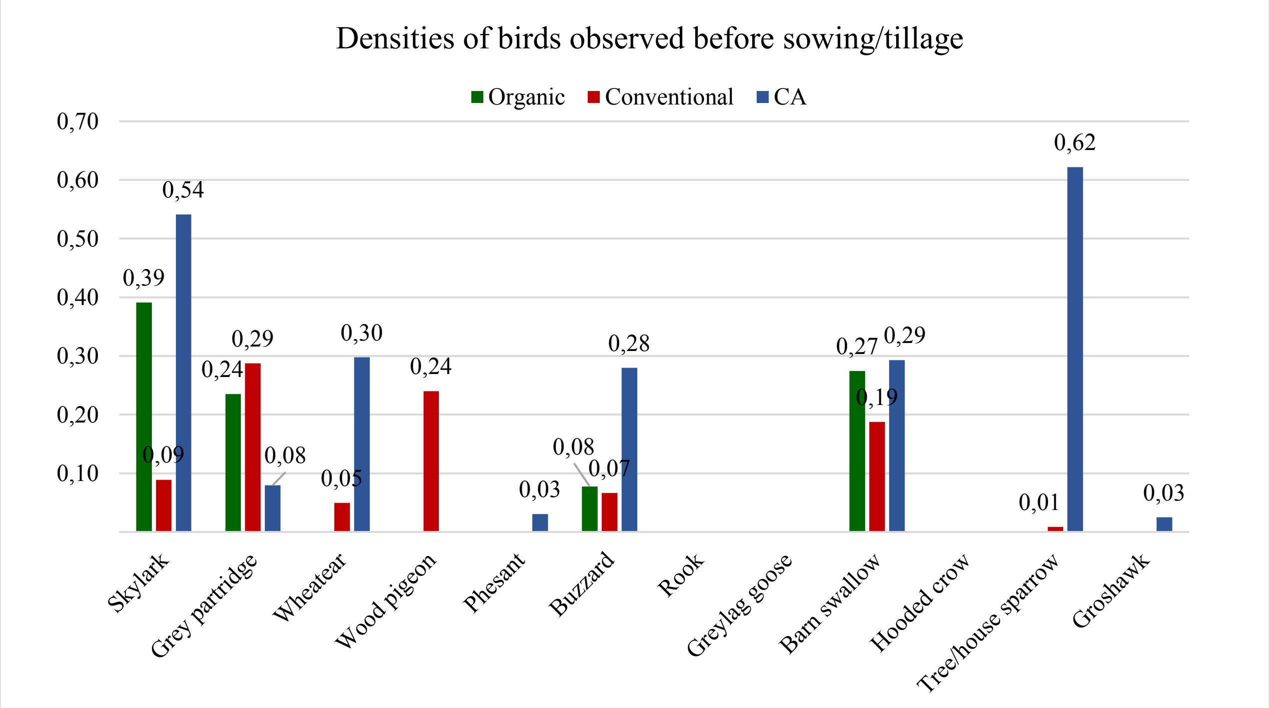


Fig 7 Densities of the nine bird species observed before sowing/tillage, sorted in agricultural system. Three pillars are present for each species, but zeroes are not visible.

Table 9 Observed bird species in agricultural systems.

Latin name	**Common name**	**Danish name**	**RHU index to farmland**	**RHU Arable land/Grassland**	**Organic**	**Conventional**	**CA**
I. Farmland specialists (RHU > 2)							
Alauda arvensis	Skylark	Sanglærke	5.9	5.6/1.0	X	X	X
Perdix perdix	Grey partridge	Agerhøne	5.2	4.2/1.6	X	X	X
Falco tinnunculus	Krestel	Tårnfalk	2.8	2.1/2.1	X	X	
Hirundo rustica	Barn swallow	Landsvale	2.8	2.5/1.6	X	X	X
II. Intermediate specialists (2 >RHU >1) also classified as farmland species by DOF (2018)							
Corvus frugilegus	Rook	Råge	1.7	1.7/1.1	X		X
Corvus cornix	Hooded crow	Gråkrage	1.6	1.5/1.3	X	X	X
Passer montanus/ Passer domesticus	Tree sparrow/ house sparrow	Skovspurv/ gråspurv	1.6/ 1.0	1.9/0.5 1.3/0.4		X	X
II. Intermediate habitat use farmland species (2 >RHU >1)							
Chroicocephalus ridibundus	Black-headed gull	Hættemåge	1.8	1.5/1.8		X	
Anser anser	Greylag goose	Grågås	1.7	0.5/6.0			X
Pica pica	Eurasian magpie	Husskade	1.5	1.5/1.1			X
Buteo buteo	Common buzzard	Musvåge	1.2	1.1/1.4	X	X	X
Coloeus monedula	Western jackdaw	Allike	1.0	1.1/0.8			X
Columba palumbus	Common wood pigeon	Ringdue	1.0	1.1/0.9	X	X	X
III. Farmland species (1>RHU) classified by DOF							
Oenanthe oenanthe	Northern wheatear	Stenpikker				X	X
IV. Not farmland species							
Phasianus colchicus	Common pheasant	Fasan				X	X
Accipiter gentilis	Northern goshawk	Duehøg					X
Chloris chloris	European greenfinch	Grønirisk					X

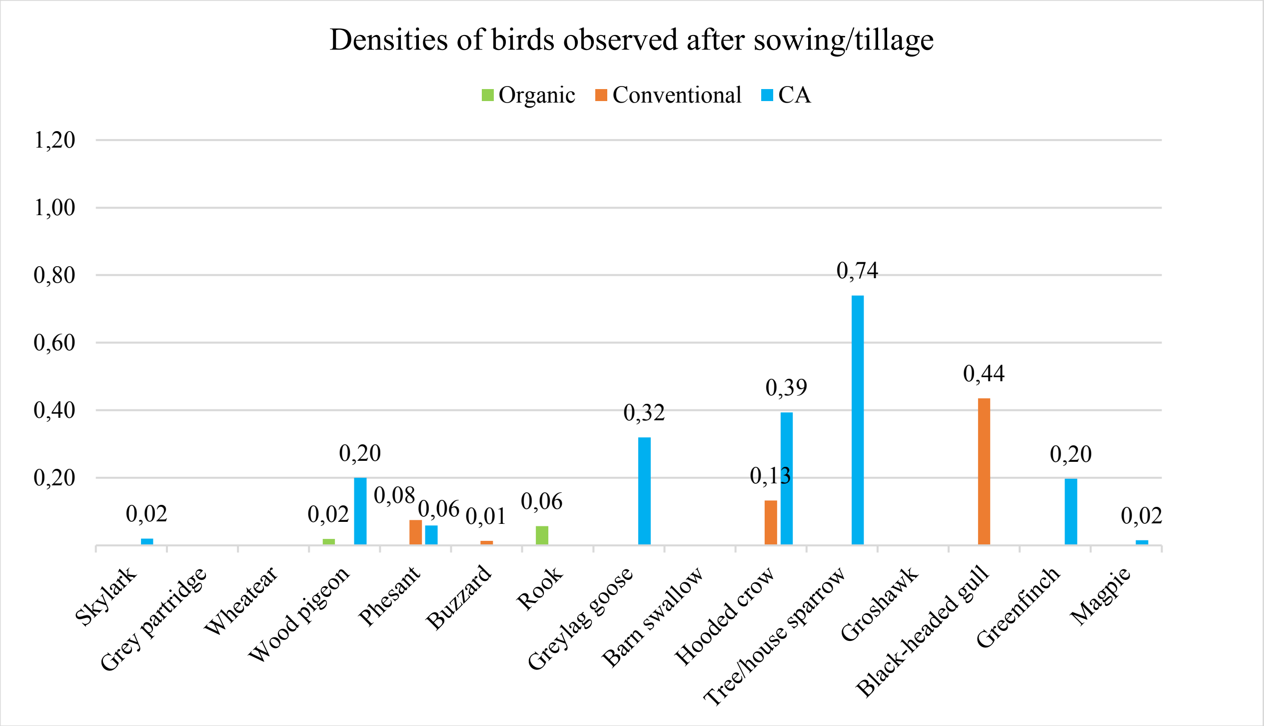


Fig 8 Densities of the 11 bird species observed after sowing/tillage, sorted in agricultural system. Three pillars are present for each species, but zeroes are not visible.

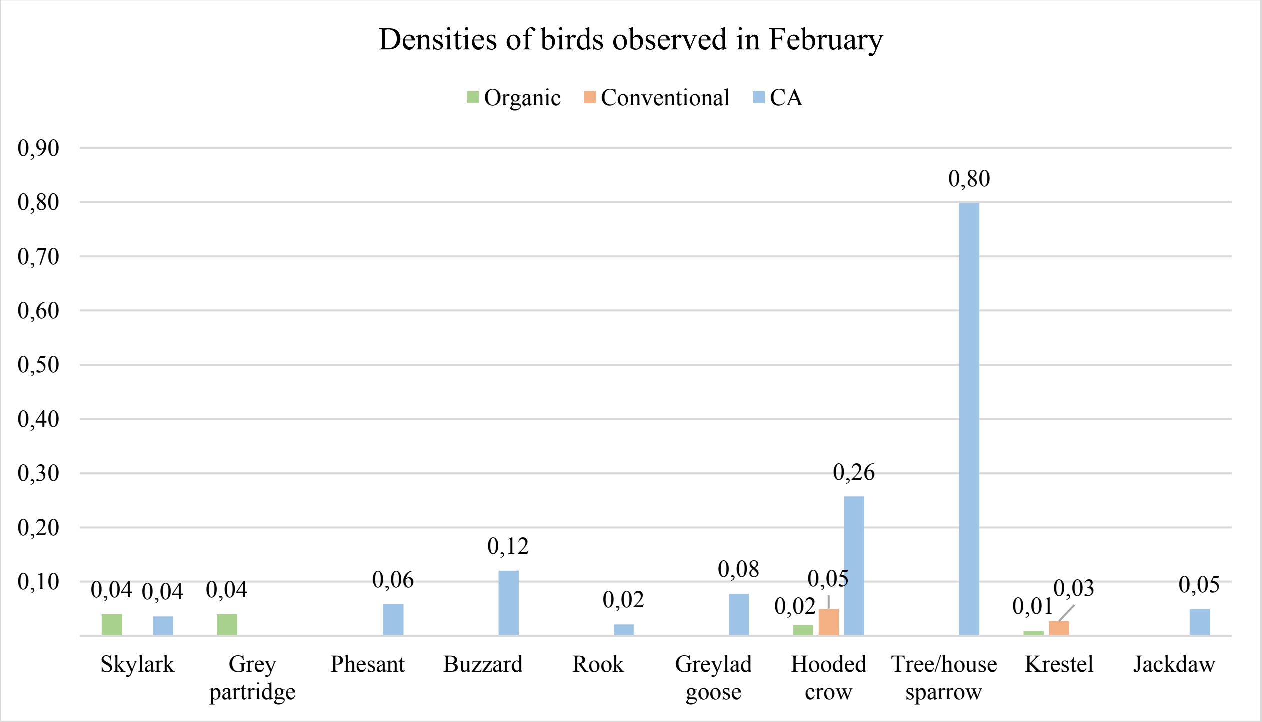


Fig 9 Densities of the 10 bird species observed in February, sorted in agricultural system. Three pillars are present for each species, but zeroes are not visible.

3.2 Analyses overview

Results of statistical analyses are summarized in Table 10, and the most important predictors for seeds, arthropods and birds are highlighted in the table. The separate analyses on which the summary table is based, are reviewed in the referred sections listed in the first column of the table. The final models that provided the identification of the most important predictors for seeds, arthropods and birds are reviewed at the very end of this chapter.

Table 10 Overview of statistical results. "X" mark significant effects ($p<0.05$) of predictor on response in ANOVA (one-, and twoway) and linear regressions. "-" or "+" indicate negative or positive linear relationships, respectively. 18/19 and 19/20 are pesticide use in the crop cycles 2018/2019 and 2019/2020. X in bold red mark significant predictors included in conclusive models in 3.7 (not removed by stepwise selection) - they are the most important predictors. The explanatory power of the conclusive models based on the most important predictors (red, bold) are listed in the last row.

Ref.	Predictors	**Seed diversity**	**Seed density**	**Arthropod diversity**	**Arthropod density**	**Bird diversity**	**Bird density**
3.3	Sampling time		**X**		**X**		**X**
3.4	Agricultural system		**X**		**X**	**X**	**X**
3.5.1	Tillage				X	X	X
3.5.1	Tillage depth	**X (+)**					
3.5.2	Pesticide use		X (18/19) X (19/20)	**X (18/19)**			X (19/20)
3.5.3	Fertilizer type		X			X	X
3.5.3	N pr. ha					X (+)	X (+)
3.5.4	Mulch		X				
3.6.1	Field size		X (-)	**X (-)**			
3.6.2	Landscape heterogeneity					X	**X**
3.6.3	Field location						
3.6.3	Years in system						
3.6.3	Soil type						
3.7	% variance in response explained by model (R^2)	30%	67.57%	35.64%	57.21%	19.93%	40.85%

The response variables with skewness and kurtosis after transformation are shown in Table 11.

Table 11 Skewness and kurtosis of all six response variables, including the applied transformations. Skewness and kurtosis values are after the applied transformation.

Response variables	**Skewness**	**Kurtosis**	**Transformation**
Seed diversity	-0.03465	-0.228562	Exp
Seed density	0.3965867	1.7650436	Log +1
Arthropod diversity	-0.282904	-0.89939	
Arthropod density	0.4632641	-0.521727	
Bird diversity	0.2885322	-1.534455	Log +1
Bird density	0.9048929	-0.352292	Log +1

Correlations between variables can be found in Table 12. Here, the positive correlations between bird density and bird diversity (Fig 10A), and bird diversity and arthropod density (Fig 10B) are significant. Arthropod density has an almost significant positive correlation to seed density (Fig 10C), whereas the positive correlation to bird density is further from significant (Fig 10D).

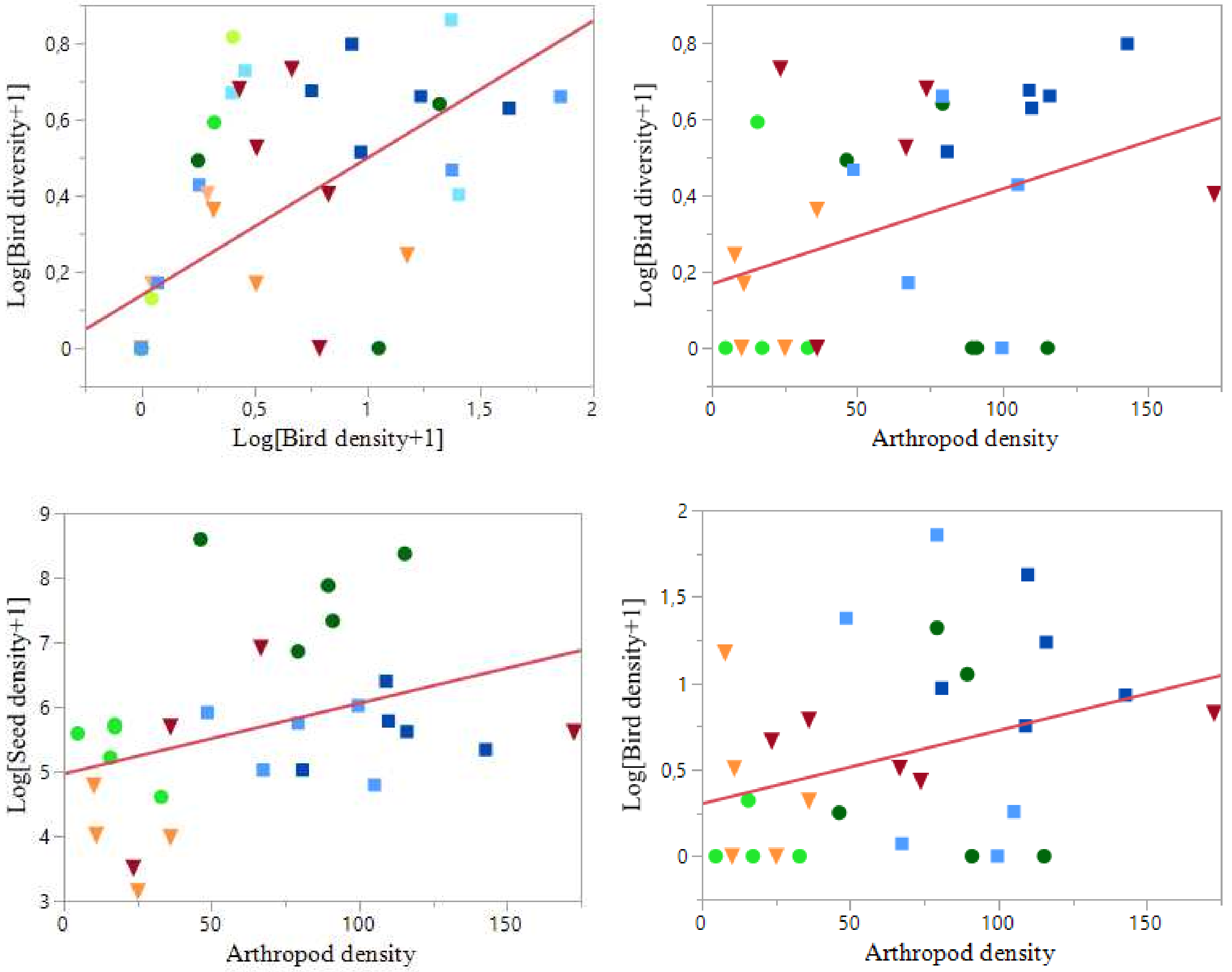
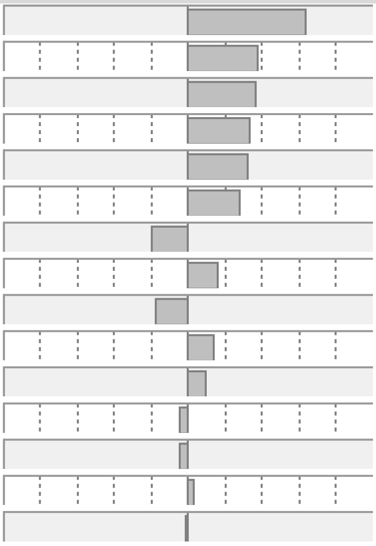


Fig 10 Linear regressions between bird diversity and bird density (A), arthropod density and bird diversity (B), arthropod density and seed density (C), and arthropod density and bird density (D). Greens circles are organic farms; red/orange triangles are conventional farms and blue squares are CA farms. Dark colors are the samplings before sowing/tillage, and lighter colors after. Significant difference between groups in C are described with different letters.

Table 12 Pearson's correlations between the six predictor variables. Significant correlations are shown in bold, and the table is sorted according to p-value. Plot correlation show negative correlations (bar to the left of midline) and positive correlations (bar to the right of midline.

Variable	by Variable	Correlation	P-value	Plot correlation
Bird density	Bird diversity	0.6406	**<0.0001**	
Bird diversity	Arthropod density	0.3811	**0.0377**	
Seed density	Arthropod density	0.3694	0.0530	
Bird density	Arthropod density	0.3404	0.0656	
Seed density	Arthropod diversity	0.3196	0.0973	
Seed diversity	Arthropod diversity	0.2792	0.1503	
Seed diversity	Bird diversity	-0.1955	0.3187	
Bird diversity	Arthropod diversity	0.1638	0.3871	
Seed density	Seed diversity	-0.1697	0.3879	
Arthropod density	Arthropod diversity	0.1453	0.4435	
Seed density	Bird density	0.0973	0.6224	
Seed diversity	Bird density	-0.0456	0.8179	
Seed density	Bird diversity	-0.0406	0.8374	
Bird density	Arthropod diversity	0.0303	0.8737	
Seed diversity	Arthropod density	-0.0156	0.9373	



3.3 Sampling time

All model results for agricultural system can be found in Table 13. There was a significant difference between the two sampling times for the densities of seeds (Fig 11A) and arthropods (Fig 11B) . Here, the sampling before sowing/tillage showed higher densities than the sampling after sowing/tillage. For birds, there was a significant difference between the three sampling times of birds, where the sampling before sowing and tillage had the highest densities, and a significant difference was found between the sampling before sowing/tillage and in February (Fig 11C). There was no significant difference between the two sampling times for the diversities of seeds, arthropods and birds.

Table 13 Seed density and diversity in relation to sampling time, before or after sowing/tillage. Significant pvalues are in bold.

Response	Model type	DF	F-value	P value	Tukey-Kramer HSD/ Parameter estimates	
Seed diversity	One-way ANOVA	27	0.0154	0.9023		
Seed density	One-way ANOVA	27	9.2152	**0.00054**		
Arthropod diversity	One-way ANOVA	29	1.9784	0.1706		
Arthropods density	One-way ANOVA	29	14.7313	**0.0006**		
Bird diversity	One-way ANOVA	44	2.7224	0.0773		
Birds pr. ha	One-way ANOVA	44	3.3606	**0.0443**	Before/Feb Before/Feb After/February	**0.0468** 0.1398 0.8634

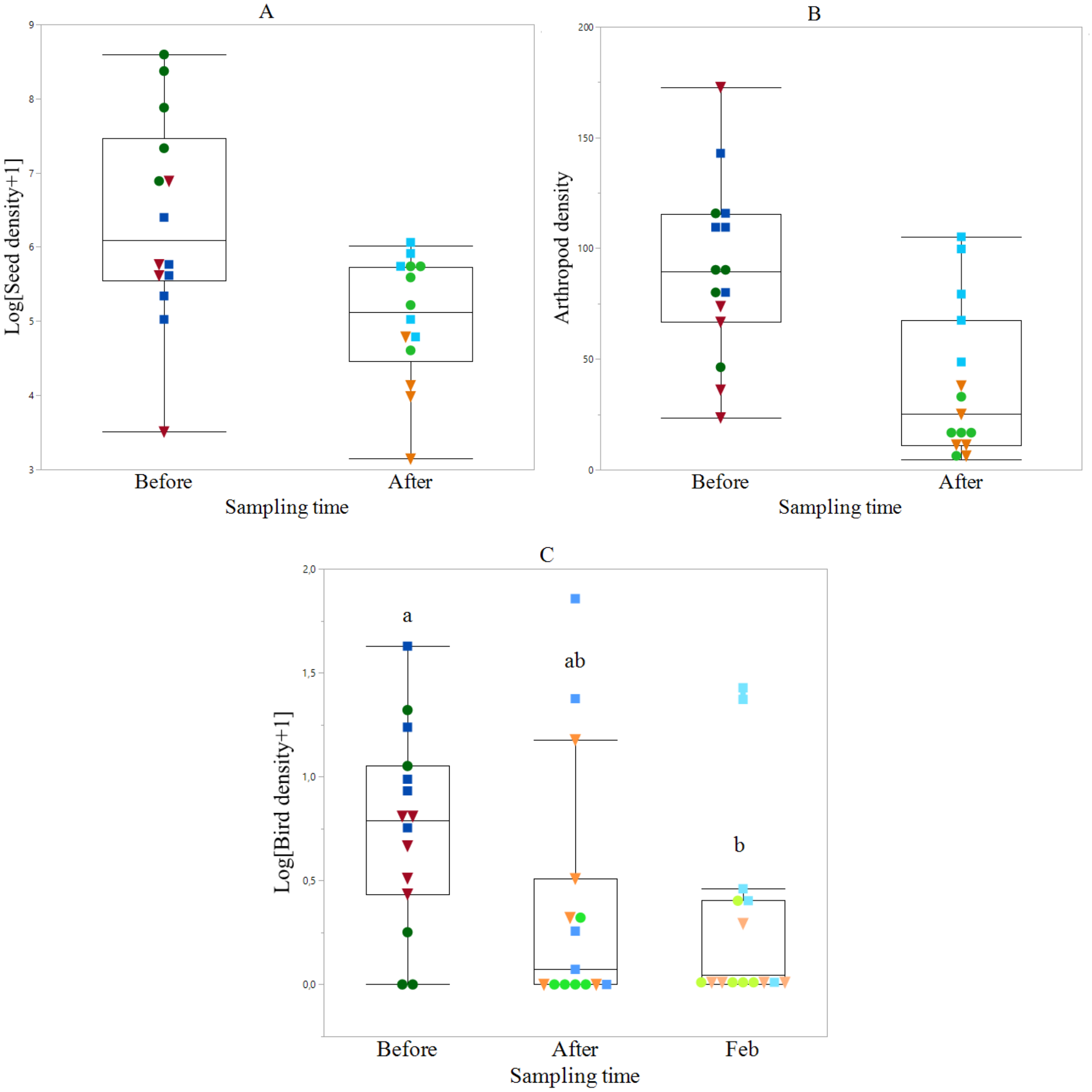


Fig 11 Density and diversity in relation to sampling time. Sampling time and the densities of seeds (A), arthropods (B) and birds(C). "Before" is the sampling before sowing/tillage, and "After" is the sampling after sowing and tillage. "February" is the sampling for birds in February. Greens circles are organic farms; red/orange triangles are conventional farms and blue squares are CA farms. Dark colors are the samplings before sowing/tillage, medium light is after, and samplings in February are the lightest. Significant difference between groups in (C), (Tukey-Kramer HSD test results) are described with different letters.

3.4 Agricultural system

All model results for agricultural system can be found in Table 14. Agricultural system significantly affected top-soil seed densities. There was a significant difference between organic and conventional fields, whereas no difference was found between organic and CA and between CA and conventional fields (Fig 12A). The interaction between system and sampling was significant, which means that the above-mentioned relationship between the systems are different before and after sowing/tillage. In the twoway ANOVA (Fig 12B and Fig 12C), CA had significant negative effect on seed densities before sowing/tillage and positive after. The opposite is the case for the organic system, with significant positive effect before sowing/tillage and negative after. Regardless of sampling time, conventional fields had a significant negative effect on seeds densities, organic fields had a significant positive effect on seeds densities and CA had a nonsignificant negative effect. There was a non-significant relationship between seed diversity and agricultural system. However, the seed diversity in organic fields was higher than in CA and conventional (Fig 12D).

Agricultural system significantly affected ground arthropod densities. There was significant difference between CA and conventional, and CA and organic whereas no difference was found between organic and conventional (Fig 13A). The interaction in between agricultural system and sampling was not significant, thus the before mentioned differences between systems does not change for arthropod densities. CA had significant positive effects on arthropod densities, whereas the effect from conventional fields and organic were negative (two-way ANOVA). There was a non-significant relationship between ground arthropod diversity and agricultural system (Fig 13B). However, the mean density is lowest in conventional fields, whereas CA and organic fields have a more similar mean.

Agricultural system also significantly affected bird density and diversity, and they had very similar responses. For both, there were significant differences between CA and conventional, and CA and organic, whereas no differences were found between organic and conventional (Fig 13C and Fig 13D). The interaction between agricultural system and sampling was not significant for bird density and diversity, thus the before-mentioned differences between systems does not change. CA had a significant positive relationship with bird density and diversity, whereas the relationship for conventional was negative, and a significant negative relationship was found for the organic system (two-way ANOVA's).

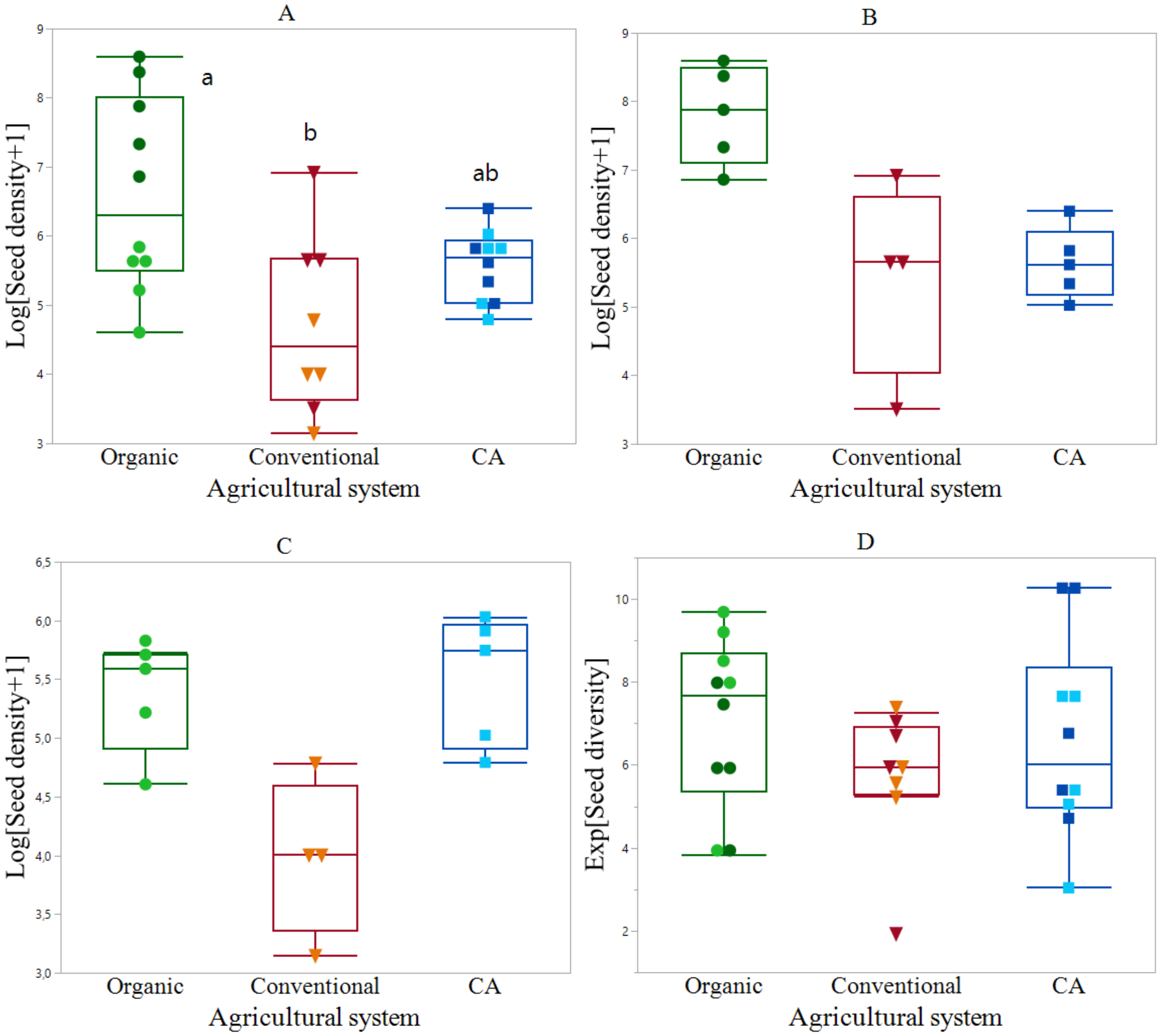


Fig 12 Seed density and diversity in the three agricultural systems. (A) densities of seeds in both samplings, (B) seed densities before sowing/tillage, (C) seed densities after sowing/tillage (D) seed diversity. Significant difference between groups (Tukey-Kramer HSD test results) are described with different letters.

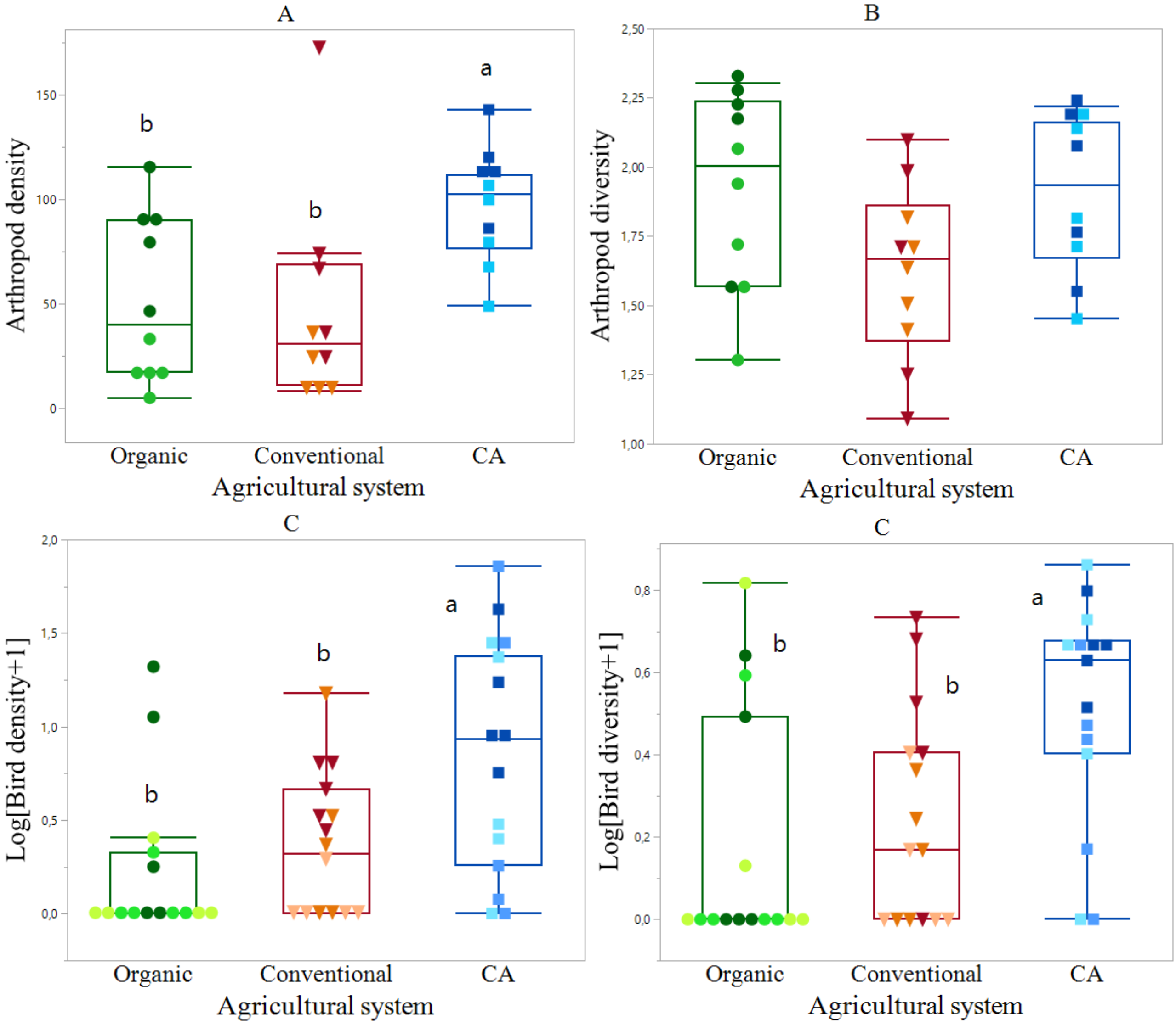


Fig 13 Arthropod and bird density and diversity in the three agricultural systems. (A) arthropod density, (B) arthropod diversity, (C) bird density, (D) bird diversity. Significant difference between groups in (Tukey-Kramer HSD test results) are described with different letters.

*Table 14 Results of ANOVA analyses of agricultural system and the density and diversity of seeds, arthropods and birds. Significant results are marked in bold. "AS" is agricultural system. "Org" is organic, "Conv" is conventional, and "CA" is CA. * indicate interaction. "(+)" and "(-)" are positive and negative relationships, respectively.*

Response	**Predictor(s)**	**Model type**	**DF**	**F-value**	**P value**	**Tukey-Kramer HSD/ Parameter estimates**	
Seed diversity	AS	One-way ANOVA	27	0.9789	0.3897		
Seed density	AS	One-way ANOVA	27	6.4909	**0.0063**	Org/Conv	**0.0036**
						Org/CA	0.1132
						CA/Conv	0.3028
Seed density	(Intercept)	Two-way ANOVA	27	12.2533	**<0.0001**	CA (-)	0.7870
	AS		2	13.8794	**0.0001**	Conv (-)	**0.0003**
	Sampling time		1	21.7998	**0.0001**	Org (+)	**<0.0001**
	Interaction		2	5.8591	**0.0091**	CA*Sampling A (+)	**0.0061**
						Conv*Sampling A (-)	0.8003
						Org*Sampling A (-)	**0.0114**
Arthropod diversity	AS	One-way ANOVA	29	2.6691	0.0875		
Arthropod density	AS	One-way ANOVA	29	4.7130	**0.0176**	CA/Conv	**0.0257**
						CA/Org	**0.0458**
						Org/Conv	0.9636
Arthropod density	(Intercept)	Two-way ANOVA	29	8.4254	**0.0001**	Org (-)	0.0938
	AS				**0.0017**	Conv (-)	**0.0276**
	Sampling time				**<0.001**	CA (+)	**0.0004**
	Interaction				0.4162		
Bird diversity	AS	One-way ANOVA	44	6.8047	**0.0046**	CA/Org	**0.0053**
						CA/Conv	**0.0308**
						Conv/Org	0.7778
Bird diversity	(Intercept)	Two-way ANOVA	44	6.6054	**0.0158**	Org (-)	**0.0221**
	AS				**0.0036**	Conv (-)	0.2481
	Sampling time				**0.0461**	CA (+)	**0.0010**
	Interaction				0.6400		
Bird density	AS	One-way ANOVA	44	6.8047	**0.0028**	CA/Org	**0.0029**
						CA/Conv	**0.0262**
						Conv/Org	0.6909
Bird density	(Intercept)	Two-way ANOVA	44	7.3336	**0.0112**	Org (-)	**0.0132**
	AS				**0.0021**	Conv (-)	0.2674
	Sampling time				**0.0242**	CA (+)	**0.0078**
	Interaction				0.9082		

Effects of agricultural system on bird diversity and on seed, arthropod and bird density are reviewed in Table 15. The conventional system has negative effects on seed density, arthropod density, bird density and bird diversity. The organic system positively affects seed density but have negative effects for arthropod density, bird density and bird diversity. CA has negative effects on seed density but positive effects on arthropod density, bird density, and bird diversity. Furthermore, a negative effect is found from the organic system in autumn after sowing/tillage, whereas a positive effect is found from CA in this time.

Table 15 The effect of agricultural systems on the 4 response variables where agricultural system was significant. "+" indicate significant positive effect, and "- "indicate significant negative effect. Effects in parentheses are non-significant. "Before" is sampling before sowing/tillage and "After" is after sowing/tillage. Effects of sampling is included if there is a significant interaction between agricultural system and sampling. "a" and "b" is used to illustrate significant difference between systems received from Tukey-Kramer HSD tests. For seed densities, organic and conventional is significantly different, but no significant difference is found between CA and organic and CA and conventional. For arthropod density, bird diversity and bird density, there are significant differences between: CA and organic, CA and conventional, but not between organic and conventional.

		Seed density	**Arthropod density**	**Bird diversity**	**Bird density**
Organic		+ a	(-) b	- b	- b
	Before	+	-	-	-
	After	-	-	-	-
Conventional		- b	(-) b	(-) b	(-) b
	Before	(+)	(-)	-	-
	After	(-)	(-)	-	-
CA		(-) ab	+ a	+ a	+ a
	Before	-	+	+	+
	After	+	+	+	+

In the PCA (Fig 14) on the density and diversity of seeds, arthropods and birds with including agricultural system as a supporting variable (z), the first two components explained a total of 52% of the variariation found in seeds, arthropods and birds. It is evident how the conventional system as a group is located in the lower left quadrant of the biplot where it is negatively correlated with axis 1 and axis 2, and overall mostly negatively correlated with all predictors. Conventional field plots are mostly negatively correlated with seeds, arthropods and birds as a whole, but several fields from the sampling before sowing/tillage(purple triangles) are located closely to bird density and diverisy and to arthropod density. Organic as a system is located in the top right quadrant of the biplot, making it positively correlated with axis 2, but negatively correlated with axis 1. Organic field plots are positively correlated with seed diversity and density, and some fields before sowing/tillage (dark green circles) have positive correlations to arthropod diversity and density. CA as a system is located in the top right quadrant of the biplot, making it positively correlated with both axis. However, CA field plots have the most variation in field plots of the three systems. The CA plots after sowing/tillage in the top left quadrant are more similar to organic plots and some plots in the lower left corner are similar to conventional plots. This show how the variation between CA fields after sowing/tillage are relatively greater than for conventional and organic fields who are more clustered together. Field plots from samplings before sowing/tillage (light colors) are more negatively correlated with seeds, arthropods and birds and more positively correlated in the field plots from the samplings after sowing/tillage.

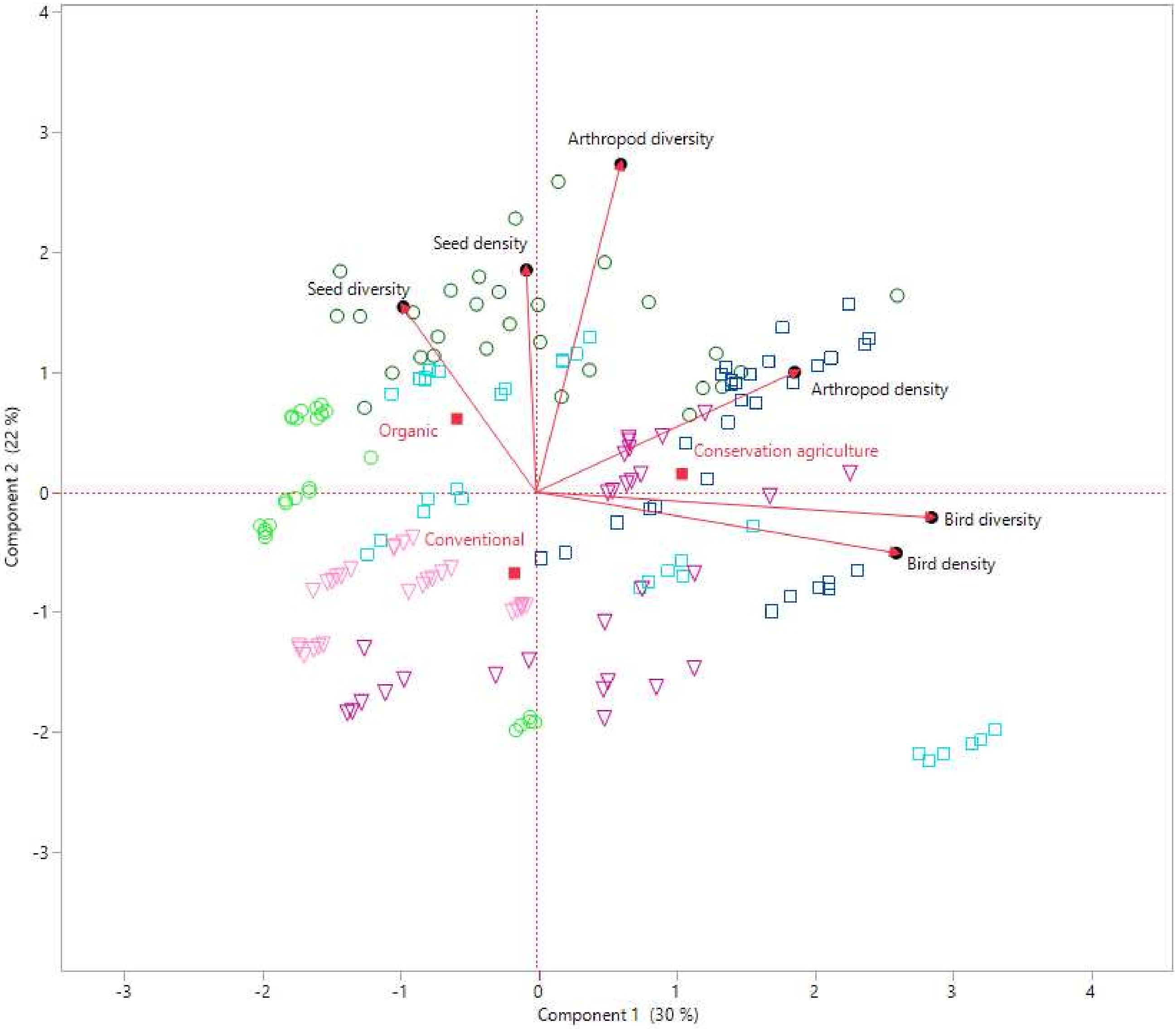


Fig 14. PCA biplot on density and diversity of seeds, ground-living arthropods and birds(red arrows) compared to agricultural systems(red squares). Organic field plots are represented by green circles, conventional field plots by pink triangles and CA field plots with blue squares. Dark colors represent samplings from before sowing/tillage and lighter colors represent samplings from after sowing/tillage. Axis 1 and 2 combined explain 52% of the variation in density and diversity of seeds, ground-living arthropods and birds.

3.5 Agricultural treatments

In this section, the particular agricultural system that each field belonged to, is not included in the following tests. Therefore, only the effects of the treatments reported by the farmers are used in the tests on density and diversity of seeds, arthropods and birds.

3.5.1 Tillage

All model results for tillage can be found in Table 16 and Table 17. There was a significant positive relationship between seed diversity and tillage depth (Fig 15A). The other 5 responses were not significantly affected by tillage depth. There was no significant relationship between tillage and seed diversity or seed density. Tillage significantly affected arthropod density with significantly higher densities of arthropods with no-tillage (Fig 15B) and no significant difference was found for arthropod diversity. Tillage significantly affected bird diversity and density with significantly higher diversity and density when tillage was absent (Fig 15C and Fig 15D).

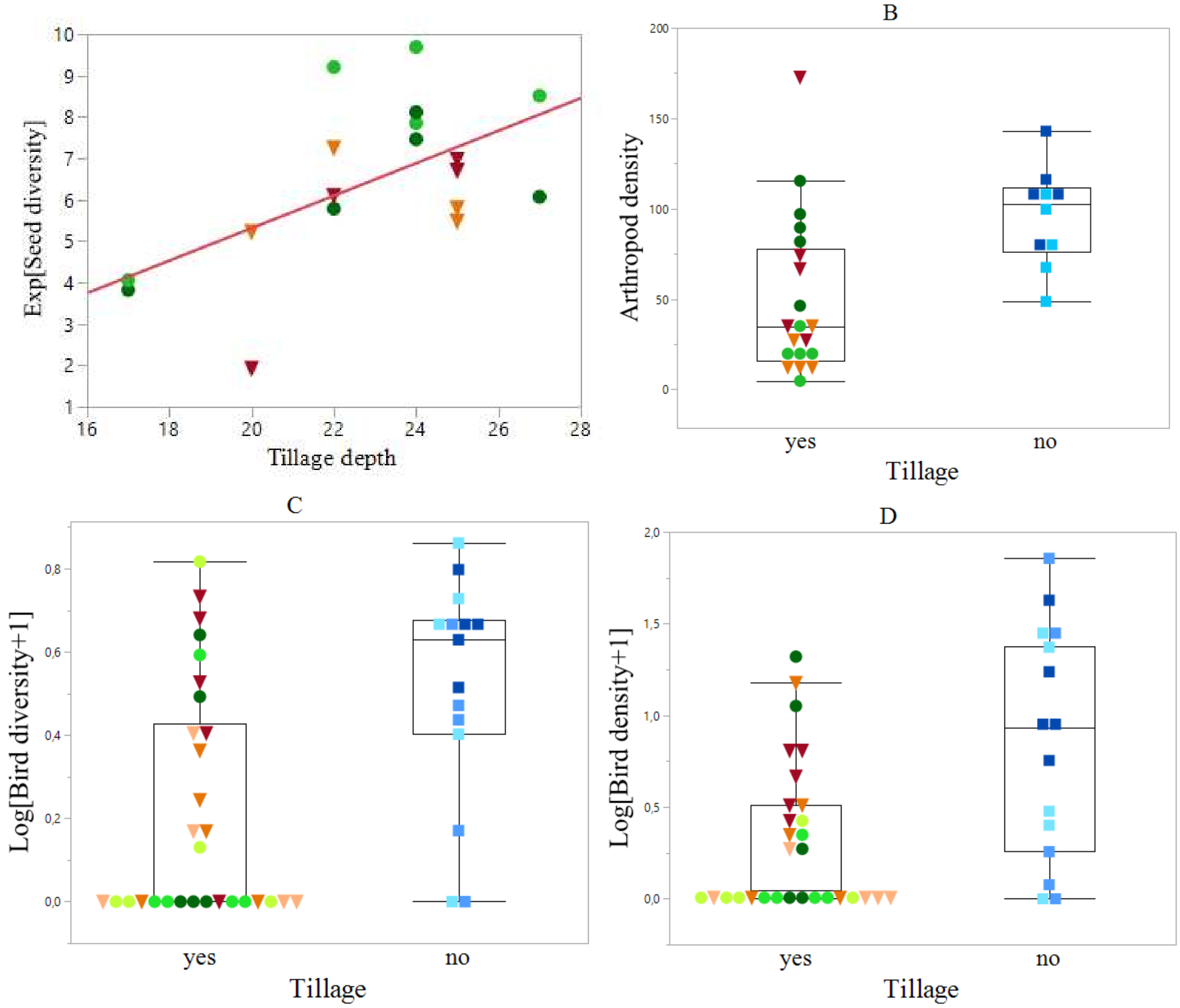


Fig 15 Seed, arthropod and birds in relation to tillage. (A) seed diversity and tillage depth, (B) arthropod densities and tillage, (C) bird diversity and tillage, (D) bird density and tillage. Organic field plots are represented by green circles, conventional field plots by red triangles and CA field plots with blue squares. Dark colors represent samplings from before sowing/tillage and medium light colors represent samplings from after sowing/tillage, and the lightest colors represent bird observations in February.. In (B), the outlier with tillage sampled before sowing/tillage is a conventional field with the highest recorded density of 172 pr. m^2.

Table 16 Results from linear regression on tillage depth and the diversity and density of seeds, arthropod and birds. Significant pvalues are shown in bold. "(+)" is a positive relationship.

Response	**Adj R**	**DF**	**F-stats**	**P value**	**Effect**
Seed diversity	0.300031	17	8.2868	**0.00109**	(+)
Seeds density	-0.01266	17	1.0012	0.3319	
Arthropod diversity	-0.04727	19	0.1424	0.7104	
Arthropods density	-0.05166	19	0.0668	0.7991	
Bird diversity	-0.00246	29	0.9289	0.3434	
Birds density	-0.0274	29	0.2267	0.6377	

Table 17 Results from one-way ANOVA's on tillage (yes/no) and the diversity and density of seeds, arthropod and birds. Results are from One-way ANOVA's. Significant pvalues are in bold.

Response	DF	F-value	P value
Seed diversity	29	0.0276	0.8694
Seeds density	29	0.1220	0.7297
Arthropod diversity	29	1.0505	0.3142
Arthropods density	29	9.6812	**0.0043**
Bird diversity	44	11.9519	**0.0012**
Birds pr. ha	44	13.0295	**0.0008**

3.5.2 Pesticides

All model results for pesticides in 2018/2019 and 2019/2020 can be found in Table 18 and Table 19 respectively. The absence of herbicides and fungicides used in 2018/2019 had significant positive effects on seed density (Fig 16A and Fig 16B). The same significant relationship from herbicide use in 2018/2019 was evident when testing the use of herbicides this season, 2019/2020, where the absence of herbicides also had a positive impact on seed density (Fig 16C).

The absence of insecticide and fungicide application in 2018/2019 had significant positive effects on arthropod diversity (Fig 16D and Fig 16E). In these figures it is evident, that in this study, most fields have no application of insecticides whereas herbicides and fungicides are more commonly used.

The effects of pesticides from 2018/2019 and 2019/2020 on seed and bird diversity and arthropod density were not significant. Unexpectedly, fungicides applied in 2019/2020 had significant positive effects on bird densities (Fig 16F). However, it is evident from the figure how most of the fields that applied fungicides in 2019/2020 are CA fields, and we already know that significantly more birds were observed there.

Table 18 Results from one-way ANOVA on pesticide application from the crop cycle 2018/2019 and the diversity and density of seeds, arthropod and birds. Significant pvalues are shown in bold.

Response	Predictor	DF	F-value	P value
Seed diversity	Herbicide 18/19	25	0.6236	0.4374
Seed diversity	Fungicide 18/19	25	3.2452	0.0842
Seed density	Herbicide 18/19	25	7.1631	**0.0132**
Seed density	Fungicide 18/19	25	5.1875	**0.0319**
Arthropod diversity	Fungicide 18/19	27	4.3480	**0.0470**
Arthropod diversity	Insecticide 18/19	27	9.5423	**0.0047**
Arthropod density	Fungicide 18/19	27	1.2415	0.2754
Arthropod density	Insecticide 18/19	27	0.00661	0.7991
Bird diversity	Herbicide 18/19	41	2.3244	0.1352
Bird diversity	Fungicide 18/19	41	0.6296	0.4322
Bird diversity	Insecticide 18/19	41	0.0388	0.8448
Bird density	Herbicide 18/19	41	3.2389	0.0795
Bird density	Fungicide 18/19	41	0.5282	0.4716
Bird density	Insecticide 18/19	41	0.3065	0.5829

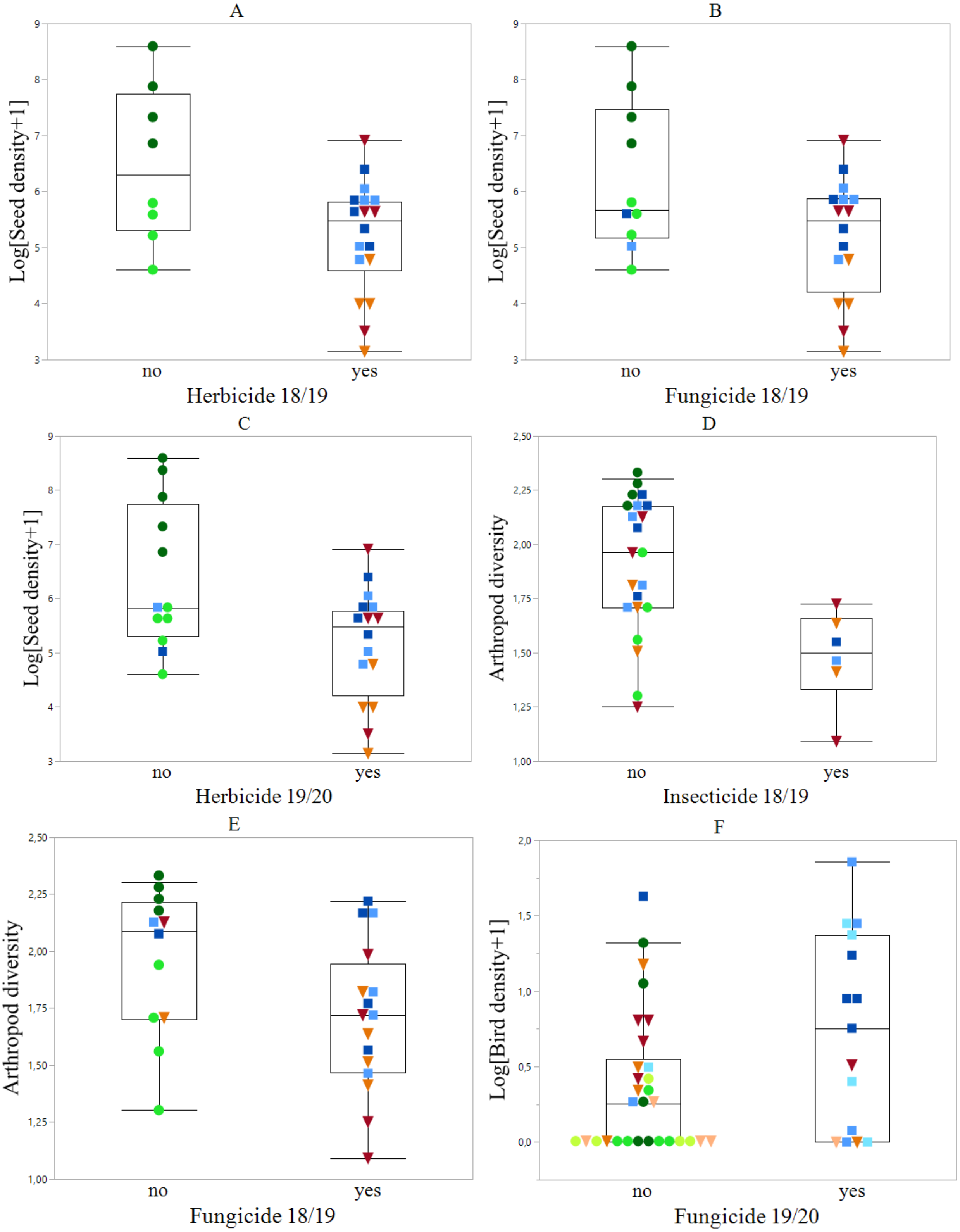


Fig 16 Pesticide use. (A) seed densities and herbicide use in 18/19, (B) seed densities and the use of fungicides in 2018/2019, (C) seed densities and herbicide use in 19/20, (D) arthropod diversity and the use of insecticides in 2018/2019, (E) arthropod diversity and the use of fungicides in 2018/2019, (F) bird densities and fungicide use in 2019/2020. Organic field plots are represented by green circles, conventional field plots by red triangles and CA field plots with blue squares. Dark colors represent samplings from before sowing/tillage and lighter colors represent samplings from after sowing/tillage.

Table 19 Pesticide application in the crop cycle 2019/2020. Significant pvalues are in bold.

Response	Predictor	DF	F-value	P value
Seed diversity	Herbicide 19/20	25	0.6862	0.4150
Seed diversity	Fungicide 19/20	27	3.8168	0.0616
Seed density	Herbicide 19/20	27	7.5478	**0.0108**
Seed density	Fungicide 19/20	27	0.0004	0.9843
Arthropod diversity	Fungicide 19/20	29	0.1537	0.6980
Arthropod diversity	Insecticide 19/20	29	0.1134	0.7388
Arthropod density	Fungicide 19/20	29	2.4711	0.1272
Arthropod density	Insecticide 19/20	29	0.1107	0.7418
Bird diversity	Herbicide 19/20	44	1.6729	0.2028
Bird diversity	Fungicide 19/20	44	3.3778	0.0730
Bird diversity	Insecticide 19/20	44	0.9211	0.3425
Bird density	Herbicide 19/20	44	2.0643	0.1580
Bird density	Fungicide 19/20	44	4.9441	**0.0315**
Bird density	Insecticide 19/20	44	1.7593	0.1917

3.5.3 Fertilizer and N application

All model results for fertilizer type and N application can be found in Table 20 and Table 21. Fertilizer type significantly affected seed densities. The pattern of fertilizer effects was very similar to the effect of agricultural system on seed densities. There was a significant difference between organic and both types of fertilizers and no significant difference between organic and inorganic and between both types and inorganic (Fig 17A). Investigating this with a twoway ANOVA including sampling time and the interaction between fertilizer and sampling time, organic fertilizer had significant positive effects on seed densities whereas the effects from inorganic and both types were negative but not significant. Both fertilizers had a significant positive effect after sowing/tillage whereas inorganic and organic had negative effects.

For birds, fertilizer type significantly affected density and diversity (Fig 17B and Fig 17C). Comparing fertilizer groups, there was significant difference between organic and both types of fertilizers and no significant difference between both types and inorganic fertilizer and between organic and inorganic.

Fertilizer type did not affect seed and arthropod diversity and arthropod density. Furthermore, nitrogen application (kg/ha) did not affect seed or arthropod density and diversity, but there were significant positive effects on bird density and diversity. All CA fields except one used both types of fertilizer (Fig 17A,B,C) and their nitrogen application was significantly higher than conventional and organic fields (Fig 17D). Furthermore, there was a significant difference in nitrogen application between CA and conventional and CA and organic but not between organic and conventional fields.

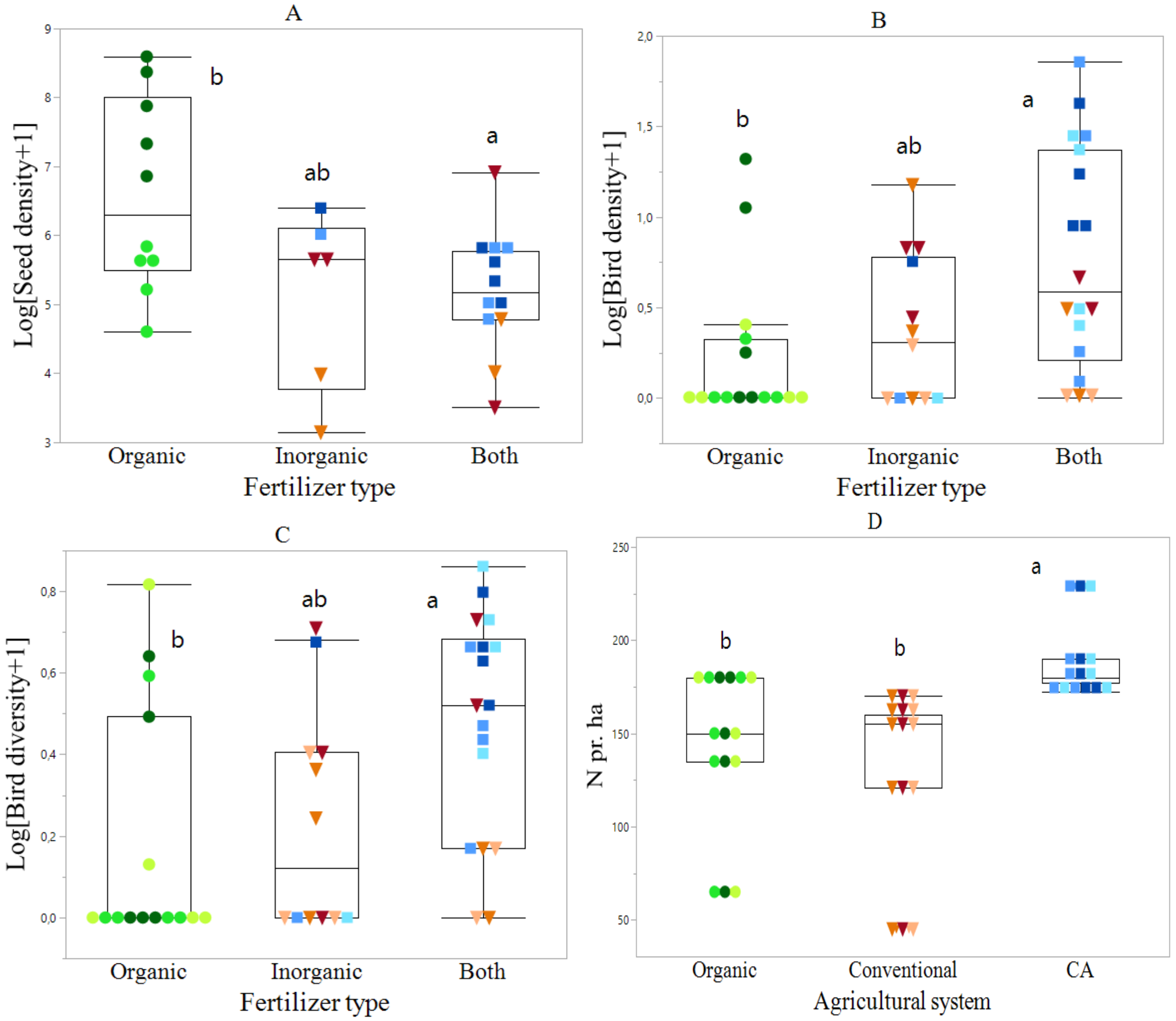


Fig 17 Seeds and birds in relation to fertilizer. (A) seed density and fertilizer type, (B) bird densities and fertilizer type, (C) bird diversity and fertilizer, (D) nitrogen application and agricultural system. Organic field plots are represented by green circles, conventional field plots by red triangles and CA field plots with blue squares. Dark colors represent samplings from before sowing/tillage and lighter colors represent samplings from after sowing/tillage.

Table 20 Results of ANOVA analyses on fertilizer type and the diversity and density of seeds, arthropod and birds. Significant results are marked in bold.

Response	**Predictor(s)**	**Model type**	**DF**	**F-value**	**P value**	**Tukey-Kramer HSD/ Parameter estimates**	
Seed diversity	Fertilizer	One-way ANOVA	27	0.5896	0.5621		
Seed density	Fertilizer	One-way ANOVA	27	4.5120	**0.0212**	Organic/Inorganic	0.0656
						Both/organic	**0.0301**
						Both/Inorganic	0.9939
Seed density	Intercept	Two-way ANOVA	27	8.4449	**0.0001**	Both (-)	0.0609
	Fertilizer		2		**0.0018**	Inorganic (-)	0.0712
	Sampling time		1		**0.0004**	Organic (+)	**0.0005**
	Interaction		2		**0.0287**	Both/Sampling A (+)	**0.0207**
						Inorganic/Sampling A (-)	0.8633
						Organic/Sampling A (-)	**0.0390**

Arthropod diversity	Fertilizer	One-way ANOVA	2	1.5020	0.2407		
Arthropod density	Fertilizer	One-way ANOVA	2	0.6659	0.5221		
Bird diversity	Fertilizer	One-way ANOVA	44	5.3848	**0.0083**	Both/Organic	**0.0104**
						Both/Inorganic	0.0575
						Inorganic/Organic	0.8771
Birds density	Fertilizer	One-way ANOVA	44	5.0167	**0.0111**	Both/Organic	**0.0104**
						Both/Inorganic	0.1167
						Inorganic/Organic	0.6994

Table 21 Results of linear regression on nitrogen application and the diversity and density of seeds, arthropod and birds. Significant results are marked in bold. "(+)" are positive relationships.

Response	**Adj R**	**F-value**	**P value**	**Effect**
Seed diversity	0.035339	2.0624	0.1621	
Seed density	-0.02872	0.1904	0.6659	
Arthropod diversity	0.014162	1.4166	0.2440	
Arthropod density	-0.02257	0.3598	0.5534	
Bird diversity	0.190327	11.3429	**0.0016**	(+)
Birds density	0.13217	7.7012	**0.0081**	(+)

3.5.4 Mulch

All model results for mulch can be found in Table 22. The normal amount of mulch in this study was 3-4 tons of straw applied pr. ha. Mulch significantly affected seed density where fields with absence of mulch had significantly lower seed densities (Fig 18). In this cropping cycle, all conventional fields did not use mulch, all organic did and most of CA used mulch.

Mulch had no significant effect on the diversity of seeds, arthropods and birds or on arthropod and bird density.

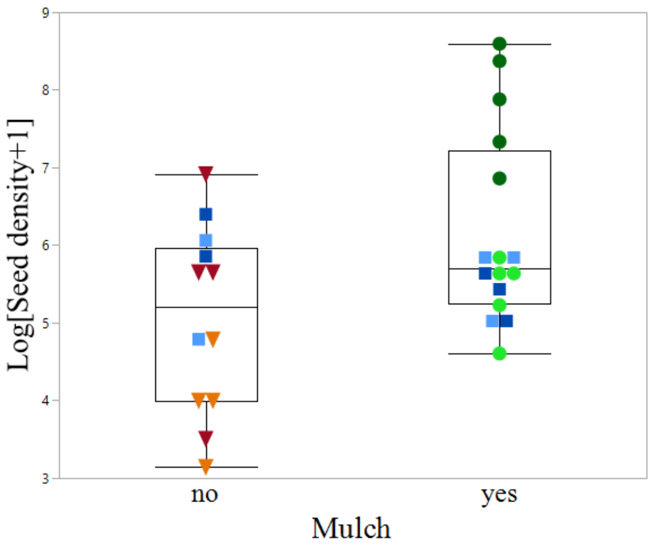


Fig 18 Seed density and mulch application. Organic field plots are represented by green circles, conventional field plots by red triangles and CA field plots with blue squares. Dark colors represent samplings from before sowing/tillage and lighter colors represent samplings from after sowing/tillage.

Table 22 Results of ANOVA on mulch and the diversity and density of seeds, arthropod and birds. Significant results are marked in bold.

Response	**Model type**	**DF**	**F-value**	**P value**
Seed diversity	One-way	27	0.9308	0.3429
Seed density	One-way	27	5.5138	**0.0268**
Arthropod diversity	One-way	27	0.9103	0.3482
Arthropod density	One-way	27	0.0136	0.9081
Bird diversity	One-way	44	0.1455	0.7047
Birds density	One-way	44	0.6321	0.4309

3.6 Field and landscape information

3.6.1 Field size

All model results for field size can be found in Table 23. Field size had a significant negative relationship with seed density (Fig 19A) and with arthropod diversity (Fig 19B). However, there were no significant relationships between field size and seed and bird diversity and arthropod and bird density.

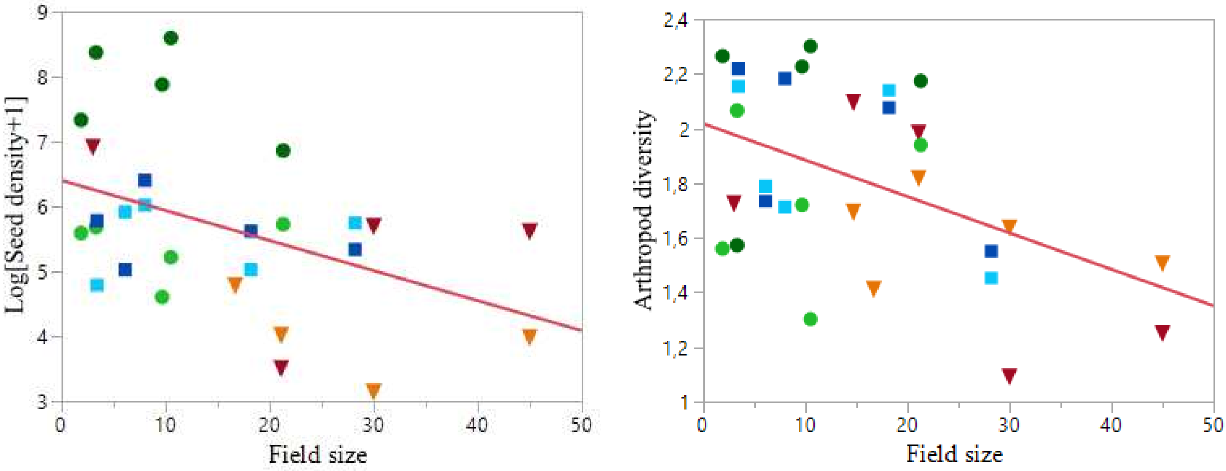


Fig 19 Seed density and field size, arthropod diversity and field size. Organic field plots are represented by green circles, conventional field plots by red triangles and CA field plots with blue squares. Dark colors represent samplings from before sowing/tillage and lighter colors represent samplings from after sowing/tillage

Table 23 Results of linear regression on field size and the diversity and density of seeds, arthropod and birds. Significant results are marked in bold. "(+)" and "(-)" are positive and negative relationships, respectively.

Response	**Adj R**	**F-value**	**P value**	**Effect**
Seed diversity	-0.03255	0.0858	0.7717	
Seed density	0.154248	6.2890	**0.0182**	(-)
Arthropod diversity	0.19731	8.1285	**0.0081**	(-)
Arthropods density	-0.0308	0.1336	0.7175	
Bird diversity	-0.01987	0.1426	0.7075	
Birds density	0.003618	1.1598	0.2875	

3.6.2 Landscape heterogeneity

All model results for landscape heterogeneity can be found in Table 24. Landscape heterogeneity scores and descriptions for all fields can be found in Appendix A. There was no significant relationship between landscape heterogeneity and the density and diversity for seeds and arthropods.

Landscape heterogeneity (category 1-4) significantly affected bird densities (Fig 20A). There was significant difference between 4 and 1 and between 4 and 2, where the high scores had significantly higher bird densities. There was no significant difference between the other pairs (4/3, 3/1, 3/2, 2/1). Thus, there was only significant difference between the highest and (second) lowest scores. A very similar pattern was evident for landscape heterogeneity and bird diversity. There was a significant effect on bird diversity, and there was a significant difference between 4 and 1, and no significant difference between the other pairs (4/2, 4/3, 3/1, 2/1). Thus, there is only significant difference between the highest and the lowest score, as shown in (Fig 20B). Interestingly, landscape scores differed between agricultural systems (Fig 20C). CA had higher landscape scores, with scores 2-4. Conventional systems had scores 1-3 and organic scores were only 1 and 2.

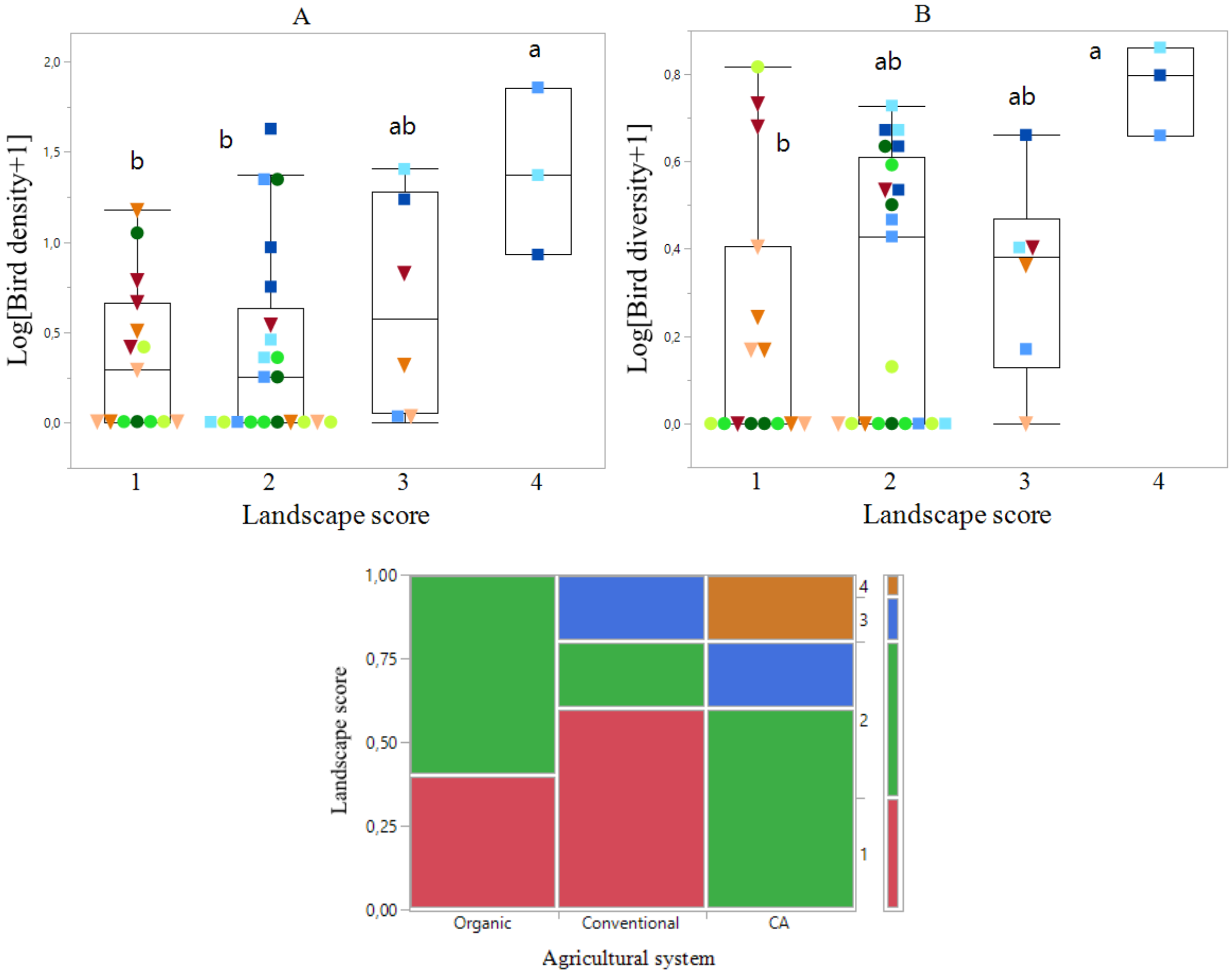


Fig 20 Bird density and landscape heterogeneity score (A), bird diversity and landscape heterogeneity score (B) and landscape score and agricultural system. In A and B, organic field plots are represented by green circles, conventional field plots by red triangles and CA field plots with blue squares. Dark colors represent samplings from before sowing/tillage and lighter colors represent samplings from after sowing/tillage. For C, scores are represented by percentages of fields in the agricultural systems with the assigned landscape heterogeneity score. Red represent percentages of fields with score 1, green for score 2, blue for score 3 and yellow/brown for score 4, as seen in the right bar.

Table 24 Landscape heterogeneity, oneway ANOVA

Response	**DF**	**F-value**	**P value**	**Tukey-Kramer HSD/ Parameter estimates**	
Seed diversity	29	1.8900	0.1561		
Seed density	29	0.9513	0.4304		
Arthropod diversity	29	0.8839	0.4623		
Arthropod density	29	2.6011	0.0735		
Bird diversity	44	3.2236	**0.0323**	4/1	**0.0175**
				4/2	0.0546
				4/3	0.1448
				3/1	0.8221
				2/1	0.7584
				3/2	0.9977
Birds density	44	4.1164	**0.0122**	4/1	**0.0104**
				4/2	**0.0116**
				4/3	0.1606
				3/1	0.6301
				3/2	0.6972
				2/1	0.9961

For in-field heterogeneity, which was not tested for, personal observations during sampling where, that the heterogeneity was highest in CA fields, and there was a tendency of dry and hard surface soil in conventional fields. The observed differences can be seen in Fig 21.

Fig 21 In-field heterogeneity of organic (left), conventional (mid-left) and CA (mid-right) after sowing/tillage in October. Closeup of CA field in October after sowing showing the structural complexity on the soil surface (right).

3.6.3 Other variables

Soil type, years in agricultural system and field location were also tested, but none were significant. These results can be found in the following tables respectively.

Table 25 Soil type, in the JB system.

Response	**DF**	**F-stats**	**P value**
Seed diversity	27	2.9532	0.0528
Seed density	27	0.8643	0.4731
Arthropod diversity	29	1.2957	0.2969
Arthropod density	29	0.7069	0.5566
Bird diversity	44	0.6214	0.6052

Bird density	44	0.3425	0.7947

Table 26 Years in agricultural system

Response	Adj R	F-stats	P value
Seed diversity	0.087745	2.8275	0.1099
Seed density	-0.05375	0.0308	0.8627
Arthropod diversity	-0.05516	0.0067	0.9356
Arthropod density	0.013535	1.2607	0.2763
Bird diversity	-0.01063	0.6951	0.4115
Bird density	-0.03569	0.0008	0.9780

Table 27 Longitudinal (X) and latitudinal coordinates (Y)

Response	Predictor	Adj R	F-stats	P value
Seed diversity	X	-0.02291	0.3953	0.5350
Seed diversity	Y	-0.036887	0.0400	0.8430
Seed density	X	0.008225	1.2239	0.2787
Seed density	Y	-0.02926	0.2324	0.6338
Arthropod diversity	X	-0.03101	0.1278	0.7234
Arthropod diversity	Y	-0.02958	0.1669	0.1669
Arthropod density	X	-0.020303	0.3471	0.5605
Arthropod density	Y	-0.03429	0.0387	0.8455
Bird diversity	X	-0.01091	0.5249	0.4727
Bird diversity	Y	-0.02103	0.0938	0.7609
Bird density	X	0.021436	1.9639	1.1683
Bird density	Y	0.03193	2.4513	0.1248

3.7 Conclusive models

All concluding models can be found in Table 28. These “best” models are the conclusion on all the above-mentioned analyses in this chapter. In summary, 13 predictors were tested for each of the density and diversity of seeds, arthropods and birds (Table 10). All significant predictor variables for density and diversity of seeds, arthropods and birds were introduced in a stepwise selection process, and final models were constructed to identify the most important predictors. The results of these models are described in the following. The adjusted R^2, are the variance in seeds, arthropods or birds explained by one or more predictors in this study, and for this reason it is a qualitative measure. It was not possible to find other studies using this value for comparison.

Table 28 Concluding models for the density and diversity of seeds, arthropods and birds. "AS" is agricultural system. Significant results are in bold.

Response	**Predictor(s)**	**Model type**	**DF**	**R^2_{adj}**	**F-value**	**P value**	**Parameter estimates**	
Seed diversity	Tillage depth	Linear regression	17	0.300031	8.2868	**0.00109**	(+)	
Seed density	(Intercept) AS Sampling Interaction	Twoway ANOVA	27 2 1 2	0.675739	12.2533	**<0.0001** **0.0001** **0.0001** **0.0091**	CA (-) Conv (-) Org (+) Sampling A (-) CA*Sampling A (+) Conv*Sampling A (-) Org*Sampling A (-)	0.7870 **0.0003** **<0.0001** **0.0001** **0.0061** 0.8003 **0.0114**
Arthropod diversity	(Intercept) Insecticide 18/19 Field size	Twoway ANOVA	27 1 1	0.3564	8.4774	**0.0015** **0.0179** **0.0249**	Insecticides 18/19 (-) Field size (-)	**0.0179** **0.249**
Arthropod density	(Intercept) Sampling AS	Twoway ANOVA	29 1 1	0.57216	20.3912	**<0.0001** **<0.0001** **0.0003**	Sampling AS (Conv-Org/CA)	**<0.0001** **0.0003**
Bird diversity	AS	Oneway ANOVA	44	0.1993	11.9519	**0.0012**	AS (Conv-Org/CA)	**0.0012**
Birds density	(Intercept) AS Sampling Landscape heterogeneity	Twoway ANOVA	44 1 1 1	0.408556	11.1314	**<0.0001** **0.0059** **0.0031** **0.0166**	AS (Conv-Org/CA) Sampling (A-Feb/B) Landscape score (1-2-3/4)	**0.0059** **0.0031** **0.0166**

3.7.1 Seeds in the topsoil

For seeds diversity, tillage depth is positively correlated, and the only significant predictor. Tillage depth explained 30% of the variation in seed diversity. No stepwise selection model was run as only this predictor was significant.

The stepwise model selection for seed densities included the nine significant predictors: sampling time, agricultural system, the interaction between sampling and agricultural system, herbicides 18/19, fungicides 18/19, herbicide 19/20, mulch, fertilizer type and field size. With the BIC criterion, the stepwise regression removed six predictors and kept three. The final model (BIC 76.6331, AIC_c 74.0487) revealed that that the two most important predictors of seed densities were agricultural system and sampling time. Organic had a positive significant relationship, conventional had a negative significant relationship and CA had a non-significant negative relationship with seed density. The sampling affected seed density positively before sowing/tillage and negatively after. Including the interaction of agricultural system and sampling time, the organic system had negative effects after sowing/tillage, and CA had positive effects. This model, with sampling time agricultural system and the interaction between them, explained 67.57% of the variation in seed densities.

3.7.2 Ground-living arthropods

The use of insecticides and fungicides in 2018/2019 together with field size were the three significant predictors of arthropod diversity. Fungicides was removed in the stepwise selection, leaving insecticides and field size in the final model (BIC 17.1546, AIC_c 13.5651). Insecticide use and field size had a significant negative effect on arthropod diversity, and this model explain 35.64% of the variation in arthropod diversity.

Three predictors significantly affected arthropod densities: sampling time, agricultural system and tillage. Tillage was removed in the stepwise model selection, leaving sampling time and agricultural system as significant predictors in the final model (BIC 298.164, AIC_c 294.159). In this model selection, agricultural systems were separated into two groups by the stepwise selection: organic and conventional opposite of CA. Thus, this grouping (Conv-Org/CA) accounted for differences in arthropod densities. The grouping is consistent with the previous results where CA was significantly different from the two other systems with higher arthropod densities. As for seed densities, the sampling affected arthropod density positively before sowing/tillage and negatively after. This model, with sampling time and the groupings in agricultural system, explained a total of 57.22% of the variation in seed densities.

3.7.3 Birds

Five predictors significantly affected bird diversity in this study: agricultural system, tillage, fertilizer type, N application and the proxy variable for landscape heterogeneity. The stepwise regression removed all predictors except one; agricultural system, resulting in a final model (BIC 20.3379, AIC_c 15.5032). As for arthropod densities, agricultural systems were separated into two groups by the stepwise selection: organic and conventional opposite of CA. Thus, this grouping (Conv-Org/CA) accounted for differences in bird diversity. The grouping is also consistent with the previous results where CA was significantly different from the two other systems with significantly higher bird diversity. This final model, with groupings in agricultural system, explained 19.93% of the variation in bird diversity.

For bird densities, seven predictors had significant effects: agricultural system, sampling, tillage, fungicides 19/20, fertilizer type, N application and landscape heterogeneity. Four predictors were removed, leaving agricultural system, sampling and landscape heterogeneity as significant predictors in for bird density in the final model (BIC 63.9139, AIC_c 56.419). As for arthropod density and bird diversity, agricultural systems were separated into two groups by the stepwise selection: organic and conventional opposite of CA. This grouping is also consistent with the previous results where CA was significantly different from the two other systems with significantly higher bird diversity. The same type of grouping was produced for sampling and landscape heterogeneity. For sampling, the sampling after sowing/tillage and in February were grouped together opposite of the sampling before sowing/tillage. This grouping is also consistent with the previous results where the sampling before sowing/tillage was significantly different from the two other sampling times with significantly higher bird densities. For landscape heterogeneity score, scores 1, 2 and 3 were grouped together opposite of score 4. This grouping is also consistent with the previous results where the highest score, 4, was significantly different from the lowest scores with significantly higher bird densities. This final model, with grouping in agricultural system, sampling time and landscape heterogenity explained 40.85% of the variation in bird densities.

4 Discussion

In this chapter, focus will be on discussing the most important effects of agricultural system, treatments and landscape effects on seeds, arthropods and birds with emphasis on variables with the strongest effects (Table 10). The most important effect, agricultural system, will be reviewed in the first section. This is followed by four sections discussing the first four hypotheses in relation to the findings of this study, interrupted by a section on landscape effects, before the discussion of the fifth hypothesis. Hereafter, a short section on pesticides is followed by a discussion on seasons and crop rotation. Finally, perspectives and implications of the findings are discussed in 4.10.

4.1 Agricultural system differences and tillage effects

One of the most noteworthy results of this study was that the organic and conventional systems were grouped together opposite of CA for arthropod density, bird diversity and bird density. This grouping reflected the continuous absence of significant difference between organic and conventional fields for these groups (Table 14 and Table 15) and this is most likely driven by tillage. Tillage is the dominating treatment in the autumn and winter, whereas pesticides are usually applied in the spring. For this reason, it can be expected that the biggest difference between the three systems in the autumn and winter is to a very large extend a result of the use of tillage. Because this study was carried out in these winter months, from late august to early February, pesticide effects in this time of year are certainly more indirect. The balance between the effects of tillage and pesticide application over the course of the year is important to consider in judging their effects. It will be discussed further in relation to the results of this study in section 4.8.

It must be stressed that tillage in the autumn is an independent and strong force in agroecosystems. For seeds, arthropods and birds in this study, densities after sowing and tillage were significantly lower than before the event across all three systems. Across all three groups, organic fields had the strongest declines, intermediate declines for conventional fields and lowest in CA fields. Because it can be assumed that all three systems return to the original densities from autumn to summer, organic fields in particular undergo a massive transformation over the year, whereas CA fields in the other end of the spectrum are more stable. Seed density decline in organic fields were 92%, compared to 13% in CA; arthropod density decline was 78% and 29% for organic and CA respectively, and birds declined 92% and 20% in the same order. These different seed densities in organic fields also emphasize a large weed potential in fields, and that the tillage regimes by organic farmers to control weeds are very efficient.

4.2 Correlations between densities and diversities

In this study, positive correlations were found between seed density and arthropod density. Additionally, arthropod density was positively correlated to bird density - and diversity. These findings illustrate the links between the three studied groups; seeds from the basis of the foodwebs in the field in the field, and they support arthropods and birds. In turn, arthropods are eaten by birds. For these reasons, a treatment affecting seeds could easily have cascading effects on arthropods and farmland birds that depend on both groups as food items.

The first hypothesis included correlations between both density and diversity of seeds, arthropods and birds. This study can confirm the hypothesis of the positive correlation between densities of seeds and arthropods, and between densities of arthropods and birds. However, it does not support the hypothesis for the densities of seeds and birds as well as the positive correlations between the diversities of all three groups.

4.3 Seed densities across agricultural systems

Before the sowing and tillage event, organic fields had more than eight, and more than ten times higher average seed densities than conventional and organic fields, respectively. However, with a 92% decrease in seeds densities after the event, organic and CA fields had comparable seed densities, with no significant difference between them. In fact, CA fields had slightly higher densities (1.2 times) than organic fields after the event. The second hypothesis included the expectation of highest seed densities in organic fields. This was confirmed for the densities before sowing and tillage event but rejected after the event.

The high average seed density in organic fields before sowing/tillage compared to conventional fields was consistent with the findings of Hald and Reddersen (1990) and Hald (1999) in summer. In spring, Hald (1999) found comparable densities of arable flora in conventional and organic fields before the application of herbicides, and the abovementioned difference in summer. One study compared the effects of no-tillage, conventional and organic fields. Menalled et al. (2001) compared weed seed banks and aboveground biomass and diversity for the three mentioned systems over six years in USA. They found consistently higher aboveground species diversity, density and biomass in organic systems, intermediate in conventional and lowest in CA. However, the seed bank analysis from that study found an increase in mean number of seedlings and species in no-tillage fields from 1993 to 1999. The increase reported by Menalled et al. (2001) could be due to the differences between the treatments of no-tillage and CA as argued by Nichols et al. (2015) in their review on weed dynamics in CA. They argue, that weed control only by herbicides and no-tillage without the two other principles of diverse crop rotations and soil cover can be insufficient. Thus, adaptation of the three principles of CA gradually does not result in the benefits from the weed control properties of the combined principles. Investigating the topsoil seeds over a period of several years in the fields in this study could provide insights in comparing the developments in the weed potential for CA, organic and conventional fields.

Seed density was also affected by field size; densities decreased when field size increased. This is in line with the study by Geiger et al. (2010), who found a significant negative effect of mean field size for plant species, and Marshall (1989) reported how 60% of species represented in hedges were not present in the field itself, and species decreased from the edge to the middle. Thus, some species could struggle to disperse into larger fields, and perhaps densities would reflect this too. Weeds in fields are pioneers, and colonization of larger fields could be relatively more difficult than smaller fields with more edge area. In conclusion, field size matters. Nevertheless, field size was removed as a predictor for seed density in the stepwise model selection, likely because it is a weaker link in the presence of systems.

The only important predictor of seed diversity in this study was tillage depth. Here, diversity increased with tillage depth. Thus, when tillage is deep, seeds are transported to the topsoil.

4.4 Spiders and ground-living arthropods

Spider densities were highest in CA, and this was most prominent after sowing and tillage, where average densities were six times higher than conventional and more than nine times higher than organic. The third hypothesis included the expectation of highest spider densities in CA fields. This hypothesis was confirmed for the sampling before and after sowing/tillage.

Arthropod densities were significantly higher in CA fields compared to conventional and organic fields. The main benefit from CA for spiders is low disturbance, and even reducing tillage can increase densities significantly (Samu et al. 1999). Jørgensen (2017) found more carabids, spiders and springtails in CA in the summer compared to conventional and reduced tillage systems. That study also explained 23.32% of the variance in carabid species densities and 46 % of variance in springtail species densities, by these systems. The results from my study are in accordance with the findings of Jørgensen (2017) for carabids and spiders, and for springtails after sowing/tillage. The density of springtails before sowing/tillage was higher in conventional systems than the other two systems, but this can be explained by the collection method used in this study. During ground search, personal observations were that the soil surface in CA fields were full of small springtail individuals, but they were too small to be captured with the pooter. In addition, springtails were frequently “lost” in the mulch layer in CA fields. Thus, the sampling method used in this study was clearly underrepresenting springtails. Proper sampling of springtails could be using a core sampler, and/or spreading out the mulch on a plastic canvas for additional search.

Arthropod densities in CA fields decreased with 29% after sowing, and this decrease can obviously not be attributed to tillage effects. The decrease in arthropod densities could be attributed to the disturbance from sowing. The sowing technique in CA is direct drilling. In direct drilling, a false seed bed is formed of shallow rows, by slicing through the mulch layer. However gentle compared to deep tillage, some disturbance from this event is inevitable.

Compared to the mean of 32 carabids pr.m^2 in fields reported by Kromp (1999), all systems in this study had lower carabid densities. Menalled et al. (2007) compared carabids in conventional, no-till and organic experimental field plots. More carabids were found in conventional than in no-tillage and organic plots, but the diversity was more than two times higher in organic and no-tillage plots compared to conventional plots. Of these species, a high proportion of seedeaters was found in no-tillage fields at 32% of the captured carabids compared to 10% in organic and 4% in conventional plots. Menalled et al. (2007) found that the high proportion of seedeaters in the no-tillage system was strongly correlated with the higher removal of weed seeds in the no-tillage plots. These results could point to a higher degree of weed suppression by carabids in no-tillage systems compared to organic and conventional. However, these findings on difference in carabid communities were obtained using pitfall traps, and they have limitations in community analysis because they have the tendency to capture larger rather than smaller species, and because various designs of the pitfall trap yield different results (Kromp 1999). Furthermore, the plots in Menalled et al. (2007) were not CA, but no-tillage plots. Mulching was not used in the no-tillage plots, and it is known how mulch can be important to ground-living arthropods (Wardle et al. 1999) and that the microhabitats derived e.g. from mulch is crucial when recruiting agents in biocontrol (Hajek 2004). CA benefits ground-living arthropods, and spiders in particular, through increased structural complexity, e.g. from mulch, soil cover and soil depressions (which make excellent web sites for linyphiids), a diversity of microclimates (Samu et al. 1999) and high prey availability. As suggested by Jørgensen (2017), there could be increased biocontrol potential in CA fields compared to conventional systems, and perhaps compared to the organic system as well because of the comparable arthropod densities between organic and conventional fields in this study.

Field size and insecticides (2018/2019) were the most important predictors explaining arthropod diversity. As for seed density, field size had a negative relationship with arthropod diversity. Because arthropods are mainly recruited from the field edges, and the edge accounts for a relatively smaller proportion of the larger fields, some arthropods could have trouble reaching the middle of the field. This explanation is supported by a study of Gallé et al. (2019) on functional diversity of spiders and carabids in relation to infield position, in conventional and organic fields. They found primarily ballooning and active hunting spider in the middle of the field, and non-ballooning, larger spiders and web builders in association to the field edges, however this effect was not evident in organic fields. Gallé et al. (2019) found carabid carnivores in association to the midfield, and herbivorous associated to the edge. In relation to the structural complexity in CA fields, it could be that arthropods in CA fields are recruited from edges in a lesser extend because the low disturbance within the field allow for a permanent habitat the whole season. For this reason, it could be interesting to investigate functional diversity of arthropods comparing all three systems.

4.5 Birds, food availability and stubble

Bird densities in organic and conventional fields were comparable, and not significantly different. Furthermore, bird diversity was lowest in organic fields. The fourth hypothesis included the expectation of highest bird densities and diversities in organic and CA fields in the autumn and winter months. CA had the highest average bird densities; two, twelve and twenty-one times higher than organic fields before sowing/tillage, after sowing/tillage and in February respectively. Moreover, the diversity in CA fields was significantly higher than in organic fields. These results rejected the fourth hypothesis.

Comparing food availability for birds in the three agricultural systems in this study, reveal that conventional fields have the lowest availability because density of seeds and arthropods were lowest before and after sowing and tillage. Organic fields definitely had more available weed seeds before sowing and tillage, most likely also during the summer season. After sowing and tillage, similar seed densities were available to birds in organic and CA fields. CA fields did have four times higher arthropod densities than organic fields after sowing and tillage, and this food type could attract species such as house or tree sparrows which were seen predominantly in CA fields. Because many birds have a stronger preference towards seeds in the winter, this food item availability is not likely to explain the differences in bird density and diversity between organic and CA fields. However, comparing grains in organic and CA fields, CA fields did in fact have higher grain densities before and after sowing and tillage. 19.1 spring barley grain pr. m^2 were present in CA, compared to 4.1 spring barley grain pr. m^2 in organic before sowing and tillage. After sowing and tillage, no grains were present in organic fields whereas four grain types were present in CA fields at densities of 0.7 pr. m^2 (spring barley), 1.5 pr. m^2 (wheat), 2.0 pr. m^2 (cereal sp.) and 8.3 pr. m^2 (barley). For these reasons, it is reasonable to assume that the food availability of arthropods and grains in CA fields are greater than in organic and conventional fields. The positive effects of CA on birds and some of their food items found in this study, imply that CA fields have consistent food items available, also during the winter, and that this is some of the explanation for higher densities and diversity of birds in these fields.

Birds only reside in fields in the non-breeding season if resources are present (Newton 2017, chap. 1). Remaining stubble on fields are important particularly to granivorous birds as they tend to prefer these fields, due to more available weed seeds and spilled grain (Wilson et al. 1996, Moorcroft et al. 2002). Additionally, stubble fields are important in predator avoidance particularly for smaller species like passerines, and species relying on crypsis such as the grey partridge (Butler et al. 2005). Gillings et al. (2005) observed farmland bird in summer and winter and found that winter stubble was positively associated with yellowhammer, chaffinch, greenfinch, linnet, skylark and house sparrow. The presence of stubble and mulch on the soil surface could be an explanation for higher density and diversity of birds in CA fields, as these elements are available during the winter months. In comparison, fields using tillage as preparations from winter crop to winter crop in the next cycle, will receive less of the benefits from mulch and stubble on ground-living arthropods and birds because stubbles and mulch are incorporated into the soil during tillage, leaving a bare soil surface.

Bird density and diversity in the winter months, the nonbreeding season, may be very different from density and diversity the breeding season. For this reason, it is not necessarily meaningful to compare results in this study with studies on farmland birds in late spring and summer – the breeding season. The bird findings from this study does therefore not aim to represent bird density and diversity of birds during the whole year. However, winter populations can in fact be relative to summer populations if suitable winter habitats are available (Gillings et al. 2005). For this reason, further studies could include bird observations during the entire season to understand if and how winter and summer populations in CA, organic and conventional fields are related.

Lokemoen and Beiser (1997) compared birds in organic, conventional and minimum-tillage fields in spring, summer and fall in the USA excluding field borders. Passerines had higher hatching success in minimum tillage, compared to organic and conventional fields, and they found a significant negative correlation between nest density and tillage treatment in organic fields. In their study, organic fields were tilled 4.0 times/year, conventional fields were tilled 2.8 times/year and minimum tillage fields were tilled 1.1 times/year, on average. Organic and minimum tillage fields had higher density and diversity of nesting species and nests, and they attributed this to more cover from residuals and to more vegetation cover in fields. Furthermore, they found higher densities of birds in minimum tillage fields in the spring (Lokemoen and Beiser 1997). However, as the mentioned study was carried out in minimum tillage, it can be assumed that the effects of that treatment would be enhanced with CA. Danish transect count data on one CA field and one conventional field over spring and summer revealed more birds and species in CA fields (Wejdling 2018, unpublished). However, edges were included, and so were overflying birds. For these reasons, together with the fact that this study found great variation between CA fields as shown in the PCA (Fig 14), it could be problematic to represent the CA system with only one field. Results from (Hundebøl 2020) covered four pairs of CA and conventional fields in the breeding season, and counted 4.8 times more birds in the CA compared to conventional fields.

4.6 Landscape effects

To discuss the consistent non-significant differences between organic and conventional fields, the landscape heterogeneity effect, which was one of the three most important factors explaining bird density, must also be included. In this study, landscape heterogeneity was scored in a very simple way. Landscape scores had unequally distribution amongst systems. CA had the highest scores, conventional intermediate and organic had the lowest scores. There was no distinction between quality of landscape elements, e.g. a hedgerow and a body of water received the same score. In Canada, Freemark and Kirk (2001) found that more bird species were associated with high heterogeneity between farms, e.g. the edge heterogeneity, than species associated to low heterogeneity. Additionally, species like yellowhammer and tree sparrow are dependent on shrubby landscape features e.g. hedgerows for nesting, and high densities of birds in farmland are generally associated with edge habitats, like hedgerows, and other landscape features (Newton 2017). In the review by Benton et al. (2003), habitat heterogeneity in the agricultural landscape within fields, and between fields, farms and regions was emphasized as strongly associated with high farmland biodiversity. They advocated for a stronger focus on restoring and promoting habitat heterogeneity, compared to focusing on specific treatments or agricultural systems. Furthermore, Benton et al. (2003) asked the question whether the beneficial effects from organic farming on farmland biodiversity can be attributed to the increased integrated habitat heterogeneity associated with this type of farming and not the absence of agrochemicals.

If the landscape heterogeneity is a significant contribution to the effects usually attributed to the organic system, then this could be an explanation for the lack of difference between the organic and conventional systems in this study. The reason being, that the distribution of landscape scores was highest in CA, intermediate in conventional and lowest in organic. This is exactly the observed pattern between systems for bird density and diversity: highest density and diversity in CA, intermediate in conventional and lowest in organic. It could be possible that landscape heterogeneity in this study evens out the differences in conventional and organic fields regarding bird densities, and is part of the explanation of the high bird density and diversity in CA. In accordance with this, Batáry et al. (2010) found a stronger, significant and positive effect of hedge length on farmland bird species richness and abundance in wheat fields and meadows, than of the system, whether organic or conventional, in the breeding season. They did also observe more birds and species in organic plots, and these observations were mainly in hedgerows. For this reason, distinction between landscape elements in or bordering the field could be a very important addition in this study, just like hedgerow length and, as discussed by Batáry et al. (2010), height and thickness of hedgerows. In addition, the fact that a very simple representation of landscape heterogeneity was significant in this study, points to the key importance of including landscape effects in studies regarding farmland biodiversity. It is likely, that landscape effects could explain at least some of the remaining unexplained 48% variation in the PCA.

The fact that simple proxy for landscape heterogeneity was one of the most important factors explaining birds in this study highlight the importance of including landscape effects in future studies. It could be that including landscape elements and landscape heterogeneity, also the heterogeneity in the field, in greater detail together with agricultural systems and treatment could identify the relative importance of landscape on farmland biodiversity.

4.7 Conventional agriculture and agricultural intensity

In this study, conventional fields did not have consistently lower densities and diversity of seeds, arthropods and birds. Seed densities were lowest in conventional fields before and after sowing/tillage, but the seed diversity was comparable between CA and conventional fields, even though the difference was non-significant. Arthropod densities were lowest in conventional fields, but there was no significant difference between conventional and organic fields. Arthropod diversity was lowest in conventional fields, but the difference was not significant. Bird density in conventional was comparable to organic, and more bird species were observed in conventional fields than in organic. The fifth and final hypothesis in this study was the expectation of lowest densities and diversities of all three groups in conventional fields compared to organic and CA fields. For the reasons mentioned above, this hypothesis was rejected.

One explanation of the similarity of organic and conventional fields in terms of bird density and diversity and arthropod densities could be the landscape effects mentioned in the previous section. In addition to this Kirk et al. (2020) found support for stronger positive effects of organic farming on birds when the surrounding agricultural landscape was managed intensively, and less strong effect of organic farming if the landscape was managed more extensively. Agricultural intensity was not evaluated in this thesis, and it could be that the five conventional fields in question are managed less intensively, and that the landscape effects on these fields also resulted in a more positive response by birds. Measures of agricultural intensity could be included in future studies to investigate this unexpected result of no difference between these two systems.

4.8 Pesticide effects

The point on pesticide application, agricultural systems and the time of year mentioned in the beginning of this chapter will be reviewed here. As mentioned, tillage is the main treatment during the months were this study was carried out, because pesticides are usually applied in the spring, and it was therefore assumed that the pesticide effects are mostly indirect. This was the case because pesticide application from the previous crop cycle (2018/2019) had significant effects on seed density and arthropod diversity. However, pesticides were in fact also applied by CA farmers in the autumn. Three CA farmers had already applied herbicides in the autumn, before the sampling from after sowing/tillage was carried out, and one farmer planned to apply later in the autumn. The autumn herbicide application from the three farmers could explain the average seed density decrease of 13% from before sowing to after, and why the herbicide application (2019/2020) significantly affected seed densities. Additionally, three CA farmers had plans of applying herbicides again in the spring, one also planned to apply insecticides here, and four planned to apply fungicides in May or June. Thus, pesticides were not as "out of season" as expected. The fact that pesticides significantly affected all three groups in the winter season further emphasizes the importance on including pesticide effects in studies on farmland biodiversity.

Pesticides were consistently removed in the model selections when agricultural system or tillage were present as significant variables. The negative effects of pesticides on farmland biodiversity are indisputable (Geiger et al. 2010), but in this study, tillage was identified as the most detrimental treatment in the winter season. Perhaps this pattern would change if this study also included density and diversity of the three groups together with detailed pesticide information. As an example of changing patterns over the season, Hald (1999) compared the species density of weed flora in conventional fields in the spring, before the herbicide application, with organic fields in summer. In this study, significant differences were evident from late summer to autumn, and Hald (1999) reported a decrease in conventional fields of two thirds from spring to summer after herbicide application. Thus, spring densities in organic fields compared to conventional fields in the summer. The measures of pesticides in this project were simple, as only presence or absence of herbicides, fungicides and insecticides were accounted for. More detailed information on pesticides could have been used, such as frequency of application and applied amounts of active ingredients, which both had significant effects on number of plant, carabid and breeding bird species in Geiger et al. (2010). It could be interesting to compare effects of pesticides to effects of tillage on farmland biodiversity, based on detailed information on both treatments from a whole season.

Use of pesticides for this cropping season (2019/2020) and for the previous season (2018/2019) were both included as predictors of seeds, arthropods and birds. Negative effects from the pesticide use in the previous cropping season were found for seed densities (herbicides and fungicides) and arthropod diversity (insecticides and fungicides), and no effects were recorded for pesticide application in this cropping season for these groups. This is most likely due to the fact, that samplings of seeds and arthropods took place before the application of eventual pesticides.

Insecticide use in the previous crop cycle had a negative effect on arthropod diversity and was the explanatory variable together with field size. Insecticide application has direct effects on arthropods, but those of fungicides could be more indirect. Collembola feed mainly on microorganisms like fungal hyphae (Neher 1999) and for this reason, fungicide application could affect collembola density and diversity, and in turn the other meso-predator species feeding on them. In this study, fungicide application in the 2019/2020 cropping season was positively correlated with bird diversity. Birds are traditionally negatively affected by pesticides like fungicides, as mentioned by Boatman et al. (2004) and found by Geiger et al. (2010) for breeding bird species. However, the explanation of positive correlation between bird diversity and fungicide application could be non-causal, because CA fields have high bird densities to begin with and it was predominantly the CA farmers who used fungicides during this cropping season. As for both types of fertilizer, fungicide application could reflect the high bird diversity in CA.

4.9 Seasons and crop rotation

Crop rotation order has proven a small, but important determinant for arthropod communities in organic and conventional fields. Patterson et al. (2019) investigated the response of functional arthropod diversity in a field setup of crop rotations in a half split 8-year organic with five crops and 5-year conventional with three crops. They found small but significant “lag effects” from crops in the previous years on the arthropod community, but the current crop had the strongest effect. The previous crop type was important to skylark, linnet, wood pigeon, reed bunting and corn bunting in fallow stubble fields, because it affected the weed composition in the stubble (Moorcroft et al. 2002). These findings could have implications for this study, as crop rotations, and possible cover crops, from previous years were not included. Because the samplings were carried out shortly after harvest, in the beginning of the next cropping cycle, lag effects from the previous crop could affect the species densities of seeds, arthropods and birds.

Changing seasons from late summer to autumn was not accounted for in this thesis. It would have been possible to test for effects of sampling dates in each field and to include climate variables such as temperature and precipitation for the sampling dates. Furthermore, samplings along time gradients in each system would have been ideal to capture the changes over an entire crop cycle with the same crop for seeds, arthropods and birds. This was the motivation for the third bird observation in February, to see if patterns between systems change over time. The pattern did not change: the same number of species were recorded, even though they were different, and densities had the same pattern as previously observed, with most birds in CA and similar lower densities for organic and conventional fields. The fact that Lokemoen and Beiser (1997) found more birds in the spring in minimum tillage, and that this study found higher densities and diversity in CA for winter and February could point to these fields being attractive in winter months, as previously discussed. Chamberlain et al. (2010) found significantly higher densities of bird in the winter in organic fields compared to conventional, but they conclude that the habitat around, and infield, is a better predictor for birds and that organic fields could have limited resources for birds in the winter. The February count in this study found 0.08 birds pr. ha in conventional fields and 0.11 birds pr. ha in organic, thus a slight but not significant difference. Furthermore, density in organic fields increased slightly from autumn to February from 0.08 to 0.11 pr. ha and decreased in the same period from 0.66 to 0.08 pr. ha in conventional fields.

Species composition of birds change over the year, and it could have been very interesting to compare winter bird density and diversity with observations in the breeding season. On that note, it could be interesting for future studies to carry out bird observations, and samplings of arthropods and birds in an entire season, from harvest to harvest, for all three systems, to investigate seasonal changes in densities and diversities from summer to summer. There will inevitably be a massive change happening in the field from autumn to summer because of the pronounced differences in densities and diversities of all three groups. When these supposed differences are most prominent during the season could have important management implications for biodiversity conservation in farmland. The large differences in densities of seeds, arthropods and birds before and after sowing/tillage emphasize that the agroecosystem is remarkably resilient, e.g. the ability to recover from disturbances, despite continuous intensive treatments to increase crop productivity.

4.10 Perspectives

Two opposing views, the “land-sharing” and “land-sparing” views, are prominent in the debate on the quest for finding the best management and conservation support system for biodiversity in farmland. Here, the sparing viewpoint is on the separation of agriculture and nature conservation e.g. sparing land to biodiversity, or the accomplishment of both agendas in the farmland, e.g. sharing land with biodiversity (Kremen 2015). Management suggestions on biodiversity in agricultural land in Denmark advice both sparing and sharing initiatives. As examples, sparing initiatives are set-aside land and protections of small landscape elements such as hedges to provide invaluable habitats in the agricultural landscape. Examples of sharing initiatives are reducing pesticides and tillage (Ejrnæs et al. 2019). The latter are in accordance with the results in this study. The results from this study show, that sharing land with biodiversity through less usage, or complete absence of, tillage and pesticides have significant positive effects on farmland biodiversity. The midfield can indeed support considerable densities and species of plants, arthropods and birds. Bearing in mind that the midfield is inevitably the largest proportion of the farm, every little positive influence on biodiversity here, is a win. Reducing, or even ceasing, tillage in conventional cereal fields could provide increased support for plants and arthropods resulting in food availability for farmland birds in the crucial winter months. To support the birds even more, crop rotations should also focus on spring crop cereals, and fallowing fields in the winter, leaving stubbles or short vegetation for ground nesting birds.

Combining the benefits for biodiversity from the absence of tillage and pesticides known from organic and CA systems, seems an obvious solution. However, marrying these two systems proves a great challenge. While crop rotations, mulching and the use of cover crops are a joint focus in organic and CA, reducing tillage in organic fields is a great challenge. Water loss due to tillage in organic fields is a major issue in organic farming in water limited areas, like the Northern Great Plains (Lehnhoff et al. 2017). However, advancements in reduced tillage farming in organic systems are evident: In Europe, equipment and new methods for tackling the challenges with weeds are being developed, and experiments to gain knowledge of the reduced and no-tillage treatments to organic farming are ongoing (Mäder and Berner 2012). In their study comparing functional diversity in conventional and organic fields, Patterson et al. (2019) found less epigeal predators in the organic fields with the highest soil disturbance from tillage, compared to organic fields with a lower tillage intensity. Yet, lower yields and increased weed abundance are still challenges to overcome in order for organic reduced tillage systems to work (Lehnhoff et al. 2017). In Denmark, few organic farmers are adopting and experimenting with reduced tillage (Nielsen 2019), but the challenges are still prominent. A study on biodiversity in fields of organic reduced tillage system, traditional organic, CA and conventional systems in the future could investigate the effects of reduced tillage in organic systems.

5 Conclusion

In this study, agricultural systems explained 52% of the variance found in the density and diversity of seeds in the topsoil, ground-living arthropods and birds in fields. Substantial positive, and significant, effects of CA were found on arthropod and bird densities, and on bird diversity. CA had four to five times higher arthropod densities in the autumn. It was expected that CA and organic fields had comparable bird diversity and density, but this was not the case. CA had two, four- and twenty-one-times higher bird densities in late summer, autumn and February respectively. Unexpectedly, organic and conventional fields was grouped opposite of CA, due to the non-significant difference between them. For seed densities, the average density in organic fields dropped 92% as the result of tillage, leaving comparable seed densities in organic and CA fields after this event. The strong positive effect from CA in the winter months was attributed largely to the absence of tillage. The absence of tillage positively, and significantly, affected the densities of seeds, arthropods and birds and landscape effects was a significant predictor of bird densities. These results are obtained in the late summer to winter months and does therefore not include the breeding season of farmland birds.

Future studies of organic, organic with reduced tillage, conventional and CA fields throughout the whole crop rotation, including landscape and pesticide details, could provide further evidence on how agricultural management affects farmland biodiversity. For now, implementing reduced, or even absence, of tillage could provide better support for farmland biodiversity through habitats and food resource availability.

References

Agustí, N. et al. 2003. Collembola as alternative prey sustaining spiders in arable ecosystems: Prey detection within predators using molecular markers. - Mol. Ecol. 12: 3467–3475.

Andersen, L. W. et al. 2014. Øger økologisk landbrug biodiversiteten? Hovedkonklusioner fra REFUGIA-projektet. - ICROFS nyt: 1–17.

Andreasen, C. and Stryhn, H. 2008. Increasing weed flora in Danish arable fields and its importance for biodiversity. - Weed Res. 48: 1–9.

Andreasen, C. et al. 1996. Decline of the Flora in Danish Arable Fields. - Br. Ecol. Soc. 33: 619–626.

Andreasen, C. et al. 2018. Decreasing diversity in the soil seed bank after 50 years in Danish arable fields. - Agric. Ecosyst. Environ. 259: 61–71.

Axelsen, J. A. and Kristensen, K. T. 2000. Collembola and mites in plots fertilised with different types of green manure. - Pedobiologia (Jena). 44: 556–566.

Baessler, C. and Klotz, S. 2006. Effects of changes in agricultural land-use on landscape structure and arable weed vegetation over the last 50 years. - Agric. Ecosyst. Environ. 115: 43–50.

Baines, M. et al. 1998. The effects of arable field margin management on the abundance and species richness of Araneae (spiders). - Ecography (Cop.). 21: 74–86.

Bàrberi, P. et al. 2010. Functional biodiversity in the agricultural landscape: Relationships between weeds and arthropod fauna. - Weed Res. 50: 388–401.

Barré, K. et al. 2018. Weed control method drives conservation tillage efficiency on farmland breeding birds. - Agric. Ecosyst. Environ. 256: 74–81.

Batáry, P. et al. 2010. Landscape-moderated importance of hedges in conserving farmland bird diversity of organic vs. conventional croplands and grasslands. - Biol. Conserv. 143: 2020–2027.

Beare, M. H. et al. 1994. Aggregate-Protected and Unprotected Organic Matter Pools in Conventional- and No-Tillage Soils. - Soil Sci. Soc. Am. J. 58: 787–795.

Beecher, N. A. et al. 2002. Agroecology of birds in organic and nonorganic farmland. - Conserv. Biol. 16: 1620–1631.

Bengtsson, J. et al. 2005. The effects of organic agriculture on biodiversity and abundance: A meta-analysis. - J. Appl. Ecol. 42: 261–269.

Benton, T. G. et al. 2003. Farmland biodiversity: Is habitat heterogeneity the key? - Trends Ecol. Evol. 18: 182–188.

Bilde, T. et al. 2000. The value of Collembola from agricultural soils as food for a generalist predator. - J. Appl. Ecol. 37: 672–683.

Biodiversity Information System for Europe Cropland and grassland.

Boatman, N. D. et al. 2004. Evidence for the indirect effects of pesticides on farmland birds. - Ibis (Lond. 1859). 146: 131–143.

Boelt, B. et al. 2011. Ukrudtsbogen (P Kudsk and JB Jespersen, Eds.). - Aarhus Universitet.

Boutin, C. et al. 2014. Herbicide impact on non-target plant reproduction: What are the toxicological and ecological implications? - Environ. Pollut. 185: 295–306.

Braae, L. et al. 1988. Fuglefaunaen på konventionelle og økologiske landbrug. Sammenlignende undersøgelser af fuglefaunaen, herunder virkningen af bekæmpelsesmidler. Miljøprojekt nr.102.

Buhler, D. D. 1995. Influence of tillage systems on weed population dynamics and management in corn and soybean in the Central USA. - Crop Sci. 35: 1247–1258.

Burnham, K. P. and Anderson, D. R. 2004. Multimodel inference: Understanding AIC and BIC in model selection. - Sociol. Methods Res. 33: 261–304.

Butler, S. J. et al. 2005. Stubble height affects the use of stubble fields by farmland birds. - J. Appl. Ecol. 42: 469–476.

Chamberlain, D. E. et al. 2000. Changes in the Abundance of Farmland Birds in Relation to the Timing of Agricultural Intensification in England. - J. Appl. Ecol. 37: 771–788.

Chamberlain, D. E. et al. 2010. Does organic farming benefit farmland birds in winter? - Biol. Lett. 6: 82–84.

Chauhan, B. S. et al. 2012. Ecology and management of weeds under conservation agriculture: A review. - Crop Prot. 38: 57–65.

Chen, B. and Wise, D. H. 1999. Bottom-Up Limitation of Predaceous Arthropods in a Detritus-Based Terrestrial Food Web. - Ecology 80: 761.

Costanzo, A. and Bàrberi, P. 2014. Functional agrobiodiversity and agroecosystem services in sustainable wheat production. A review. - Agron. Sustain. Dev. 34: 327–348.

Cunningham, H. M. 2004. The effect of non-inversion tillage on farmland birds , soil and surface-active invertebrates and surface seeds.

Cunningham, H. M. et al. 2004. Non-inversion tillage and farmland birds: A review with special reference to the UK and Europe. - Ibis (Lond. 1859). 146: 192–202.

Cunningham, H. M. et al. 2005. Effect of non-inversion tillage on field usage by UK farmland birds in winter. - Bird Study 52: 173–179.

Danmarks statistik 2020. AFG5: Det dyrkede areal efter område, enhed og afgrøde.

Derrouch, D. et al. 2020. Weed Management in the Transition to Conservation Agriculture: Farmers' Response. - Agronomy in press.

Donald, P. F. et al. 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. - Proc. R. Soc. B Biol. Sci. 268: 25–29.

Ejrnæs, R. et al. 2011. Danmarks biodiversitet 2010 - status, udvikling og trusler.

Ejrnæs, R. et al. 2019. Virkemiddelkatalog for Natur. De vigtigste mål i biodiversitetsforvaltningen og deres tilhørende virkemidler. - Aarhus Universitet.

Emmerson, M. et al. 2016. How Agricultural Intensification Affects Biodiversity and Ecosystem Services. - In: Advances in Ecological Research. Academic Press Inc., pp. 43–97.

Eraud, C. et al. 2015. Weed seeds, not grain, contribute to the diet of wintering skylarks in arable farmlands of Western France. - Eur. J. Wildl. Res. 61: 151–161.

Eskildsen, D. P. et al. 2020. Overvågning af de almindelige fuglearter i Danmark 1975-2019. Årsrapport for Punkttællingsprogrammet. Dansk Ornitologisk Forening.

Eurostat 2018. Agriculture, forestry and fishery statistics - 2018 Edition.

Everts, J. W. et al. 1989. Side-effects of pesticides on ground-dwelling predatory arthropods in arable ecosystems. - Environ. Pollut. 59: 203–225.

Ewald, J. A. et al. 2015. Influences of extreme weather, climate and pesticide use on invertebrates in cereal fields over 42 years. - Glob. Chang. Biol. 21: 3931–3950.

FAO/WHO 1999. Organic Agriculture.

FAO 2005. Building on Gender, Agrobiodiversity and Local Knowledge.

FAO 2017. Conservation agriculture. 66: 1–2.

FiBL and IFOAM 2020. The World of Organic Agriculture (H Willer, B Schlatter, J Trávnícek, L Kemper, and J Lernoud, Eds.). - Organics International.

Freemark, K. E. and Kirk, D. A. 2001. Birds on organic and conventional farms in Ontario: Partitioning effects of habitat and practices on species composition and abundance. - Biol. Conserv. 101: 337–350.

Gallé, R. et al. 2019. Landscape configuration, organic management, and within-field position drive functional diversity of spiders and carabids. - J. Appl. Ecol. 56: 63–72.

Geiger, F. et al. 2010. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. - Basic Appl. Ecol. 11: 97–105.

Gillings, S. and Fuller, R. J. 2001. Habitat selection by skylarks alauda arvensis wintering in Britain in 1997/98. - Bird Study 48: 293–307.

Gillings, S. et al. 2005. Winter availability of cereal stubbles attracts declining farmland birds and positively influences breeding population trends. - Proc. R. Soc. B Biol. Sci. 272: 733–739.

Głab, T. and Kulig, B. 2008. Effect of mulch and tillage system on soil porosity under wheat (Triticum aestivum). - Soil Tillage Res. 99: 169–178.

Gliessman, S. R. 2015. Agroecology: the ecology of sustainable food systems (EW Engles, Ed.). - CRC Press.

Hajek, A. E. 2004. Natural Enemies - An Introduction To Biological Control. - Cambrigde University Press.

Hald, A. B. 1999. Weed vegetation (wild flora) of long established organic versus conventional cereal fields in Denmark. - Ann. Appl. Biol. 134: 307–314.

Hald, A. and Reddersen, J. 1990. Fuglefóde i kornmarker - insekter og vilde planter. - Miljøministeriet: 5–108.

Heldbjerg, H. et al. 2018. Continuous population declines for specialist farmland birds 1987-2014 in Denmark indicates no halt in biodiversity loss in agricultural habitats. - Bird Conserv. Int. 28: 278–292.

Hobbs, P. R. et al. 2008. The role of conservation agriculture in sustainable agriculture. - Philos. Trans. R. Soc. B Biol. Sci. 363: 543–555.

Hole, D. G. et al. 2005. Does organic farming benefit biodiversity? - Biol. Conserv. 122: 113–130.

Holland, J. M. 2004. The environmental consequences of adopting conservation tillage in Europe: Reviewing the evidence. - Agric. Ecosyst. Environ. 103: 1–25.

Holland, J. M. and Luff, M. L. 2000. The effects of agricultural practices on Carabidae in temperate agroecosystems. - Integr. Pest Manag. Rev. 5

Holland, J. M. et al. 2006. A review of invertebrates and seed-bearing plants as food for farmland birds in Europe. - Ann. Appl. Biol. 148: 49–71.

Holstrup, G. et al. 2017. Sådan ligger landet - tal om landbruget 2017.: 45.

Hundebøl, N. R. G. 2020. Arthropods as food items for farmland birds in no tillage farming.

Ingram, E. R. et al. 2000. Soil Biology Primer. - United States Dep. Agric.: 48.

Jørgensen, T. H. 2017. Can Reduced Tillage in Spring Barley (Hordeum vulgare, L.) Fields Lead to a Higher Density of Beneficial Predators and thereby a Natural Regulation of Insect Pests?

Kassam, A. et al. 2019. Global spread of Conservation Agriculture. - Int. J. Environ. Stud. 76: 29–51.

Kladivko, E. J. 2001. Tillage systems and soil ecology. - Soil Tillage Res. 61: 61–76.

Kremen, C. 2015. Reframing the land-sparing/land-sharing debate for biodiversity conservation. - Ann. N. Y. Acad. Sci. 1355: 52–76.

Kromp, B. 1999. Carabid beetles in sustainable agriculture: a review on pest control efficacy, cultivation impacts and enhancement. - Invertebr. Biodivers. as Bioindic. Sustain. Landscapes 74: 187–228.

Landbrugsstyrelsen 2019. Statistik over økologiske jordbrugsbedrifter 2019. Autorisation & produktion. - Miljø- og Fødevareministeriet. Landbrugsstyrelsen.

Lavelle, P. et al. 1995. Mutualism and biodiversity in soils. - Plant Soil 170: 23–33.

Lehnhoff, E. et al. 2017. Organic agriculture and the quest for the holy grail in water-limited ecosystems: Managing weeds and reducing tillage intensity. - Agric. 7: 1–16.

Levin, G. and Normander, B. 2008. Arealanvendelse i Danmark siden slutningen af 1800-tallet. - Fagl. Rapp. fra DMU

Lokemoen, J. T. and Beiser, J. A. 1997. Bird Use and Nesting in Conventional, Minimum-Tillage, and Organic Cropland. - J. Wildl. Manage. 61: 644–655.

Lövei, G. L. and Sunderland, K. D. 1996. Ecology and behaviour of ground beetles (Coleoptera: Carabidae). - Annu. Rev. Entomol. Vol. 41: 231–256.

Mäder, P. and Berner, A. 2012. Development of reduced tillage systems in organic farming in Europe. - Renew. Agric. Food Syst. 27: 7–11.

Marshall, E. J. . 1989. Distribution Patterns of Plants Associated with Arable Field Edges. - J. Appl. Ecol. 26: 247–257.

Marshall, E. J. P. et al. 2003. The role of weeds in supporting biological diversity within crop fields. - Weed Res. 43: 77–89.

Matson, P. A. et al. 1997. Agricultural intensification and ecosystem properties. - Science (80-.). 277: 504–509.

McLaughlin, A. and Mineau, P. 1995. The impact of agricultural practices on biodiversity. - Agric. Ecosyst. Environ. 55: 201–212.

Meeus, J. H. A. 1993. The transformation of agricultural landscapes in Western Europe. - Sci. Total Environ. 129: 171–190.

Menalled, F. D. et al. 2001. Weed aboveground and seedbank community responses to agricultural management systems. - Ecol. Appl. 11: 1586–1601.

Menalled, F. D. et al. 2007. Impact of agricultural management on carabid communities and weed seed predation. - Agric. Ecosyst. Environ. 118: 49–54.

Moeslund, J. E. et al. 2019. Den danske Rødliste 2019.

Møller, A. P. 2019. Parallel declines in abundance of insects and insectivorous birds in Denmark over 22 years. - Ecol. Evol. 9: 6581–6587.

Moorcroft, D. et al. 2002. The selection of stubble fields by wintering granivorous birds reflects vegetation cover and food abundance. - J. Appl. Ecol. 39: 535–547.

Moreby, S. J. and Sotherton, N. W. 1997. A Comparison of Some Important Chick-Food Insect Groups Found in Organic and Conventionally-Grown Winter Wheat Fields in Southern England. - Biol. Agric. Hortic. 15: 51–60.

Moshøj, C. . et al. 2019. Overvågning af de almindelige fuglearter i Danmark 1975-2018. Årsrapport for Punkttællingsprogrammet. Dansk Ornitologisk Forening.

Navntoft, S. et al. 2006. Effects of reduced pesticide dosages on carabids (Coleoptera: Carabidae) in winter wheat. - Agric. For. Entomol. 8: 57–62.

Neher, D. A. 1999. Soil community composition and ecosystem processes Comparing agricultural ecosystems with natural ecosystems.: 159–185.

Newton, I. 2017. Farming and Birds (SA Corbert, D Streeter, J Flegg, J Silvertown, and B Short, Eds.). - HarperCollins Publishers.

Nichols, V. et al. 2015. Weed dynamics and conservation agriculture principles: A review. - F. Crop. Res. 183: 56–68.

Nielsen, J. A. 2019. Kan Conservation Agriculture og økologisk landbrug kombineres? - Momentum+ 4: 21–23.

Oerke, E. C. 2006. Crop losses to pests. - J. Agric. Sci. 144: 31–43.

Patterson, E. S. P. et al. 2019. Soil tillage reduces arthropod biodiversity and has lag effects within organic and conventional crop rotations. - J. Appl. Entomol. 143: 430–440.

Petit, S. et al. 2017. Interactions between conservation agricultural practice and landscape composition promote weed seed predation by invertebrates. - Agric. Ecosyst. Environ. 240: 45–53.

Pfiffner, L. and Niggli, U. 1996. Effects of Bio-dynamic, Organic and Conventional Farming on Ground Beetles (Col. Carabidae) and Other Epigaeic Arthropods in Winter Wheat. - Biol. Agric. Hortic. 12: 353–364.

Ramakrishna, A. et al. 2006. Effect of mulch on soil temperature, moisture, weed infestation and yield of groundnut in northern Vietnam. - F. Crop. Res. 95: 115–125.

Ratcliffe, D. A. 1970. Changes Attributable to Pesticides in Egg Breakage Frequency and Eggshell Thickness in Some British Birds. - J. Appl. Ecol. 7: 67–115.

Robinson, R. A. et al. 2001. The importance of arable habitat for farmland birds in grassland landscapes. - J. Appl. Ecol. 38: 1059–1069.

Samu, F. et al. 1999. Scale-Dependent Dispersal and Distribution Patterns of Spiders in Agricultural Systems. - J. Arachnol. 27: 325–332.

Segberg, O. et al. 2012. Dansk flora. - Gyldendal.

Seibold, S. et al. 2019. Arthropod decline in grasslands and forests is associated with landscape-level drivers. - Nature 574: 671–674.

Stenberg, L. and Mossberg, B. 2005. Den nye nordiske flora. - Gyldendal.

Storkey, J. et al. 2012. The impact of agricultural intensification and land-use change on the European arable flora. - Proc. R. Soc. B Biol. Sci. 279: 1421–1429.

Stougaard, K. and Filsø, S. S. 2019. Conservation Agriculture i Praksis. - SEGES 66

Sunderland, K. D. 1975. The Diet of some Predatory Arthropods in Cereal Crops. - Br. Ecol. Soc. 12: 507–515.

Sunderland, K. 1999. Mechanisms Underlying the Effects of Spiders on Pest Populations. - J. Arachnol. 27: 308–316.

Sunderland, K. D. et al. 1986. Field and Laboratory Studies on Money Spiders (Linyphiidae) as Predators of Cereal Aphids. - J. Appl. Ecol. 23: 433.

Thorbeck, P. and Bilde, T. 2004. Reduced numbers of generalist arthropod predators after crop management. - J. Appl. Ecol. 41: 526–538.

Trichard, A. et al. 2014. The spatio-temporal distribution of weed seed predation differs between conservation agriculture and conventional tillage. - Agric. Ecosyst. Environ. 188: 40–47.

Tscharntke, T. et al. 2005. Landscape perspectives on agricultural intensification and biodiversity - Ecosystem service management. - Ecol. Lett. 8: 857–874.

Tuck, S. L. et al. 2014. Land-use intensity and the effects of organic farming on biodiversity: A hierarchical meta-analysis. - J. Appl. Ecol. 51: 746–755.

Vickery, J. A. et al. 2009. Arable field margins managed for biodiversity conservation: A review of food resource provision for farmland birds. - Agric. Ecosyst. Environ. 133: 1–13.

Wardle, D. A. et al. 1999. Effects of agricultural intensification on soil-associated arthropod population dynamics, community structure, diversity and temporal variability over a seven-year period. - Soil Biol. Biochem. 31: 1691–1706.

Wejdling, H. 2018. Fugles præferencer for pløjefri.

Wilson, J. D. et al. 1996. Field use by farmland birds in winter: An analysis of field type preferences using resampling methods. - Bird Study 43: 320–332.

Wilson, J. D. et al. 1997. Territory Distribution and Breeding Success of Skylarks Alauda arvensis on Organic and Intensive Farmland in Southern England. - J. Appl. Ecol. 34: 1462–1478.

Wilson, J. D. et al. 1999. A review of the abundance and diversity of invertebrate and plant foods of granivorous birds in northern Europe in relation to agricultural change. - Agric. Ecosyst. Environ. 75: 13–30.

6 Appendix

6.1 Field data

Table 29 Field data on density and diversity of seeds, arthropods and birds. Blank space indicates no findings.

Agricultural system	**ID**	**Sampling time**	**Seed diversity**	**Seed density**	**Arthropod diversity**	**Arthropod density**	**Bird diversity**	**Bird density**
Organic	Ø1	Before	1,34	5401,85	2,30	46,32	0,64	0,29
Organic	Ø2	Before	1,76	1526,85	2,27	91,07		
Organic	Ø3	Before	2,09	952,78	2,17	79,29	0,90	2,75
Organic	Ø4	Before	1,80	2638,89	2,23	89,50		1,86
Organic	Ø5	Before	2,01	4321,30	1,57	115,40		
Conventional	K1	Before	1,81	273,15	1,25	172,71	0,50	1,29
Conventional	K2	Before	1,94	32,41	1,99	23,55	1,08	0,95
Conventional	K3	Before	0,66	1008,33	1,73	66,73	0,69	0,67
Conventional	K4	Before	1,90	296,30	1,09	36,11		1,20
Conventional	K5	Before			2,10	73,79	0,97	0,54
CA	CA1	Before	1,66	600,00	2,18	109,12	0,96	1,13
CA	CA2	Before	2,33	323,15	2,22	109,91	0,88	4,09
CA	CA3	Before	1,91	150,93	1,73	80,86	0,67	1,64
CA	CA4	Before	1,55	207,41	1,55	142,88	1,22	1,54
CA	CA5	Before	2,33	274,07	2,08	116,19	0,94	2,45
Organic	Ø1	After	1,40	183,33	1,30	15,70	0,81	0,38
Organic	Ø2	After	2,22	266,67	1,56	4,71		
Organic	Ø3	After	2,27	305,56	1,94	17,27		
Organic	Ø4	After	2,14	99,07	1,72	32,97		
Organic	Ø5	After	2,06	292,59	2,07	17,27		
Conventional	K1	After	1,98	52,78	1,51	36,11	0,44	0,38
Conventional	K2	After	1,76	54,63	1,82	10,99	0,18	0,66
Conventional	K3	After	1,65	118,52	1,41	10,21		
Conventional	K4	After	1,70	22,22	1,64	25,12		
Conventional	K5	After			1,70	7,85	0,28	2,24
CA	CA1	After	1,62	410,19	1,71	99,70		
CA	CA2	After	2,03	119,44	2,15	105,20	0,53	0,29
CA	CA3	After	1,64	368,52	1,79	48,67	0,60	2,96
CA	CA4	After	1,11	312,04	1,45	79,29	0,93	5,40
CA	CA5	After	2,04	150,93	2,14	67,51	0,19	0,08
Organic	Ø1	Feb						
Organic	Ø2	Feb						
Organic	Ø3	Feb					0,14	0,05
Organic	Ø4	Feb					1,26	0,50
Organic	Ø5	Feb						

Conventional	K1	Feb		
Conventional	K2	Feb	0,18	0,05
Conventional	K3	Feb		
Conventional	K4	Feb		
Conventional	K5	Feb	0,50	0,34
Conservation agriculture	CA1	Feb		
Conservation agriculture	CA2	Feb	1,07	0,58
Conservation agriculture	CA3	Feb	0,95	0,49
Conservation agriculture	CA4	Feb	1,37	2,94
Conservation agriculture	CA5	Feb	0,50	3,08

Table 30 Treatments and landscape information.

Agricultural system	ID	Tillage	Tillage depth	Fertilizer type	N pr. ha	Mulch	Field size	Landscape score	Landscape description
Organic	Ø1	yes	17	Organic	180	yes	11	2	Hedgerows, remise
Organic	Ø2	yes	22	Organic	65	yes	2	2	Hedgerows, forest
Organic	Ø3	yes	24	Organic	150	yes	21	2	Remise, waterhole
Organic	Ø4	yes	27	Organic	180	yes	10	1	Hedgerows
Organic	Ø5	yes	24	Organic	135	yes	3	1	Hedgerows
Conventional	K1	yes	22	Inorganic	45	no	45	3	Hedgerows, waterhole, plantation
Conventional	K2	yes	25	Both	155	no	21	1	Remise
Conventional	K3	yes	20	Both	170	no	3	2	Hedgerows, sea
Conventional	K4	yes	25	Inorganic	121	no	30	1	Hedgerows
Conventional	K5	yes	20	Inorganic	160	no	15	1	Remise
CA	CA1	no		Inorganic	190	no	8	2	Forest, housing
CA	CA2	no		Both	180	no	3	2	Shrubs, housing
CA	CA3	no		Both	172	yes	6	2	Remise,waterhole
CA	CA4	no		Both	229	yes	28	4	Hedgerows, stream, remise, waterhole
CA	CA5	no		Both	177	yes	18	3	Hedgerows, stream, remise

Table 31 Pesticide application in 2018/2019 and 2019/2020.

Agricultural system	ID	Herbicide 18/19	Fungicide 18/19	Insecticide 18/19	Herbicide 19/20	Fungicide 19/20	Insecticide 19/20
Organic	Ø1	no	no	no	no	no	no
Organic	Ø2	no	no	no	no	no	no
Organic	Ø3	no	no	no	no	no	no
Organic	Ø4	no	no	no	no	no	no
Organic	Ø5				no	no	no
Conventional	K1	yes	yes	no	yes	no	no
Conventional	K2	yes	yes	no	yes	no	no
Conventional	K3	yes	yes	yes	yes	yes	yes
Conventional	K4	yes	yes	yes	yes	no	no
Conventional	K5	yes	no	no	yes	no	no
CA	CA 1	yes	yes	no	yes	yes	yes
CA	CA 2	yes	yes	no	yes	no	no
CA	CA 3	yes	yes	no	no	yes	no
CA	CA 4	yes	yes	yes	yes	yes	no
CA	CA 5	yes	no	no	yes	yes	no

*Table 32 Dates of field trips, harvest and sowing. For K4, ** is tillage dates, sowing was in April. * only two bird counts here.*

ID	Harvest	Before sowing and tillage	Sowing date	After sowing and tillage	February
Ø1	15.08.2019	23-08-2019	22-09-2019	02-10-2019	04-02-2020
Ø2	30.08.2019	30-08-2019	21-09-2019	05-10-2019	07-02-2020
Ø3	27.08.2019	12-09-2019	26-09-2019	03-10-2019	02-02-2020
Ø4	27.07.2019	29-08-2019	15-09-2019	24-10-2019	05-02-2020
Ø5		29-08-2019	01-10-2019**	24-10-2019	05-02-2020
K1	07.08.2019	29-08-2019	16-09-2019	01-10-2019	04-02-2020
K2	27.08.2019	12-09-2019	23-09-2019	01-10-2019	04-02-2020
K3	23.08.2019	07-09-2019	20-09-2019	03-10-2019	02-02-2020
K4	15.08.2019	30-08-2019	01-11-2019**		07-02-2020*
K5	25.07.2019	31-08-2019	25-09-2019	05-10-2019	07-02-2020
C1	21.09.2019	21-09-2019	26-09-2019	03-10-2019	05-02-2020
C2	21.09.2019	21-09-2019	22-09-2019	01-10-2019	04-02-2020
C3	01.08.2019	07-09-2019	21-09-2019	02-10-2019	02-02-2020
C4	23.08.2019	30-08-2019	18-09-2019	05-10-2019	07-02-2020
C5	29.07.2019	31-08-2019	22-09-2019	05-10-2019	07-02-2020

6.2 Species densities

6.2.1 Weeds

Table 33 Species densities of all plant species recorded in the three agricultural systems in the samples from before sowing and tillage (B).

Family	Genus	Species	Danish name	Org (B)	Conv. (B)	CA (B)
Græsfamilien (Poaceae)	Rapgræs (Poa)	*Poa annua*	Enårig rapgræs	802,6	195,6	58,5
Græsfamilien (Poaceae)	Kvik (Elytrigia)	*Elytrigia repens*	Alm kvik	8,3	1,1	3,3
Græsfamilien (Poaceae)	Svingel (Festuca)	*Festuca sp*	Svingel	0,4	8,0	8,7
Græsfamilien (Poaceae)	Byg (Hordeum)	*Hordeum sp*	Vårbyg	4,1		19,8
Græsfamilien (Poaceae)	Byg (Hordeum)	*Hordeum sp*	Byg	0,2		
Græsfamilien (Poaceae)			Korn sp	0,6	0,6	
Græsfamilien (Poaceae)	Hvede (Triticum)	*Triticum aestivum*	Hvede		5,6	
Græsfamilien (Poaceae)	Hejre (Anisantha)	*Anisantha sterilis*	Gold hejre	7,8		
Græsfamilien (Poaceae)	Rajgræs (Lolium)	*Lolium perenne*	Alm rajgræs		1,0	
Korsblomstfamilien (Brassicaceae)	Hyrdetaske (Capsella)	*Capsella bursa-pastoris*	Alm hyrdetaske	38,3	0,2	20,2
Korsblomstfamilien (Brassicaceae)	Kål (Brassica)	*Brassica rapa*	Agerkål	42,2		
Korsblomstfamilien (Brassicaceae)	Vejsennep (Sisymbrium)	*Sisymbrium officinale*	Rank vejsennep	1,1		1,9
Korsblomstfamilien (Brassicaceae)	Sennep (Sinapis)	*Sinapis arvensis*	Agersennep	3,5		
Korsblomstfamilien (Brassicaceae)	Springklap (Cardamine)	*Cardamine hirsuta*	Rosetspringklap		0,4	
Korsblomstfamilien (Brassicaceae)	Kål (Brassica)	*Brassica napus*	Raps	19,3	13,3	3,0
Krapfamilien (Rubiaceae)	Snerre (Galium)	*Galium aparine*	Burresnerre	0,7		2,2
Kurvblomstfamilien (Asteraceae)	Tidsel (Cirsium)	*Cirsium arvense*	Agertidsel	68,3		2,8
Kurvblomstfamilien (Asteraceae)	Svinemælk (Sonchus)	*Sonchus sp*	Svinemælk	9,3	1,1	24,3
Kurvblomstfamilien (Asteraceae)	Brandbæger (Senecio)	*Senecio vernalis*	Vårbrandbæger			5,0
Kurvblomstfamilien (Asteraceae)	Brandbæger (Senecio)	*Senecio vulgaris*	Alm brandbæger			5,9
Kurvblomstfamilien (Asteraceae)	Kamille (Tripleurospermum)	*Tripleurospermum perforatum*	Lugtløs kamille	385,7	4,1	18,7
Kurvblomstfamilien (Asteraceae)	Kamille (Tripleurospermum)	*Tripleurospermum sp*	Kamille			2,0
Kurvblomstfamilien (Asteraceae)	Knopurt (Centaurea)	*Centaurea cyanus*	Kornblomst	1,7		0,2
Kurvblomstfamilien (Asteraceae)	Haremad (Lapsana)	*Lapsana communis*	Haremad	0,4		1,1
Kurvblomstfamilien (Asteraceae)	Gåseurt (Anthemis)	*Anthemis arvensis*	Agergåseurt			3,0
Læbeblomstfamilien (Lamiaceae)	Tvetand (Lamium)	*Lamium sp*	Tvetand	35,6	0,2	0,4
Læbeblomstfamilien (Lamiaceae)	Hanekro (Galeopsis)	*Galeopsis sp*	Hanekro	1,1		1,3
Mangeløvfamilien (Dryopteridaceae)	Mangeløv (Dryopteris)	*Dryopteris sp*	Mangeløv	0,2	2,0	0,6
Maskeblomstfamilien (Scrophulariaceae)	Ærenpris (Veronica)	*Veronica persica*	Storkronet ærenpris	527,8	27,8	4,6

Maskeblomstfamilien (Scrophulariaceae)	Ærenpris (Veronica)	*Veronica chamaedys*	Tveskægget ærenpris	48,5	21,5	6,3
Natlysfamilien (Onagraceae)	Dueurt, Gederams (Epilobioum)	*Epilobioum montanum*	Glat dueurt	6,5	1,3	7,0
Natlysfamilien (Onagraceae)	Dueurt, Gederams (Epilobioum)	*Epilobioum sp*	Dueurt sp	0,2	0,4	
Natskyggefamilien (Solanaceae)	Natskygge (Solanum)	*Solanum sp*	Natskygge			0,4
Nellikefamilien (Caryophyllaceae)	Fladstjerne (Stellaria)	*Stellaria media*	Alm fuglegræs	310,0	9,6	55,6
Nellikefamilien (Caryophyllaceae)	Spergel (Spergula)	*Spergula sp*	Spergel			0,2
Nellikefamilien (Caryophyllaceae)	Hønsetarm (Cerastium)	*Cerastium fontanum ssp. vulgare*	Alm hønsetarm	1,3		
Perikonfamilien (Clusiaceae)	Perikon (Hypericum)	*Hypericum sp*	Buskperikon		1,0	
Rubladfamilien (Boraginaceae)	Forglemmigej (Myosotis)	*Myosotis arvensis*	Markforglemmigej	45,2	0,4	2,0
Salturtfamilien (Chenopodiaceae)	Gåsefod (Chenopodium)	*Chenopodium album*	Hvidmelet gåsefod	56,5	12,6	3,1
Salturtfamilien (Chenopodiaceae)	Gåsefod (Chenopodium)	*Chenopodium suecicum*	Grøn gåsefod	0,2		
Sivfamilien (Juncaceae)	Siv (Juncus)	*Juncus sp*	Siv			0,2
Sivfamilien (Juncaceae)	Siv (Juncus)	*Juncus tenuis*	Tuesiv	0,2		
Skærmplantefamilien (Apiacea)	Hundepersille (Aethusa)	*Aethusa cynapium*	Hundepersille	0,4		5,7
Storkenæbsfamilien (Geraniaceae)	Storkenæb (Geranium)	*Geranium robertianum*	Stinkende storkenæb		0,4	
Surkløverfamilien (Oxalidaceae)	Surkløver (Oxalis)	*Oxalis sp*	Surkløver	37,2	5,0	4,1
Syrefamilien (Polygonaceae)	Skræppe (Rumex)	*Rumex rugosus*	Havesyre	1,5	9,0	0,2
Syrefamilien (Polygonaceae)	Skræppe (Rumex)	*Rumex obtusifolius*	Butbladet skræppe	4,6		
Syrefamilien (Polygonaceae)	Skræppe (Rumex)	*Rumex crispus*	Kruset skræppe	0,2		
Syrefamilien (Polygonaceae)	Pileurt (Persicaria)	*Persicaria maculosa*	Fersken pileurt	1,7		
Syrefamilien (Polygonaceae)	Pileurt (Fallopia)	*Fallopia convolvulus*	Snerlepileurt	0,2		
Valmuefamilien (Papaveraceae)	Valmue (Papaver)	*Papver sp*	Valmue	1,5		2,6
Vejbredfamilien (Plantaginaceae)	Vejbred (Plantago)	*Plantago major*	Glat vejbred	2,2	0,2	
Vejbredfamilien (Plantaginaceae)	Vejbred (Plantago)	*Plantago lanceolata*	Lancet vejbred	0,9		
Violfamilien (Violaceae)	Viol (Viola)	*Viola arvensis*	Agerstedmoderblomst	11,3	24,8	23,1
Violfamilien (Violaceae)	Viol (Viola)	*Viola sp*	Stedmoderblomst	37,8	19,3	8,9
Vortemælkfamilien (Euphorbiaceae)	Vortemælk (Euphorbia)	*Euphorbia sp*	Vortemælk	0,7		
Ærteblomstfamilien (Fabaceae)	Kløver (Trifolium)	*Trifolium sp*	Kløver			0,2
Ærteblomstfamilien (Fabaceae)	Vikke (Vicia)	*Vicia sp*	Vikke	0,6		0,2
Ærteblomstfamilien (Fabaceae)	Vikke (Vicia)	*Vicia faba*	Hestebønne	0,7	0,2	0,4
			Vedplante	0,6	1,3	2,0

Table 34 Species densities of all species recorded in the samples from after sowing and tillage (A). "" show the 9 excluded species.*

Familie	**Slægt**	**Art**	**Dansk navn**	**Organic (A)**	**Conv. (A)**	**CA (A)**
Bergoniefamilien (Bergoniaceae)			Begonie		0,2*	
Græsfamilien (Poaceae)	Rapgræs (Poa)	*Poa annua*	Enårig rapgræs	42,0	14,6	59,1
Græsfamilien (Poaceae)	Kvik (Elytrigia)	*Elytrigia repens*	Alm kvik	1,1	0,2	0,7
Græsfamilien (Poaceae)	Svingel (Festuca)	*Festuca sp*	Svingel	3,5	0,4	1,9
Græsfamilien (Poaceae)	Byg (Hordeum)	*Hordeum sp*	Vårbyg			0,7
Græsfamilien (Poaceae)	Byg (Hordeum)	*Hordeum sp*	Byg			8,3
Græsfamilien (Poaceae)			Korn sp		0,2	2,0
Græsfamilien (Poaceae)	Hvede (Triticum)	*Triticum aestivum*	Hvede			1,5
Græsfamilien (Poaceae)	Hejre (Anisantha)	*Anisantha sterilis*	Gold hejre	0,2		
Græsfamilien (Poaceae)	Rajgræs (Lolium)	*Lolium multiflorum*	Italiensk rajgræs			0,4
Græsfamilien (Poaceae)	Hejre (Bromus)	*Bromus hordeaceus*	Blød hejre	0,4		
Kodriverfamilien (Primulaceae)	Arve (Anagallis)	*Anagallis arvensis*	Rød arve	0,9		
Korsblomstfamilien (Brassicaceae)	Hyrdetaske (Capsella)	*Capsella bursa-pastoris*	Alm hyrdetaske	5,2	5,7	24,6
Korsblomstfamilien (Brassicaceae)	Kål (Brassica)	*Brassica rapa*	Agerkål	2,2		
Korsblomstfamilien (Brassicaceae)	Vejsennep (Sisymbrium)	*Sisymbrium officinale*	Rank vejsennep	0,2		
Korsblomstfamilien (Brassicaceae)	Kål (Brassica)	*Brassica napus*	Raps		0,6	3,7
Krapfamilien (Rubiaceae)	Snerre (Galium)	*Galium aparine*	Burresnerre			1,3
Kurvblomstfamilien (Asteraceae)	Tidsel (Cirsium)	*Cirsium arvense*	Agertidsel	2,0		0,7
Kurvblomstfamilien (Asteraceae)	Svinemælk (Sonchus)	*Sonchus sp*	Svinemælk	1,3	0,6	41,3
Kurvblomstfamilien (Asteraceae)	Brandbæger (Senecio)	*Senecio vulgaris*	Alm brandbæger			4,3
Kurvblomstfamilien (Asteraceae)	Kamille (Tripleurospermum)	*Tripleurospermum perforatum*	Lugtløs kamille	24,8	2,0	12,8
Kurvblomstfamilien (Asteraceae)	Kamille (Tripleurospermum)	*Tripleurospermum sp*	Kamille	0,6	0,2	1,3
Kurvblomstfamilien (Asteraceae)	Kamille (Tripleurospermum)	*Matricaria discoidea*	Skive kamille	0,2		
Kurvblomstfamilien (Asteraceae)	Knopurt (Centaurea)	*Centaurea cyanus*	Kornblomst			0,2
Kurvblomstfamilien (Asteraceae)	Haremad (Lapsana)	*Lapsana communis*	Haremad	0,6		0,7
Kurvblomstfamilien (Asteraceae)	Gåseurt (Anthemis)	*Anthemis arvensis*	Agergåseurt			0,2
Kurvblomstfamilien (Asteraceae)	Haremad (Lapsana)	*Lapsana communis*	Haremad	0,6		0,7
Kurvblomstfamilien (Asteraceae)	Evighedsblomst (Gnaphalium)	*Gnaphalium sp*	Evighedsblomst	0,4	0,9*	1,9
Kurvblomstfamilien (Asteraceae)	Bynke (Artemisia)	*Artemisia vulgaris*	Gråbynke		0,4	0,2
Læbeblomstfamilien (Lamiaceae)	Tvetand (Lamium)	*Lamium sp*	Tvetand	2,2	0,4	
Læbeblomstfamilien (Lamiaceae)	Hanekro (Galeopsis)	*Galeopsis sp*	Hanekro	0,6	0,7	1,5

Læbeblomstfamilien (Lamiaceae)	Citronmelisse (Melissa)	*Melissa officinalis*	Citronmelisse		0,2*	
Mangeløvfamilien (Dryopteridacae)	Mangeløv (Dryopteris)	*Dryopteris sp*	Mangeløv	0,7	0,2	0,4
Maskeblomstfamilien (Scrophulariaceae)	Ærenpris (Veronica)	*Veronica persica*	Storkronet ærenpris	22,0	5,7	5,4
Maskeblomstfamilien (Scrophulariaceae)	Ærenpris (Veronica)	*Veronica chamaedys*	Tveskægget ærenpris	21,3	0,7	
Maskeblomstfamilien (Scrophulariaceae)	Ærenpris (Veronica)	*Veronica arvensis*	Markærenpris	0,6		
Maskeblomstfamilien (Scrophulariaceae)	Ærenpris (Veronica)	*Veronica sp*	Ærenpris			0,2
Maskeblomstfamilien (Scrophulariaceae)	Kongelys (Verbascum)	*Verbascum*	Ruhåret kongelys		0,6*	
Natlysfamilien (Onagraceae)	Dueurt, Gederams (Epilobioum)	*Epilobioum montanum*	Glat dueurt	1,5	2,2	9,3
Natskyggefamilien (Solanaceae)	Petunia (Petunia)	*Petunia x hybrida*	Petunia		0,2*	
Natskyggefamilien (Solanaceae)	Bulmeurt (Hyoscyamus)	*Hyoscyamus niger*	Bulmeurt		0,2*	
Nellikefamilien (Caryophyllaceae)	Fladstjerne (Stellaria)	*Stellaria media*	Alm fuglegræs	33,5	9,8	22,6
Nellikefamilien (Caryophyllaceae)	Spergel (Spergula)	*Spergula sp*	Spergel		0,4	
Nellikefamilien (Caryophyllaceae)	Hønsetarm (Cerastium)	*Cerastium fontanum ssp. vulgare*	Alm hønsetarm	5,6	2,2	0,2
Nellikefamilien (Caryophyllaceae)	Limurt (Silene)	*Silene noctiflora*	Natlimurt	1,3		
Nellikefamilien (Caryophyllaceae)	Spergel (Spergula)	*Spergula arvensis*	Alm spergel		1,7	
Nældefamilien (Urticaceae)	Nælde (Urtica)	*Urtica urens*	Liden nælde		0,9	0,4
Padderokfamilien (Equisetaceae)	Padderok (Equisetum)	*Equisetum sp*	Padderok	0,2		
Perikonfamilien (Clusiaceae)	Perikon (Hypericum)	*Hypericum sp*	Perikon		0,6	0,2
Rosenfamilien (Rosaceae)	Løvefod (Alchemilla)	*Alchemilla sp*	Løvefod		0,4*	
Rubladfamilien (Boraginaceae)	Forglemmigej (Myosotis)	*Myosotis arvensis*	Markforglemmigej	7,0	0,9	0,6
Rubladfamilien (Boraginaceae)	Forglemmigej (Myosotis)	*Myosotis sp*	Forglemmigej		0,4	
Salturtfamilien (Chenopodiaceae)	Gåsefod (Chenopodium)	*Chenopodium album*	Hvidmelet gåsefod	18,1	0,9	0,6
Salturtfamilien (Chenopodiaceae)	Gåsefod (Chenopodium)	*Chenopodium suecicum*	Grøn gåsefod	0,6	0,2	0,2
Sivfamilien (Juncaceae)	Siv (Juncus)	*Juncus minutulus*	Småblomstret siv		0,2	
Skærmplantefamilien (Apiacea)	Hundepersille (Aethusa)	*Aethusa cynapium*	Hundepersille			2,6
Sommerfuglebusk-familien (Buddlejaceae)	Sommerfuglebusk (Buddleja)	*Buddleja davidii*	Sommerfuglebusk		1,5*	
Storkenæbsfamilien (Geraniaceae)	Storkenæb (Geranium)	*Geranium sp*	Storkenæb	0,2		
Surkløverfamilien (Oxalidaceae)	Surkløver (Oxalis)	*Oxalis sp*	Surkløver	0,6	0,2	0,2
Syrefamilien (Polygonaceae)	Skræppe (Rumex)	*Rumex rugosus*	Havesyre	7,4		
Syrefamilien (Polygonaceae)	Skræppe (Rumex)	*Rumex obtusifolius*	Butbladet skræppe	0,4		
Syrefamilien (Polygonaceae)	Skræppe (Rumex)	*Rumex crispus*	Kruset skræppe	0,2		

Syrefamilien (Polygonaceae)	Pileurt (Fallopia)	*Fallopia convolvulus*	Snerlepileurt	0,7	0,6	
Syrefamilien (Polygonaceae)	Pileurt (Polygonum)	*Polygonum aviculare*	Vejpileurt	0,4	0,4	
Valmuefamilien (Papaveraceae)	Valmue (Papaver)	*Papver sp*	Valmue	0,7	0,2	30,9
Vejbredfamilien (Plantaginaceae)	Vejbred (Plantago)	*Plantago major*	Glat vejbred	4,6	1,3	1,7
Vejbredfamilien (Plantaginaceae)	Vejbred (Plantago)	*Plantago lanceolata*	Lancet vejbred	0,2		
Violfamilien (Violaceae)	Viol (Viola)	*Viola arvensis*	Agerstedmoderblomst	14,1	3,9	18,7
Vortemælkfamilien (Euphorbiaceae)	Vortemælk (Euphorbia)	*Euphorbia sp*	Vortemælk	0,4	0,2	
Vortemælkfamilien (Euphorbiaceae)	Vortemælk (Euphorbia)	*Euphorbia cyparissias*	Cypres vortemælk		0,2	
Ærteblomstfamilien (Fabaceae)	Kløver (Trifolium)	*Trifolium sp*	Kløver			0,2
Ærteblomstfamilien (Fabaceae)	Vikke (Vicia)	*Vicia faba*	Hestebønne			0,4
			Vedplante	6,7	2,6	1,7

6.2.2 Ground-living arthropods

Table 35 Species densities of ground-living arthropods in the three agricultural systems. (B) are the samplings from before sowing/tillage and (A) are the samplings from after sowing/tillage.

Order	**Family or genus**	**Name or description**	**Organic (B)**	**Organic (A)**	**Conv. (B)**	**Conv. (A)**	**CA (B)**	**CA (A)**
Beetles (Coleoptera)	Ladybugs (Coccinella)	Sevens-spot ladybug *Coccinella septempunctata*	0,16					
Beetles (Coleoptera)	Carabids (Carabidae)	Carabid above 1 cm	0,47		0,47		0,16	
Beetles (Coleoptera)	Carabids (Carabidae)	Carabid below 1 cm	1,41		0,94	0,16	0,47	0,47
Beetles (Coleoptera)	Carabids (Carabidae)	Læderløber *Carabus coriaceus*					0,16	
Beetles (Coleoptera)	Carabids (Carabidae)	*Trechus quadristriatus/obtutus*	1,41	0,16	2,51	0,79	0,94	2,04
Beetles (Coleoptera)	Carabids (Carabidae)	*Trechus sp.*			0,47			
Beetles (Coleoptera)	Carabids (Carabidae)	Toplettet spejlløber *Notiophilus biguttatus*			0,16		4,08	2,04
Beetles (Coleoptera)	Carabids (Carabidae)	Spejlløber sp. *Notiophilus sp.*			0,16		0,16	0,31
Beetles (Coleoptera)	Carabids (Carabidae)	Markglansløber *Bembidion lampros*	5,02	1,88	0,31	0,31	2,83	2,20
Beetles (Coleoptera)	Carabids (Carabidae)	Stor glansløber *Bembidion tetracolum*	1,10	0,16	0,31		4,87	0,16
Beetles (Coleoptera)	Carabids (Carabidae)	*Bembidion sp.*		3,45		2,67		8,64
Beetles (Coleoptera)	Weevil (Curculionoidea)	Weevil sp.	0,16					
Beetles (Coleoptera)	Leaf beetles (Chrysomelidae)	Leaf beetle						0,31
Beetles (Coleoptera)	Leaf beetles (Chrysomelidae)	*Altica sp*					0,16	
Beetles (Coleoptera)	Leaf beetles (Chrysomelidae)	Yellow-striped flea beetle *Phyllotreta nemorum*						0,16
Beetles (Coleoptera)	Rove beetles (Staphylinidae)	Staphylinid above 5 mm	0,63	0,63	0,47	0,31	1,26	0,94

Beetles (Coleoptera)	Rove beetles (Staphylinidae)	Staphylinid below 5 mm	0,94	2,83	0,31	0,63	1,73	1,57
Beetles (Coleoptera)		Beetle sp. below 5 mm	0,16	0,16	0,31		0,63	0,16
Beetles (Coleoptera)		Beetle sp. over5 mm						0,16
Beetles (Coleoptera)	Leaf beetles (Chrysomelidae)	Broad bean weevil *Bruchus rufimanus*					1,26	
Beetles (Coleoptera)	Weevil (Curculionoidea)	Pea leaf weevil Sitona lineatus	0,47		0,16	0,16	1,10	0,31
Twotails (Diplura)		Dipluran sp.			0,16		0,31	
Flies (Diptera)		Flie sp. 1	0,16	0,47				0,63
Flies (Diptera)		Flie sp. 2		0,47				
Flies (Diptera)	Nematocera	Nematocera below 5 mm	2,51	0,79	1,73	1,26	3,14	1,73
Flies (Diptera)	Assasain flies (Asilidae)	Asilid sp.	0,16	0,31	0,16			0,31
Flies (Diptera)	Phoridae (Pukkelfluer)	Phoridae sp.	0,94	0,47	0,79	0,16	0,47	0,31
Harvestmen (Opiliones)		Opilion sp.	0,16					
Hymenopteran (Hymenoptera)		Hymenopteran sp.	0,63		0,16		0,31	
Hymenopteran (Hymenoptera)	Ants (Formicidae)	Ant sp.					0,16	0,16
Hymenopteran (Hymenoptera)		Wasp sp. 1	0,79	0,16	1,88	0,31	0,94	0,63
Hymenopteran (Hymenoptera)		Wasp sp. 2	0,47					
Hymenopteran (Hymenoptera)		Larvae below 5mm	0,16	0,16	0,47	0,47	0,16	0,94
Hymenopteran (Hymenoptera)		Larvae above 5 mm	0,94	0,31	0,79		0,79	0,94
Mites (Acari)		Mite sp.	2,67		0,63	0,16	3,30	1,73
Myriapods (Myriapoda)		Centipede sp.	0,63		0,16		0,63	0,31
Myriapods (Myriapoda)		Milipede sp.					0,47	0,94
Snails		Snegl sp. under 3 mm					0,79	
Spiders (Araneae)	Wolf spiders (Lycosidae)	Wolf spider sp.	0,47	0,16	0,31		2,36	0,31
Spiders (Araneae)	Sac spiders (Clubionidae)	Sac spider sp.	0,47		0,16		1,26	0,31
Spiders (Araneae)	Sheet weavers (Linyphiidae)	Linyphiid sp.	27,01	2,67	22,14	4,40	38,94	29,20
Spiders (Araneae)		Spider sp.	1,57	0,31	1,73		4,40	0,16
Spiders (Araneae)	Crab spiders (Thomisidae)	Crab spider sp.	0,47		0,16		0,79	0,16
Springtails (Collembola)		Springtail sp.	19,16	1,88	34,07	1,26	29,36	19,47
Springtails (Collembola)	Globular springtails (Sminthuridae)	Sminthurid sp.	0,79				0,63	0,79
True bugs (Hemiptera)	Auchenoorhyncha	Cicada sp.	2,36		0,63		0,79	0,47
True bugs (Hemiptera)	Heteroptera	Heteropteran sp.	6,75		1,10		0,16	0,16
True bugs (Hemiptera)	Miridae	Blomstertæge sp. 1 (Mididae sp.)	0,79					

True bugs (Hemiptera)	Miridae	Blomstertæge sp. 2 (Mididae sp.)	1,88		0,63		0,94	0,31
True bugs (Hemiptera)	Shield bugs (Pentatomidae)	Shield bug sp.			0,16			
True bugs (Hemiptera)	Heteroptera	Hemipteran sp.					0,16	
Woodlouse (Oniscidea)		Woodlouse sp.	0,47	0,16			0,63	0,63
Earwigs (Dermaptera)	Forficulidae	Common earwig (Forficula auricularia)					0,16	

6.2.3 Birds

Table 36 Bird species density int he three agricultural systems in the sampling before sowing/tillage.

Latin name	**Danish name**	**Organic**	**Conventional**	**CA**
Accipiter gentilis	Duehøg	0	0	0,03
Alauda arvensis	Sanglærke	0,39	0,09	0,54
Anser anser	Grågås	0	0	0
Buteo buteo	Musvåge	0,08	0,07	0,28
Columba palumbus	Ringdue	0	0,24	0
Corvus cornix	Gråkrage	0	0	0
Corvus frugilegus	Råge	0	0	0
Hirundo rustica	Landsvale	0,27	0,19	0,29
Oenanthe oenanthe	Stenpikker	0	0,05	0,30
Passer domesticus	Gråspurv	0	0,01	0,62
Perdix perdix	Agerhøne	0,24	0,29	0,08
Phasianus colchicus	Fasan	0	0	0,03

Table 37 Bird species density in the three agricultural systems in the sampling after sowing/tillage

Latin name	**Danish name**	**Organic**	**Conventional**	**CA**
Alauda arvensis	Sanglærke	0	0	0,02
Anser anser	Grågås	0	0	0,32
Buteo buteo	Musvåge	0	0,013605	0
Chroicocephalus ridibundus	Hættemåge	0	0,435374	0
Columba palumbus	Ringdue	0,019048	0	0
Corvus cornix	Gråkrage	0	0,132701	0,394089
Corvus frugilegus	Råge	0,057143	0	0
Cloris chloris	Grønirisk	0	0	0,197044
Pica pica	Husskade	0	0	0,015038
Passer domesticus	Gråspurv	0	0	0,74
Phasianus colchicus	Fasan	0	0,075472	0,05848

Table 38 Bird species density in the three agricultural systems in the sampling in February.

Latin name	Danish name	Organic	Conventional	CA
Alauda arvensis	Sanglærke	0,04	0	0,036152
Anser anser	Grågås	0	0	0,077959
Buteo buteo	Musvåge	0	0	0,120385
Coloeus monedula	Allike	0	0	0,04961
Corvus cornix	Gråkrage	0,02	0,050295	0,257035
Corvus frugilegus	Råge	0	0	0,021262
Passer domesticus	Gråspurv	0	0	0,798218
Perdix perdix	Agerhøne	0,04	0	0
Phasianus colchicus	Fasan	0	0	0,05848
Falco tinnunculus	Tårnfalk	0,00939	0,027211	0