Journal of Central European Agriculture, 2013, 14(3), p.305-317

Integrated farming methods and their impact on herb and bird communities of agricultural land – a review

Šetrnější způsoby hospodaření a jejich dopad na na rostlinná a ptačí společenstva zemědělské krajiny - review

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Abstract

During the last century, the changing forms of agriculture drastically influenced many native plant and animal populations. In the efforts to reduce these negative impacts on biodiversity, a number of agricultural enterprises began farming in a more environmentally friendly ways; in addition to conventional farm management, new forms of integrated and organic farming appeared, the latter having a tradition of only a few years. These new approaches have a number of variations, one of which is termed integrated farming. It exerts less pressure on the given environment, and, together with organic agriculture, plays an important role in the efforts to renew long lost cultures. Support for integrated farming can be one of the intermediate stages between organic farming and agri-environmental programmes that very often complement one another. Despite the organic farming may have a negative impact on crop yields and considers individual approaches to problematic sites as well as applications of locally specific rules, a number of studies have confirmed that this kind of farming positively influences biodiversity of a given area. This review highlights importance of integrated farming and calls for its larger use in agricultural practice.

Keywords: biodiversity, conventional versus organic farming, farmland, bird diversity, herb communities

Abstract in native language

Měnící se způsob zemědělského hospodaření v průběhu 20. století výrazně ovlivnil populace mnoha původních druhů rostlin a živočichů. V zájmu snižování těchto negativních dopadů na biologickou rozmanitost se řada zemědělských podniků odhodlala uplatňovat postupy šetrnější k životnímu prostředí; kromě konvenčního (nešetrného) přístupu se objevily nové formy integrovaného a ekologického zemědělství, z nichž druhá forma má dosud jen několikaletou tradici. Tyto nové

přístupy mají řadu variant, z nichž jedna se nazývá integrované zemědělství. To vyvíjí menší tlak na přírodní prostředí a spolu s ekologickým zemědělstvím sehrává důležitou roli v úsilí o obnovení přírodních hodnot zemědělské krajiny. Integrované farmaření tvoří určitý přechod mezi ekologickým zemědělstvím a šetrným farmařením široce využívajícím agro-environmentální programy. Přestože ekologické zemědělství může do určité míry snižovat výnosy plodin a vyžaduje individuální přístupy na problematickým lokalitách a uplatňování místně specifických pravidel, řada studií potvrdila, že tento druh hospodaření pozitivně ovlivňuje biodiverzitu dané oblasti. Tato práce zdůrazňuje význam integrovaného zemědělství a podporuje jeho širší uplatňování v zemědělské praxi.

Klíčová slova: biodiversita, konvenční versus organické hospodaření, zemědělská činnost, ptačí společenstva, rostlinná společenstva

Introduction

Farmland currently comprises more than 50% of land in Europe. Agriculture is among the main land uses and, at the same time, Europe is home to approximately 150 species of birds directly dependent on farming methods (Wilson, et al., 1999; Zámečník, 2004a). Such farmland occupies approximately 54% of the total area of the Czech Republic. Together, then, this constitutes almost three-fifths of the country's territory (Marhoul, 2001).

Many species (among those most observed being plants, invertebrates and birds) tied to the agricultural landscape exhibit declining abundance (Potts, 1997; Hald, 1999; Marhoul, 2001; Hora, et al., 2003; Rusek, 2003; Newton, 2004; Purtauf, et al., 2005; Šťastný, et al., 2006; Václavík, 2006; Stoate, et al., 2009). These reductions are mainly associated with activities carried out during the last 50 to 60 years. During this period, there occurred large-scale land consolidation, ploughing of bounds, removal of hedgerows (hedgerows constitute an environment for many plant species while providing food, shelter, wintering sites, and corridors for large numbers of animals (Kleijn, et al., 1997; Marshall, et al., 2003), lone trees and bushes (e.g., Janda and Řepa (1986) report that dispersed greenery is exceptionally important in the agricultural landscape for the presence and nesting of birds), and narrow specialization of agricultural production on certain crop varieties. Habitats that were refugia for individual species disappeared from the landscape, causing immense loss of heterogeneity and biodiversity in given areas as well as large landscape units (Andreska, 1990; van Elzakker, 1991; Potts, 1997; Šarapatka and Zídek, 2005). Soil compaction and excessive use of fertilizers and pesticides also occurred. While fertilizers and pesticides are mainly applied in agricultural activities in the interest of increasing yields, their negative impacts on the agro-ecosystem are perhaps even greater (Kropáč and Nejedlá, 1956; Chamberlain, et al., 2000; Tilman, et al., 2001; Vickery, et al., 2002; Hora, et al., 2003; Báldi, et al., 2005).

A task of modern society is to renew long lost ecosystems and ensure the permanent sustainability of existing ones. Among those factors responsible for the disappearance of animal and plant species may be the methods of farming individual plots (Wilson, et al., 1999; Donald, et al., 2001; Newton, 2004; Piha, et al., 2007), which are understood to include the methods of cultivation and use of machinery, fertilizers and pesticides (protective substances). Thus, this refers to the overall land management undertaken by agricultural enterprises and individual farmers.

Farming methods can be divided into three basic categories: integrated, conventional, and organic. Integrated farming is defined by the size of the agricultural enterprises, which are mostly represented by private farmers. Conventional farming is governed by a number of laws and also by the Nitrates Directive (important from the perspective of this study). Organic farming is certified and must fulfil a number of criteria according to Act No. 242/2000 Coll. on organic farming and the Council Regulation (EC) No. 834/2007 on organic production and labelling of organic products, which is binding for all EU member countries.

Influence of farming

Over the course of several decades, new methods of land and crop management have emerged in agriculture and have had generally negative impacts on the abundance of field inhabitants. Some of these affect individuals directly while others affect their environments. From the perspective of biotic diversity, an agricultural landscape is considered to be a very rich ecosystem. There were times when large numbers of especially bird species were found in the Czech Republic's landscape, the abundance of which many times over surpassed today's (frequently) residual states (Marhoul, 2001; Rusek, 2003; Newton, 2004; Václavík, 2006; Šťastný, et al., 2006).

The first large changes in the agricultural landscape were recorded in the 20th century, when herbicides of various chemical compositions and selectivity began to appear more frequently in agricultural processes, the application rates of fertilizers, especially nitrogen fertilizers, increased, and there was a fundamental redesign of sowing processes and higher representation of cereals (Kropáč and Nejedlá, 1956; Chamberlain, et al., 2000; Tilman, et al., 2001; Vickery, et al., 2002; Hora, et al., 2003; Báldi, et al., 2005). As noted by Potts (1997), Hald (1999), Marhoul (2001), Hora et al. (2003), Rusek (2003), Václavík (2006) and Wilson et al. (1999), intensification of agricultural activity thus contributed to large-scale unfavourable changes in the natural environments of many animal species. During the first wave of collectivization in the Czech Republic, around 350–400 trees and approximately 3,000 m^2 of shrubs were removed per cadastral area in Central and Western Bohemia. The area of dispersed greenery in the landscape thus decreased from 2–3% of the area to 0.5–0.7% (the state recorded in the 1980s and 1990s). Hedges, stone walls and field paths also disappeared from the landscape (van Elzakker, 1991; Šarapatka and Zídek, 2005). In the Czech Republic, a total of 4,000 km of linear greenery was removed over the last 35 years (Kubová, 2000). Many plots were ameliorated and are used for large-scale agricultural production, and some were transformed into building plots. A number of smaller areas remain permanently uncultivated and are overgrowing with shrubbery or trees (edges of fields, inaccessible slopes, and previously less-used pastures). During the period 1960–1980 alone, the decline of meadows in favour of arable land in the Czech Republic was 20%. The liquidation of meadows and changes in their quality were apparently the main causes of the disappearance of the northern lapwing (*Vanellus vanellus)* in certain places as early as in the first half of the 20th century (Šálek, 2000). The decrease of permanent grass stands in comparison with 1950 is 450,000 ha, consisting of 280,000 ha of meadows and 170,000 ha of pastures. In contrast to the pre-war period, 270,000 ha of predominantly meadows disappeared and were transformed into arable land (Petr and Dlouhý, 1992). Today, meadow communities are being further transformed into field culture and seeded with grass–legume

mixtures in order to receive subsidies. However, this causes further disturbances and loss of nesting sites.

Corn stubble is an important winter food base for many bird species feeding on seeds, especially if there are undersown crops or green fertilization (Wilson, et al., 1999; Pekrun and Claupein, 2006; Václavík, 2006). They, too, have disappeared in a number of places in the Czech countryside as a result of farmers switching to winter crops at the expense of spring crops. Even in case of spring sowing, farmers already plough their fields in autumn in order to remove weeds and prepare the soil for spring (Marhoul, 2001). At the same time, however, spring seeding offers important nesting stands for birds nesting on the ground (Václavík, 2006). At least three additional aspects of agricultural intensification playing negative roles are: the intensity of fertilization, the use of pesticides, and the direct impacts of agricultural machinery (Hald, 1999; Šálek, 2000; Donald, et al., 2001). Wilson et al. (1999) also point out the indirect impact of the use of fungicides and herbicides on selected invertebrate species, which constitute important food sources for certain bird species (Purtauf, et al., 2005). In connection with accepting the standards of the European Union's Common Agricultural Policy, there has been a steady slight increase in the use of chemical substances for the protection of plants (Václavík, 2006). Marked differences in the abundance of individual species can be seen when comparing the abundance and occurrence of individual species in the states of eastern and western Europe (Donald, et al., 2001), as well as in island versus continental settings (Kuijper, et al., 2009), which differ in their farming styles. However, Hole et al. (2005) draw attention to the fact that a number of studies comparing conventional and organic farming comes from Western Europe.

Farming methods

Today, agricultural activity can be divided into two main types of farming: classical conventional farming and organic farming, the latter form having a tradition of only a few years. Both methods have a number of variations, one of which is so-called integrated farming (Lampkin, 1990; Genghini, et al., 2006). This involves either farming in the traditional way or farmers who do not want to or do not fully fulfil the conditions for organic farming certification, as well as smaller cooperatives running hundreds of hectares but which farm according to their (perhaps limited) financial possibilities.

Conventional farming

Conventional farming has developed in order to maximize production and profit. Six main pillars help to create this intensity worldwide. These are: intensive farming, monoculture, irrigation, application of mineral fertilizers, chemical protection of plants, and recently genetic manipulation. Dependence on these pillars means greater vulnerability for farmers and individual regions and a necessity for interconnecting the individual parts (Šnobl and Pulkrábek, 1999). In many cases, efforts are made to use integrated pest management, wherein targeted use of pesticides is made only after so-called economic thresholds of damage have been exceeded (Kohout, 2002).

Integrated farming

There are five main trends in alternative farming, which differ in their philosophies, practices and times of origin. These include organic, biodynamic, organic–biological, biological, and alternative organic agriculture (Petr and Dlouhý, 1992).

This study addresses integrated farming in connection with smaller agricultural cooperatives and private farmers. They are included in this type of farming as a result of their having limited financial resources required to purchase plant-protective substances and fertilizers. Integrated farming is characterized by lower application rates of fertilizers and pesticides versus conventional farms. Connection to the surrounding landscape and the associated size of individual plots ranging around 12 ha also play an important role here. This increases the diversity of the agricultural landscape, which in the case of conventional farming is homogeneous. Integrated farming is not, however, precisely defined in any source (Genghini, et al., 2006; Romero, et al., 2008).

Organic farming

"Organic farming is an environmentally friendly method of farming which cares about the environment and its individual components by defining limits or prohibiting the use of substances and methods that burden and pollute the environment or increase the risk of contamination of the food chain and cares about the well-being of the farm animals being reared" (Šarapatka and Zídek, 2006).

On 1 January 2001, Act No. 242/2000 Coll. on organic farming went into effect in the Czech Republic (an amendment to this act, Act No. 553/2005 Coll., became effective as from 30 December 2005). This act defines the conditions of organic farming and the conditions for the production of organic food while modifying the system for certifying the origin of organic products, organic food, and their labelling. The Act is implemented by the Decree of the Ministry of Agriculture No. 53/2001 Coll. (amendment no. 16/2006 Coll. became effective from 1 February 2006). Upon accession to the European Union, Council Regulation (EC) No. 834/2007 regulating organic farming becomes a binding norm in all member countries.

Bird communities

Birds are one of the indicator groups of organisms responding to unsuitable farming methods and intensification of agricultural activities (Chamberlain, et al., 2000; Newton, 2004; Báldi, et al., 2005; Báldi and Faragó, 2007). Analyses have proven that the level of bird population decrease in an agricultural landscape corresponds to the level of farming intensity (Fuller, et al., 1995; Donald, et al., 2001; Hora, et al., 2003; Reif, et al., 2008). In Europe, the number of grey partridges (*Perdix perdix*) has rapidly decreased in connection with the application of herbicides and change in agro-technology (Potss, 1986 cited in Wilson, et al., 1999). Vickery et al. (2004) created a table of the 20 most endangered bird species of the agricultural landscape (e.g. the common kestrel [*Falco tinnunculus*], grey partridge [*Perdix perdix*], northern lapwing [*Vanellus vanellus*], Eurasian skylark [*Alauda arvensis*], and yellowhammer [*Emberiza citrinella*]) which are suffering due to aggressive agricultural methods. In many cases, the mosaic of the surrounding landscape plays an important role (Piha, et al., 2007), that often merge and can not be exactly ruled out (Hole, et al., 2005).

In the Czech Republic, birds of the open landscape are one of the most endangered groups (Reif, et al., 2006). The Eurasian skylark and northern lapwing are in first place among the most markedly disappearing species, which negative reaction corresponds to the growing levels of farming intensity (Hudec, et al., 2000; Zámečník, 2004b; Šťastný, et al., 2006; Reif, 2007). Between 1982 and 2006, the abundance of the Eurasian skylark decreased by more than 35% and that of the northern lapwing by an incredible 85% (Reif, 2007). The decrease of their numbers

may be attributed mainly to intensification of agriculture and changes in the landscape in recent decades, which was the most significant during 1982–1990. These changes are also noted in a study by Andreska (1990), which states that changes in the composition and state of vegetation during the last several decades were penetrating and left a lasting influence on the composition of the fauna of the field landscape, especially insects and birds.

Massive use of herbicides and insecticides has decreased the diversity and abundance of insects that are food, and therefore also constitute a limiting factor, for a number of bird species (e.g. Potts, 1997; Wilson, et al., 1999; Šálek, 2000; Vickery, et al., 2002; Václavík, 2006). For example, the lesser grey shrike (*Lanius minor*), woodchat shrike (*Lanius senator*) and European roller (*Coracias garrulus*) disappeared completely, and the great bustard (*Otis tarda*), Eurasian stone-curlew (*Burhinus oedicnemus*) and Eurasian curlew (*Numenius arquata*) balance on the verge of extinction. The abundances of other previously very abundant species also have rapidly decreased, from the grey partridge (*Perdix perdix*) to the barn swallow (*Hirundo rustica*) (Šťastný, et al., 2006).

The black-headed gull (*Larus ridibundus*), corn bunting (*Emberiza calandra*), and ortolan bunting (*Emberiza hortulana*) first increased and later decreased. The process of diminishing numbers is evidently accelerating in the following way: before 1950, the numbers started to decrease for 6 species; from 1950–1970 for 14 species; and after 1970 for 34 species (Hudec, et al., 2000). Only a few species, such as the greylag goose (*Anser anser*) and the common wood pigeon (*Columba palumbus*) benefit from intensification of agriculture (Hora, et al., 2003).

Plant communities

Plants comprise another group of organisms responding to the aforementioned intensification of agriculture. Changes in plant communities depend on a complex of agro-technical measures in certain phases of agricultural development. The improving technology for cleaning seeds, improvements in soil tillage, gradual increase of the application rates of mineral fertilizers, liming, and, last but not least, the use of herbicides played a decisive role (Kropáč and Nejedlá, 1956). As a result of these techniques, species such as common corncockle (*Agrostemma githago*), field gromwell *(Lithospermum arvense*), rye brome (*Bromus secalinus*), field cow-wheat (*Melampyrum arvense*), and more recently also field mustard (*Sinapis arvensis*), white campion (*Melandrium album*), and smooth tare (*Vicia tetrasperma*) declined considerably. On the other hand, nitrophilous, shade-tolerant, and climbing species benefit the most (Mikulka, 1999).

In addition to cultured crops, various weeds also constitute an important plant component of fields. Plant communities of meadows and pastures are characterized by a prevalence of grasses over other herbs. In field and meadow areas, woody plants are predominantly represented only on bushy bounds and hillsides, and then only by a few species (Čihař, 2002). Plant communities at the edges of fields are very important and are to a significant extent dependent on the farming method (Kleijn, et al., 1997). Two independent studies were performed in Spain and the United States concerning weed communities in organic and conventional fields. Romero *et al*. (2008) concluded in their two-year research that weeds are present in the central parts of fields only in organic farming whereas they are more abundant at the edges in conventional farming. In addition to the impact of farming, Smith and Gross (2006) also focused on crop types. Cereals, and especially winter varieties, in combination

with organic farming demonstrated the best results. A similar experiment was conducted in Great Britain, where the reaction of individual crop species to the type of fertilizer (organic x artificial) and the use or absence of herbicides were also monitored (McCloskey, et al., 1996). The species differed in abundance and density. Ploughing in association with the use of organic fertilizers had the most important effect on the occurrence of weeds. Artificial fertilizers had a positive effect only on the initial stages for *Galium aparine*. Hald (1999) also established the positive influence of this type of farming at organically farmed areas in Denmark. Approximately 15% more plant species were recorded on organically farmed areas than on conventionally farmed ones. Only the total biomass and farmed biomass were 25% higher in conventional farming. The conclusions also indicate the immense impact of the use of herbicides. He also notes the importance of the interconnectedness of the entire ecosystem. The use of herbicides indirectly affects bird communities, and in connection with the use of insecticides it can be called targeted liquidation of certain communities. Wilson et al. (1999) and Rusek (2003) also identify themselves with this theory in their work.

Crops grown on arable land, in contrast to grass stands, do not have roots sufficiently developed to effectively retain water. When arable land is bare, the ability to retain water is, understandably, much lower. Rainwater quickly flows away and carries soil particles with it. Up to several tons of topsoil per hectare can be washed away from sloping plots per year. The soil washed away clogs waterways and thereby decreases their capacities as watercourses. The chemicals used thereby come into direct contact with water. In the Czech Republic, 45% of soil is endangered by water erosion.

Pesticides used to protect crops will reliably eradicate insects and weeds that could be used by birds and small mammals for nourishment. Moreover, most crops are harvested completely over the course of just several days, and the landscape thus does not provide sufficient food.

Results

The face of the landscape has been slowly changing since the Neolithic up to the present times (Šarapatka and Zídek, 2005), with the most marked change occurring during the past 60–80 years (Hora, et al., 2003). Increasingly wider use of herbicides of various chemical composition and selectivity occurred around 1960, the application rates of (especially nitrogen) fertilizers increased, sowing processes were redesigned, and cereals were represented in greater numbers (Kropáč and Nejedlá, 1956; Rusek, 2003; Báldi and Faragó, 2007). Each culture understood man's relationship to nature in different ways, which is discussed in the works by White (1967) and Lund et al. (1969). Petr and Dlouhý (1992) note that the understanding of nature characteristic for organic farming is only a continuation of the organic and holistic view of nature that was part of European culture up to the end of the 17th century. The first environmentally friendly system was developed in Europe during the first decades of the 20th century, and bore the name biological farming. The first published references to organic farming in the Czech Republic appeared only during 1985–1987 (Šarapatka and Urban, 2006).

Changes in the structure of the agricultural landscape can be observed in gradual changes of individual bird, plant and invertebrate communities. The following works discuss the decreasing numbers of these taxa: Kropáč and Nejedlá (1956), Potts (1997), Mikulka (1999), Hudec et al. (2000), Šálek (2000), Kohout (2002), Vickery et

al. (2002), Hora et al. (2003), Rusek (2003), Houdková (2004), Donald et al. (2006), Šťastný et al. (2006), Václavík (2006), and Reif et al. (2008). The structure of these communities in the agricultural landscape is thus affected by the combination of a number of factors such as size, spatial arrangement, and habitat heterogeneity of plots (Belfrage, et al., 2005; Kleijn, et al., 2006; Piha, et al., 2007; Romero, et al., 2008), as well as by the character of the surrounding environment, including the edge phenomenon (Batáry and Báldi, 2004), the ratio of dispersed greenery (Freemark and Kirk, 2001), and other factors. These studies suggest that overall heterogeneity of the environment plays a key role, especially on conventionally farmed plots. The positive impact of organic farming on bird communities is apparently much more visible in a more homogenized landscape (Smith, et al., 2010). A number of studies have confirmed that organic farming positively influences overall biodiversity of a given area, but with a negative impact on crop fields (see the review of Tuomisto, et al., 2012).

Support for integrated farming can be one of the intermediate stages between organic farming and agro-environmental programmes that very often complement one another. In a number of cases, it is necessary to select individual problematic sites and approach them according to specific rules. The results of our previous work (Štefanová and Šálek, 2012) indicate that a mere change in the method of using the plots in favour of more environmentally friendly fertilization and use of pesticides in field cultures on the local level need not have an immediate marked impact on species diversity and bird density in an agricultural landscape. It is possible that in addition to a change in farming style it is necessary to make additional adjustments to the habitats in order to increase the overall structural diversity (Fischera, et al., 2011). Changes to the structure and methods of using the agricultural landscape are taking place around the world. Certain similarities among the individual areas and sites can therefore be observed (Donald, et al., 2006). It would be appropriate to conduct similar studies at several more locations and also to include organic farming into such studies for purposes of comparison. In relation to the integrated farming system, set limits for the size of individual plots should be defined, and the maximum allowable application rates for fertilizers and pesticides applied to individual plots should be firmly established. Average per-farm values used in previous studies are misleading and imprecise for further comparison. Moreover, the introduction of new technologies in less-developed countries must be given very careful consideration, or they should be approached with great caution, in order to avoid mistakes that were made earlier in what are today's developed countries (Donald, et al., 2001).

Acknowledges

We thank to G. A. Kirking for his useful linguistic advice. The study was supported by the grant IGA CZU No. 200942110007.

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