Chapter 8

Impact of Organic Farming on Biodiversity

Martina Bavec and Franc Bavec

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/58974

1. Introduction

In last several decades agriculture has been oriented towards industrial and extremely intensive farming practices, aimed at ensuring enough food for the human population, a goal that was not achieved. These types of farming practices also caused several negative environmental impacts such as decreasing biodiversity, including the farm bird index, where a decline has been observed in Slovenia since 2008. Many farms intensified their activities and became highly mechanized, whilst those unable to do so became increasingly marginalized and were sometimes forced to abandon their land, causing equally devastating consequences for biodiversity [1]. Today, it is globally imperative that the growing demand for food be met in a manner that is socially equitable and ecologically sustainable over the long term. It is possible to design farming systems that are equally productive and that maintain or enhance the provisioning of ecosystem services (i.e., biodiversity, soil quality, nutrient management, water-holding capacity, control of weeds, diseases and pests, pollination services, carbon sequestration, energy efficiency and reducing global warming potential, as well as resistance and resilience to climate change and crop productivity) and thus agroecosystem resilience and sustainability [2].

Organic agriculture refers to a farming system that enhances soil fertility by maximizing the efficient use of local resources, while foregoing the use of agrochemicals, genetically modified organisms and the many synthetic compounds used as food additives. The high quality of organic food and its added value relies on a number of farming practices based on ecological cycles, and aims at minimizing the environmental impact of the food industry, preserving the long term sustainability of soil and reducing to a minimum the use of non-renewable resources [3].

Organic farming practices have been promoted as reducing the environmental impacts of agriculture. The results of meta-analysis of studies that compare the environmental impacts of organic and conventional farming in Europe show that organic farming practices generally have positive impacts on the environment per unit of area, but not necessarily per product unit. Significant differences between the two farming systems include soil organic matter content, nitrogen leaching, nitrous oxide emissions per unit of field area, energy use and land use. Most of the studies that compared biodiversity in organic and conventional farming demonstrated lower environmental impacts from organic farming [4]. Furthermore, organic farming appears to perform better than conventional farming and also provides other important environmental advantages such as halting the use of harmful chemicals and their spread in the environment and along the trophic chain, and reducing water use [3]. A life cycle analysis approach calculating the ecological footprint of different productions systems confirmed, respectively, 8.5 and 5.9 times better environmental performance of organic farming practices, compared to their conventional counterparts in winter wheat and spelt production [5].

Biodiversity loss and the degradation of ecosystems have important implications for the environment and are costly for society as a whole [6]. In Europe, loss of plant biodiversity is primarily reflected in the decline of many species of plants and in the disappearing of local and old plant varieties. In 2011, the European Parliament adopted the European Union (EU) Biodiversity Strategy to 2020 with aim of preventing biodiversity loss and the degradation of ecosystems. The strategy includes combating invasive alien species that jeopardize biodiversity and aims also at enhancing the positive contribution of European agriculture, forest and fishery sectors to biodiversity conservation and sustainable use, and to increase by 2020 the EUs contribution to drawing attention to global biodiversity loss [1]. The World Trade Organization notes a crop variety loss of 75% during the past 100 years, even of 90% in the EU. Only 17% of species and habitats assessed under the Habitats Directive have been deemed to be in good status and the degradation and loss of natural capital is jeopardizing efforts for attaining the EUs biodiversity and climate change objectives [7, 4], which did not reach its 2010 biodiversity target [1].

Organic farming is a production method that preserves or even enrich biodiversity at the field level, at the farm level and in the ecosystem as per its regulatory demands, where the objectives of organic farming in EU regulation 834/2007 is noted thus: that organic farming shall pursue to establish a sustainable management system for agriculture with respect to nature's systems and cycles, and sustain and enhance the health of soil, water, plants and animals and the balance between them, and to contribute to a high level of biological diversity [5]. Organic farming systems generally harbour larger floral and faunal biodiversity, more so than conventional systems; however, when properly managed, the latter can also improve biodiversity. Importantly, the landscape surrounding farmed land also appears to have the potential to enhance biodiversity in agricultural areas [3]. However, the benefits of organic farming to biodiversity in agriculture landscapes are still being discussed.

Agrobiodiversity is an important aspect of biodiversity that is directly influenced by different production methods, especially at the field level. It can also supply several ecosystem services to agriculture, thus reducing environmental externalities and the need for off-farm inputs. Organic farming is considered an environmentally-friendly agricul-

http://dx.doi.org/10.5772/58974

ture practice and a holistic approach encompassing several demands and bans from a regulatory point of view [8], and receives primarily from European countries additional agri-environmental payments for ecosystem services, including biodiversity. In some countries, payments are available as single biodiversity measures (i.e., hedgerows, insectary strips, crop rotation, or the retention of semi-natural areas) in agri-environmental programmes that are also aimed at conventional agriculture.

2. Aim and methodology

The aim of this paper is to establish whether organic farming fulfils the promise of protecting biodiversity better than conventional farming, based on the review of recent publications emphasizing the importance of precisely quantifying the effect of organic vs. conventional farming. Additional to an extensive review, data from the University of Maribor regarding the effects of different production systems on the earthworm population [9] and the biodiversity of weed species from field experiments in the north east of Slovenia [10] were compared with other findings.

The reader is kindly referred to previously mentioned sources [5, 9, 10, 36] for a detailed description of differences between farming systems. For a better general understanding, some details are explained. Earthworms were collected in October 2009, 2010 and 2011 using a mustard aqueous solution as a non-toxic irritant that drove deep burrowing earthworm species to the surface [11]. After measurements were taken, earthworms were returned back to the soil. Analyses were carried out using the Statgraphics Centurion XV statistical program [12]. The biodiversity of weed species [9] was measured using two methods: (i) above-ground weed population sampling; (ii) seedbank sampling. The size of the weed seedbank was determined within the 0 to 0.2 m soil layer of each plot using the greenhouse emergence method [13]. The in situ number of the above-ground weed population per m^2 was measured at the end of June or at the beginning of July 2009, 2010 and 2011, after mechanical control and the use of herbicides. Weeds were counted in four 0.25 m^2 quadrates randomly located in the centre of each plot, parallel to the working direction of machinery. The weed species were determined when a 2/3 population was at the stages of 2 to 3 true leaves and 1/3 was at the stages of 4 to 5 true leaves. Species diversity was calculated for both seedbank and weed communities using H’ [14].

3. Results and discussion

3.1. Overall data

Results of several research studies and published scientific articles showed that organic farming benefits to the environment, including biodiversity. Comparison of biodiversity in organic and conventional farms has shown that organic farming generally had positive impacts on many species [15]. Results of meta-analyses that compared biodiversity in organic and conventional farms found that organic farms generally have 30% higher species richness and 50% higher abundance of organisms than conventional farms. However, there are wide variations between different studies, which have to be discussed; for example, 16% of studies found a negative effect of organic farming on species richness. Additionally, it was also found that the effect of organic farming on species richness was larger for intensively managed landscapes than for diverse landscapes with many non-crop biotopes [16]. In 327 out of 396 relevant results [17], a higher degree of biodiversity in organic farming was found when compared to conventional farming. In 56 papers (14 %), no difference was verified and in 13 contributions (3%), organic farming yielded less biodiversity (seven of them for soil invertebrates). Significantly, the positive effect of organic farming on biodiversity compared to conventional farming was noticed in 80% of cases; in 16%, differences were unclear and less biodiversity was found in 4% of comparisons (Table 1).

Author	Number of comparisons[1]	Number of biodiversity indicators[2]	Significantly positive effect – more biodiversity	No significant differences – unclear, indifferent	Significantly negative effect – less biodiversity
Rahmann [17]	343	10	327	56	13
Hole et al. [15]	76	9	66	25	8
Pfiffner [18]	44	7	49	5	1
Sum			442	86	22
Share (%)			80	16	4

[1] Multiple citations of used studies are possible due to different conclusions for different species or multiple answers; [2] biodiversity indicators i.e., flora, weeds, soil biota, earthworms, pollinators, birds, etc.

Table 1. Impact of organic farming on biodiversity based on the literature review.

On average, organic farming increased species richness by about 30%. This result has been robust over the past 30 years of published studies. Organic farming had a greater effect on biodiversity as the percentage of arable fields of the landscape increased, that is, it is higher in intensively farmed regions [19]. Thus, it may be concluded that organic farming produces more biodiversity. Research gaps still exist for the understanding of functional biodiversity and ecosystem impact, which comprise soil biota, landscape (ecosystem and habitat) and genetic biodiversity on agricultural land in natural habitats [17]. The majority of current studies are from Northern and Western Europe and North American agriculture practices, while other regions with large areas of organic farming have been poorly investigated. Comparison between paired organic and conventional fields in India assessed a wide range of taxa (plants, soil microbes, earthworms, butterflies, dragonflies and other arthropods, reptiles, molluscs, amphibians/frogs and birds) trough different methods that showed similar trends. Habitat area, composition and management of organic fields were likely to favour higher levels of biodiversity by supporting higher numbers of species, dominance and abundance across most taxa. Organic fields are systems that are less dependent on external inputs to restore and rejuvenate the environment, resulting in higher biodiversity that promotes higher sustainable production on a long-term basis [20]. The effects of time since conversion to organic farming on species richness and abundance have been poorly researched. Plant and butterfly species richness was 20% higher on organic farms and butterfly abundance was about 60% higher, compared to conventional farms. Time since conversion to organic farming affected butterfly abundance gradually over a 25-year period, resulting in a 100% increase; however, no effect was found on plant or butterfly species richness, indicating that the main effect took place immediately after the conversion to organic farming [21].

Three recent multiregional studies from Europe have also demonstrated the negative effects of both agricultural intensification (increased use of synthetic fertilizers and pesticides combined with the reduced use of diversified farming system techniques) and landscape simplification on components of biodiversity [2]. The EU Biodiversity Strategy to 2020 also focuses on sustainable farming and forestry as the focus of one of six targets in the form of improving the integration of biodiversity conservation into key policies for agriculture and forestry. Combined, these two sectors include almost 72% of land in the EU and play a major role in Europe's biodiversity [1].

Crop rotation brings biodiversity in the time scale. It is mandatory on organic farms and is stated as a method to maintain and increase the fertility and biological activity of the soil, and means the prevention of damage caused by pests, diseases and weeds [8]. Due to more diverse crop rotation and the use of green manure and intercroppings on organic farms, there is also greater biodiversity. Furthermore, using domestic populations of seed varieties preserves biodiversity, but the production of alternative crops (rare, underutilized, disregarded, neglected or new) increase biodiversity at the filed level [22].

3.2. Weeds biodiversity

The biodiversity of weed communities in agro-ecosystems provides several valuable ecological functions [23]. Conventional and integrated production systems tend to be similar in both intensity of management and within-field biodiversity, but organic production tends to support greater density, species number and biological diversity in comparison with other investigated production systems [24]. At the field level, species richness was the greatest on organic farms where there was a greater abundance of weeds [24-27, 31; organic production system had the highest biodiversity of weed species [28-31]. Organic agricultural practices yielded more weed species in root crops, red clover/grass mixtures and in winter triticale. Weed species richness was reduced in red clover/grass stands, while root crops and spring barley undersown with red clover and grasses decreased weed species diversity, which is also important for achieving higher yields in an organic production system. The species composition and in particular the quantitative structure of weeds were affected more by crop species and cultivation regime, compared to different agriculture practices (organic vs. integrated). Weed communities of crops grown using organic and integrated farming systems were more similar in terms of species composition than quantitative structure [30].

The maintenance of a diverse weed community is one step towards the sustainability of an agro-ecosystem through improved nutrient cycling and pest control, improved soil chemical and physical properties, and the reduction of soil erosion. An important aspect in the evaluation of the environmental impact of production systems is the biodiversity index for weed species (Table 2). Using the Shannon-Weaver diversity index for weeds of different production systems (conventional, integrated, organic) growing white cabbage and red beet showed that the biodiversity index was significantly higher in organic systems (0.86 in organic vs. 0.66 in conventional systems for cabbage and 0.81 in organic vs. 0.59 in conventional for red beet). Using ecological footprint calculation for the evaluation of different production systems showed that organic farming had the lowest impact on the environment. In the case of white cabbage and red beet production, ratio in ecological footprint between organic and conventional production was 1 to 3.5 [10].

The emerged weed flora is more affected by recent agrochemical inputs than the seedbank, which is buffered by the persistence of weed seeds in the soil. The seedbank is more strongly influenced by soil characteristics, such as the percentage organic carbon and percentage total nitrogen than by management [26]. The same weed species were in the seedbank and at field counted as germinated weeds, totalling 29 weed species in the survey (Table 2). The accumulated number of observed species pooled over fields was highest in the organic production of white cabbage and red beet, with 29 and 28 species, respectively. Within the conventional crop rotations, 18 species were observed in the cabbage field and 17 in the red beets field, while 20 and 19 were observed in the integrated crop rotation for cabbage and red beets. The differences in the number of weed species between conventional and integrated fields for cabbage were not significantly different; however, the difference when comparing organic and conventional fields was significantly different for both vegetables. For red beet, differences among all production systems were significant, which is contrary to the findings of [30], where weed communities of crops grown under organic and integrated farming systems were similar with regard to species composition but not quantitative structure. Different farming practices (described as organic, integrated and conventional) appeared to exert selection pressure on the species composition of the seedbank, building up different communities under the three farming systems over time [26]. These effects were scale dependent. At a within-field scale, species richness was greatest in organic farms, where there was a greater abundance of weeds; this was similar to our results and those of many others [24-31]. These results suggest that weed species diversity can be promoted by using organic cropping practices [31].

	Weeds in white cabbage		**Weeds in red beet**		
Production system	**H'**	**O**	**H'**	**O**	**Earthworm population (no./ 0.25m²)**
Control	0.38d	14c	0.32d	13c	11.58b
Conventional	0.66c	18b	0.59c	17b	11.25b
Organic	0.86a	29a	0.81a	28a	22.41a
Integrated	0.74b	20b	0.64b	19b	13.00b
Biodynamic	-	-	-	-	24.00a

[a-d] Mean values followed by different letters within a column are significantly different (Duncan, α=0.05)

Table 2. Shannon-Weaver diversity index (H') and the frequency of occurrence (O) of weed species from the 30 species present in white cabbage and red beet in different production systems [10],3 and the influence on earthworm population [9, 36].

3.3. Earthworms population

Organic farming systems are generally associated with increased biological activity and increased below-ground biodiversity. The main impacts on biological fertility do not result from the systems per se, but are related to the amount and quality of the soil organic matter that is used in the farming system, as well as the disruptions of soil habitat using different tillage tools. Even within the constraints of organic farming practices, it is possible for farmers to make changes to management practices using less tillage, which will tend to improved soil biological quality [32]. An important part of soil biodiversity is arbuscular mycorrhizal fungi, which can provide several benefits to plants and ecosystems. Organic farming enhances arbuscular mycorrhizal fungi, communities of which are similar in organically managed fields and in semi-natural species-rich grasslands; however, significantly less communities are found in conventionally managed fields. Their richness increased significantly over time since conversion to organic agriculture [33]. Soil microorganisms and other parts of soil biota including earthworms are also important drivers of soil fertility. Organic farming is based on the principle of the maintenance and enhancement of soil life and natural soil fertility, soil stability and soil biodiversity for preventing and combating soil compaction and soil erosion, and for the nourishing of plants primarily through the soil ecosystem [8]. Furthermore, our research results investigating the number and mass of earthworms as an indicator of soil biodiversity confirmed the effects of different production systems (conventional, integrated, organic, biodynamic) on the population of earthworms following the harvesting of different crops [9].

The studied production systems significantly influenced total earthworm population (Table 2) and small earthworms [36]. Both were shown to be higher in number in the biodynamic and organic production systems compared to the control, conventional and integrated production systems. When compared to control plots, as well as those managed without fertilizers and plant protection agents, there were roughly 2.7 and 2.5 times more small earthworms in biodynamic and organic production systems, respectively. In the same manner, the total earthworm population in the biodynamic production system was 207% and in the organic production system, 193% of this was counted for the control treatments. Similarly, the beneficial effect of organic farming on earthworms has been emphasized by other investigations [34, 35]. The abundance of earthworms, as well as their total body mass, was affected by plant species occurring in crop rotation. Oil pumpkins were revealed to have a beneficial effect on earthworms. There was also a significant production system and plant species interaction concerning the population of small earthworms [36]. In addition to a production system, tillage is also a major driver for altering communities of earthworms and microorganisms in arable soils. The use of reduced tillage provides an approach for eco-intensification by enhancing inherent soil biota functions in organic arable farming [37].

3.4. Some other ecosystem services connected to biodiversity

Biodiversity, as one of the most important ecosystem services of organic farming, is firmly connected to biocontrol and pollination services [2]. While the field of organic crop production has increased globally, the potential interactions between pest management in organic and conventionally managed systems have to date received little attention [38]. Organic agriculture improves biodiversity at the field level, but potential interactions with the surrounding landscape and the potential effects on ecosystem services are less well known. Predation of aphids was the highest in organic fields in mixed landscapes and lower in more uniform surroundings. The results of comparing 153 farms from five countries showed that organic agriculture improved the biodiversity of plants and birds in all landscapes, but only in more diverse surroundings did it improve the potential for biological control. Contradictory results showed the necessity for taking into consideration production methods (organic vs. conventional) and regional landscape complexity for developing agri-environmental schemes for the future [39]. Organic farming is one of the most successful agri environmental schemes, as humans benefit from high quality food and farmers from higher prices for their products; additionally, this approach often successfully protects biodiversity. Based on the assessment of 30 triticale fields (15 organic vs. 15 conventional) and the comparison of five conventional fields that were treated with insecticides and 10 non-treated conventional fields, it was found out that organic fields had five times higher plant species richness and about 20 times higher pollinator species richness compared to conventional fields. In contrast, the abundance of cereal aphids was five times lower in organic fields, while predator abundances were three times higher and predator-prey ratios 20 times higher in organic fields, indicating a significantly higher potential for biological pest control in organic fields [40]. Aphid density was also significantly lower in organic wheat fields compared to conventional fields, based on the assessment of 216 wheat fields during a two-year study [41]. Another positive impact of crop genetic diversity where wheat is concerned was found on below (collembola) and aboveground arthropod (spiders and predatory carbides) diversity at the field scale, which may be the result of a wider variety of food resources or more complex crop architecture. Increasing crop genetic diversity can therefore be an easy-to-implement scheme for benefiting farmland biodiversity [42].

Despite decades of European policy to ban harmful pesticides, the negative effects of pesticides on wild plant and animal species are nonetheless present and can be observed through losses pertaining to biodiversity. Chemical pesticides minimize opportunities for biological pest control. If there is an aim for biodiversity to be restored in Europe, opportunities should be created for crop production utilizing biodiversity-based ecosystem services such as biological pest control; what is needed is a Europe-wide shift towards farming employing the minimal use of pesticides over large areas, not only on organic farming areas [43]. Insecticide treatment in conventional fields had only a short-term effect on aphid densities, while later in the season, aphid abundances were even higher and predator abundances lower in treated compared to untreated conventional fields. Preventative insecticide application in conventional fields has only short-term effects on aphid densities but long-term negative effects on biological pest control. Therefore, conventional farmers should restrict insecticide applications to situations where thresholds for pest densities have been reached. Organic farming increases biodiversity, including important functional groups like plants, pollinators and predators, which in turn enhance natural pest control [40].

Biodiversity supplies multiple ecosystem services to agriculture. In addition to the potential for biological pest control, pollination problems are a topic now also being addressed in EU agriculture policy [43]. Declines in insect-pollinated plants and their pollinators have been reported as a result of agricultural intensification [44]. Reducing farming intensity with conventionally managed leys does not seem to be as effective as organic farming for delivering crop pollination services [45]. The abundance of pollinators was more than 100 times higher on organic fields. Plant and pollinator species richness, as well as predator abundances and predator-prey ratios, were higher at field edges compared to field centres, highlighting the importance of field edges for ecosystem services [40].

Pollination systems within intensive grassland communities may be different from those in arable systems. Results from comparing plant community composition among 10 pairs of organic and conventional dairy farms indicate that organic management increases plant richness in field centres, but that landscape complexity exerts a strong influence on both organic and conventional field edges. Insect-pollinated forb richness showed positive relationships to landscape complexity, reflecting what has been documented for bees and other pollinators [44].

Hedges provide important nesting, feeding and sheltering sites for birds in agricultural areas, while organic farming also enhances the environments of farmland birds [15, 18, 46]. However, little is known about how the interaction of (the amount of) hedges and variables pertaining to the organic management of the landscape scale affects birds. Birds were surveyed in the fields and in the adjoining hedges on conventional and organic winter wheat fields and meadows. More bird species occurred in organic than in conventional fields, regardless of land-use type. Hedge length had a much stronger effect on bird richness than organic farming practice. The interaction of landscape complexity and hedge length was found to be connected. Hedge length enhanced bird richness only in the case of simple landscapes. In more complex landscapes, the local effect of hedge length levelled off, because bird richness was high even without local hedges. Adding hedges or introducing organic farming practices should be primarily promoted in simple landscapes, where it particularly makes a difference for biodiversity [46].

The effect of organic farming differs depending on the scale of uptake of a particular landscape. The local effect of organic farming was found to be consistently strong, with higher diversity in borders adjoining organic fields, most likely due to the lack of herbicides used on organically managed farmland. In addition to the proportion of semi-natural habitat, which is important for farmland biodiversity, the management practice of cropland can also influence diversity in semi-natural habitats. Forb richness, which was evaluated as an agri-environmental indicator for biodiversity was also higher within borders situated in landscapes with a high proportion of organic land, irrespective of local management; this was possibly as a result of the dispersal of primarily annual plant species from the organically managed fields into the borders (mass effect). Farming practice at a local and a landscape scale can independently influence plant species richness, indicating that organic farming can also influence diversity at larger spatial scales, as well as outside organically managed land [47]. Organic farming enhances species richness and the abundance of many common taxa, but its effects are often species specific, as well as trait or context dependant. Landscape enhances or reduces the positive effects of organic farming, or acts through interactions where the surrounding landscape affects biodiversity differently on organic and conventional farms [48].

Around the world, small farms are those that practice high-diversity agriculture. Small farmers often choose to cultivate several varieties of the same crop; additionally and perhaps more importantly, different farmers in a given locality often cultivate different varieties. On the other hand large farms usually sow a single variety over a wide area [49]. Small farms may in this way have an indirect, positive effect on biodiversity, since these farms normally have smaller land parcels and thus more field edges, which are relatively species-rich. Although the average organic farm is bigger in the EU than its conventional counterparts [50] and in some cases is "conventionalized", organic farming is nonetheless generally viewed as small farms. The world's majority of food is produced by smallholder farmers who grow over 70% of all our food. Organic farming on small farms leads to an increase in food production and to greater benefits for the ecosystem by improving soil organic matter, reducing erosion and increasing biodiversity. At the same time, organic farming also allows farmers to receive higher prices for their value-added produce and provide them with opportunities to export to markets niche [51]. The report of a study focusing on farming systems in Africa showed that it is possible to set broad priorities for agricultural intensification based on the organic principles of health, ecology, fairness and caring for the earth. Ecological principles and technologies can be used to support farmers in obtaining food security and improving their livelihoods without destroying the local indigenous biodiversity [52].

3.5. Agri-environmental payments and farmers' attitudes towards biodiversity

Agricultural intensification has caused significant declines in biodiversity, while the profound intensification of European agricultural practices in the past number of decades continues. This is due to decreasing crop diversity, simplification of cropping methods, the use of fertilizers and pesticides and the homogenization of landscapes, all of which have negative effects on biodiversity in agricultural areas. Agricultural management practices can have a substantial positive impact on the conservation of the EUs wild flora and fauna. Agri-environmental schemes including organic farming are thought to benefit biodiversity. Agri-environmental payments are part of Common agriculture policy, which promotes the multifunctional role of farming as a provider of food products and a steward of diverse landscapes, as well as the cultural and natural heritage of rural areas. Furthermore, in the future, according to the EU regulation 1305/2013, each member state has to introduce agri-environmental measures for enhancing biodiversity and the preservation of high nature value farming and forestry systems [53]. Ecosystem services payments must be based on a standardized and transparent assessment of the goods and services provided. This is especially relevant in the context of EU agri-environmental programmes, but also for organic-food companies that foster environmental services on their contractor farms [54].

Agri-environmental schemes have been introduced to minimize the effects of agricultural intensification and enhance farmland biodiversity, but evaluations have produced inconsistent results [47]. Biodiversity is in different countries supported by different measures (i.e., strips and hedges, crop rotation, autochthone varieties, Nature 2000 measures), as is organic farming, which enhances the species richness and abundance of above and below soil taxa [15-20]. Traditional farming contributes to the safeguarding of certain natural or semi-natural

http://dx.doi.org/10.5772/58974

habitats. Many valuable habitats and the presence of species have a direct interdependence with agriculture (e.g., many bird species nest and feed on farmland). Two major changes have contributed to upsetting the delicate balance between agriculture and biodiversity: (i) specialization and intensification of certain production methods (such as the use of more chemicals and heavy machinery); (ii) marginalization or abandonment of traditional land management, a key factor in preserving certain habitats and site-specific biodiversity. In some EU member states, land abandonment and the withdrawal of traditional management may become a threat to biodiversity on farmland. Therefore, preventing these processes is a key action for halting the loss of biodiversity. The Common agricultural policy addresses the preservation of habitats and biodiversity by specific rural development measures targeted at the preservation of habitats and biodiversity (agri-environmental and Nature 2000 payments), as well as requirements included in the scope of cross compliance for birds and habitats [55].

Agri-environmental payments to farmers for the conversion from conventional to organic farming or remaining inorganic should encourage them to participate in schemes, thereby responding to the increasing demand by society for the use of environmentally-friendly farm practices and also for high standards of animal welfare, as is the case in organic farming. In order to increase synergy in biodiversity and the benefits delivered by the organic farming, other measures should also be promoted and supported among organic farmers in order to cover larger areas or other protected areas, e.g., Nature 2000 [53].

In agricultural landscapes, farmers have a large impact on biodiversity through the management decisions and agricultural practices that are used on their farms. Farmers' perceptions of biodiversity and its different values influence their willingness to apply biodiversity-friendly farming practices. Organic and conventional farmers' perceptions of the different values of biodiversity were analysed across three European countries. Farmers' perceptions of biodiversity were strongly connected to their everyday lives and linked to farming practices. In addition to recognizing the importance of variety, species and habitat diversity, farmers also acknowledged wider landscape processes and attached value to the complexity of ecological systems. It was found that organic farmers tended to have a more complex and philosophical approach to biodiversity, with little differences being observed between these farmers; conventional farmers, on the other hand, exhibited more differences among themselves. Furthermore, ethical and social values were important for all farmers, but economic value was more important for conventional farmers, which has an impact on their behaviour [56].

Based on a survey among organic and conventional farmers, it was concluded that they had similar attitudes to farming results and to the environment; however, organic farmers were better informed about environmental issues and carried out more environmentally-friendly practices and behaviours. More biodiversity was found on environmentally-friendly orientated farms and less on high production-orientated farms. Organic farmers with more positive attitudes to the environment and who were better informed about environmental topics had higher biodiversity on their farms compared to others. Although there were disparities between attitudes and actual behaviours in relation to the environment among organic farmers sharing similar attitudes to conventional farmers, they were more prepared to inform themselves about and carry out environmentally-friendly farming. Results of the comparison study showed that biodiversity benefitted more from organic farming and environmentally- oriented farmers, and that there is an important link between farmers' environmental attitudes and knowledge and the beneficial effects of organic farming on biodiversity [57].

Farmers strongly acknowledged ethical and social biodiversity values. This suggests that soft policy tools can also foster biodiverse-sensitive farming methods that are complementary to mainstream monetary incentives [55]. As farmers receive a majority of agri-environmental payments, they can be more involved in data generation and conservation management. Farm size is very important in terms of the amount of payments that are provided per hectare and for improving biodiversity on a bigger scale. A standardized model for measuring on-farm biodiversity does not yet exist in practice. Performance indicators should be focused on and farmers should be included in generating this information. A framework is needed for assessment of the results and for management measures that can be employed on farms. Another requirement is ease of application, which encompasses the simplicity of gathering input data and its clarity to those farmers who will apply it [54]. Conservation-oriented thinking and better environmental education among farmers should be encouraged for those who already participate in an agri-environmental scheme and even more so amongst new-comers. In this way, the benefits of the agri-environmental schemes for the environment can be maximized [57].

An open source farm assessment system was prepared for the assessment of biodiversity including biotopes, species, biotope connectivity and the influence of land use. Interviews with the test farmers showed that the assessment methods can be implemented on farms and that they were understood by farmers [54].

4. Conclusions

The analysed data showed that in the past decades, the specialization and intensification of agriculture production methods have had negative effects on biodiversity. The future holds the challenge of designing more sustainable farming systems that are productive and maintain or enhance the provision of ecosystem services, including biodiversity. The significantly positive effect of organic farming on biodiversity compared to conventional farming was noticed in 80% of cases; in 16%, differences were unclear and less biodiversity was found in 4% of comparisons [15, 17, 18], where seven to 10 biodiversity indicators were taken into account. Small farms in particular may have an indirect positive effect on biodiversity. These farms generally have smaller land parcels and thus more field edges, which are relatively species-rich.

We can conclude that the benefits of organic farming on biodiversity are as follows:

i. Organic farming increased species richness by about 30% and had a greater effect on biodiversity, as the percentage of the landscape consisting of arable fields increased. It was found that organic fields had up to five times higher plant species richness compared to conventional fields. For example, plant and butterfly species richness was up to 20% higher on organic farms and butterfly abundance was about 60% higher. After the conversion from conventional to organic farming abundance of butterflies was increased for 100%. Organic farming enhanced arbuscular mycorrhizal fungi and its communities. This was similar in organically managed fields and in semi-natural species rich grasslands, but significantly fewer communities were found in conventionally managed fields. Their richness increased significantly over time from the point of a conversion to organic agriculture.

ii. The occurrence of weed species was significantly higher in the organic production of white cabbage and red beet compared to integrated and conventional production. The biodiversity index was significantly higher in organic production compared to the conventional method, 0.86 vs. 0.66 for cabbages and 0.81 vs. 0.59 for red beets. Conventional and integrated production systems tended to be similar both in terms of the intensity of management and regarding within-field biodiversity; however, organic production tended to support greater density, species number and biological diversity compared to other investigated production systems.

Earthworms were more abundant on organically managed fields. In organic and biodynamic farming plots, the number of earthworms was on average two times higher compared to integrated, conventional and control plots.

iii. Biodiversity as one of the most important ecosystem services of organic farming is firmly connected to biocontrol and pollination services, which are enhanced when using no or less chemicals. The abundance of cereal aphids was five times lower in organic fields, while predator abundances were 20 times higher in organic fields, indicating a significantly higher potential for biological pest control in organic fields. Organic fields had 20 times higher pollinator species richness compared to conventional fields. Pollinators and predator abundance was higher at field edges compared to field centres, highlighting the importance of field edges for ecosystem services. Edges provide important nesting, feeding and sheltering sites for birds in agricultural areas. Thus, organic farming enhances farmland birds.

Overall, organic agriculture appears to perform better than conventional farming and provides important environmental advantages such as halting the use of harmful chemicals and their spread in the environment and along the trophic chain, reducing water use, as well as reducing carbon and ecological footprints. As we have underscored, organic farming fulfils the promise to protect biodiversity better than conventional farming. However, in the European commission document, The EU Biodiversity Strategy to 2020 [1], organic farming is not even mentioned, while in the European Parliament resolution regarding the strategy [6], organic farming is mentioned only once in the context of a call for a strengthening of Pillar II and for drastic improvements to the environmental focus of that pillar, and to the effectiveness of its agri-environmental measures. Supporting farmers to convert their properties to organic land and to maintain organic farming within the scope of agri-environmental schemes as a part of Common agriculture policy can have a significant impact on biodiversity as a result of management decisions farmers apply to their agricultural land.

Acknowledgements

The results presented in this paper are in part an output of the national research project J4-9532: "The quality of food dependent on the agricultural production method", funded by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia and Slovenian Research Agency.

Author details

Martina Bavec* and Franc Bavec

*Address all correspondence to: martina.bavec@um.si

University of Maribor, Faculty of Agriculture and Life Sciences, Hoče/Maribor, Slovenia

References

[1] European Commission. The EU Biodiversity Strategy to 2020. 2011. http://ec.europa.eu/environment /nature/info/pubs/docs/brochures/2020%20Biod%20brochure%20final%20lowres.pdf (Accessed 1 April 2014).

[2] Kremen, C., Miles, A. Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. Ecology and Society. 2012;17 http://dx.doi.org/10.5751/ES-05035-170440 (Accessed 1 April 2014).

[3] Gomiero, T., Pimentel, D., Paoletti, M.G. Environmental Impact of Different Agricultural Management Practices: Conventional vs. Organic Agriculture. Critical Reviews in Plant Sciences. 2011:30 95-124.

[4] Tuomisto, H.L., Hodge, I.D., Riordan, P., Macdonald, D.W. Does organic farming reduce environmental impacts? - A meta-analysis of European research. Journal of Environmental Management. 2012;112 309-320.

[5] Bavec, M., Naradoslawsky, M., Bavec, F., Turinek, M. Ecological impact of wheat and spelt production under industrial and alternative farming systems. Renewable Agriculture and Food Systems, 2012;27 242-250.

[6] Our life insurance, our natural capital: an EU biodiversity strategy to 2020. European Parliament resolution of 20 April 2012 on our life insurance, our natural capital: an EU biodiversity strategy to 2020 (2011/2307(INI)). http://consilium.europa.eu/media/1379139/st18862.en11.pdf (Accessed 20 March 2014).

[7] EC Proposal for a Decision of the European Parliament and of the Council on a Genaral Union Environment Action Programme to 2020 "Living well, within the limits of our planet" /* COM/2012/0710 final - 2012/0337 (COD). http://www.europarl.euro-

pa.eu/sides/getDoc.do?type= REPORT&reference=A7-2013-0166&language=EN (Accessed 20 March 2014).

[8] Council Regulation (EC) No 834/2007 of 28 June 2007 on organic production and labelling of organic products and repealing Regulation (EEC) No 2092/91. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:189:0001:0023:EN:PDF (Accessed 1 April 2014).

[9] Turinek, M. Comparability of the biodynamic production system regarding agronomic, environmental and quality parameters. Ph.D. thesis. University of Maribor; 2011.

[10] Štraus, S. Potential indicators for sustainability assessment of food production on the field level. Ph.D. thesis. University of Maribor; 2012.

[11] Lawrence, A.P., Bowers, M.A. A test of the 'hot' mustard extraction method of sampling earthworms. Soil Biology and Biochemistry. 2002;34 549-552.

[12] Statgraphics® Centurion XV. User Manual. Herndon, StatPoint, Inc. 2005, 287.

[13] Teasdale, J.R., Mangum, R.W., Radhakrishnan, J., Cavigelli, M.A. Weed seedbank dynamics in three organic farming crop rotations. Agronomy Journal. 2004;96 1429-1435.

[14] Magurran, A.E. Ecological diversity and its measurement. Princeton University Press, Princeton. 1988, 179.

[15] Hole, D.G., Perkins, A.J., Wilson, J.D., Alexander, I.H., Grice, F., Evans, A.D. Does organic farming benefit biodiversity? Biological Conservation. 2005;122 113-130.

[16] Bengtsson, J., Ahnstrom, J., Weibull, A. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology. 2005;42 261-269.

[17] Rahman, R. Biodiversity and organic farming: What do we know? Agriculture and Forestry Research. 2011:61 189-208.

[18] Pfiffner, L. Which farming methods enhance faunal diversity? Agrarforschung. 1996:3 527-530.

[19] Tuck, S.L., Winqvist, C., Mota, F., Ahnstrom, J., Turnbull, L.A., Bengtsson, J. Land-use intensity and the effects of organic farming on biodiversity: a hierarchical meta-analysis. Journal of Applied Ecology, 2014;51 746-755.

[20] Padmavathy, A., Poyyamoli, G. Biodiversity comparison between paired organic and conventional fields in Puducherry, India. Pakistan Journal of Biological Sciences. 2013;16 1675-1686.

[21] Jonason, D., Andersson, G.K.S., Ockinger, E., Rundlof, M., Smith, H.G., Bengtsson, J. Assessing the effect of the time since transition to organic farming on plants and butterflies. Journal of Applied Ecology. 2011:48 543-550.

[22] Bavec, F., Bavec, M. Organic production and use of alternative crops. Boca Raton, New York, London : Taylor & Francis: CRC Press. 2006.

[23] Marshall, E.J.P., Brown, V.K., Boatman, N.D., Lutman, P.J.W., Squire, G.R., Ward, L.K. The role of weeds in supporting biological diversity within crop fields. Weed Research. 2003;43 77-89.

[24] Kleijen, D., Baquero, R.A., Clough, Y., Diaz, M., De Esteban, J., Fernandez, D.G., Herzog, F., Holzschuh, A., Johl, R., Knop, E., Kruess, A., Marshall, E.J.P., Steffan-Dewenter, I., Tscharntke, T., Verhulst, J., West, T.M., Yela, J.L. Mixed biodiversity benefits of agri-environment schemes in five European countries. Ecol. Lett. 2006;9 243-254.

[25] Hyvonen, T., Ketoja, E., Salonen, J., Jalli, H., Tiainen, J. Weed species diversity and community composition in organic and conventional cropping of spring cereals. Agric. Ecosyst. Environ. 2003;97 131-149.

[26] Hawes, C., Squire, G.R., Hallett, P.D., Watson, C.A., Young, M. Arable plant communities as indicators of farming practice. Agric. Ecosyst. Environ. 2010;138 17-26.

[27] Pacini, C., Wossink, A., Giesen, G., Vazzana, C., Huirne, R. Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. Agric. Ecosyst. Environ. 2003;95 273-288.

[28] Pacini, C., Wossink, A., Giesen, G., Vazzana, C., Omodei-Zorini, L., Huirne, R. The EU's Agenda 2000 reform in the sustainability of organic farming in Tuscany: ecological-economic modeling at field and farm level. Agric. Syst. 2004;80 171-197.

[29] Wortman, E.S., Lindquist, J.L., Haar, M.J., Francis, C.A. Increased weed diversity, density and above-ground biomass in long-term organic crop rotations. Renewable Agriculture and Food Systems. 2010;25 281-295.

[30] Jastrzebska, M., Jastrzebski, W.P. Holdynski, C. Kostrzewska, M.K. Weed species diversity in organic and integrated farming system. Acta Agrobotanica. 2013;66 113-124.

[31] Edesi, L., Jarvan, M., Adamson, A., Lauringson, E., Kuht, J. Weed species diversity and community composition in conventional and organic farming: a five-year experiment. Zemdirbyste-Agriculture. 2012;99 339-346.

[32] Stockdale, E.A., Watson, C.A. Biological indicators of soil quality in organic farming systems. Renewable agriculture and food systems. 2009;24 308-318.

[33] Verbruggen, E., Roling, WFM, Gamper, H.A., Kowalchuk, G.A., Verhoef, H.A., van der Heijden, M.G.A. Positive effects of organic farming on below-ground mutualists: large-scale comparison of mycorrhizal fungal communities in agricultural soils. New Phytologist. 2010;186 968-979.

[34] Riley, H., Pommeresche, R., Eltun, R., Hansen, S., Korsaeth, A. Soil structure, organic matter and earthworm activity in a comparison of cropping systems with contrasting

tillage, rotations, fertilizer levels and manure use. Agriculture, Ecosystems and Environment. 2008;124 275-284.

[35] Irmler, U. Changes in earthworm populations during conversion from conventional to organic farming. Agriculture, Ecosystems and Environment. 2010;135 194-198.

[36] Bavec M., Prašnički M., Grobelnik Mlakar S., Turinek M., Robačer M., Bavec F. Influence of different production systems on body mass and number of earthworms. V: 46th Croatian and 6th International Symposium on Agriculture, Opatija, Croatia, February 14-18, 2011. Pospišil, Milan (ed.). Proceedings. Zagreb: University of Zagreb, Faculty of Agriculture. 2011; 61-65.

[37] Kuntz, M., Berner, A., Gattinger, A., Scholberg, J.M., Maeder, P., Pfiffner, L. Influence of reduced tillage on earthworm and microbial communities under organic arable farming. Pedobiologia. 2013;56 251-260.

[38] Bianchi, F.J.J.A., Ives, A.R., Schellhorn, N.A. Interactions between conventional and organic farming for biocontrol services across the landscape. Ecological Applications. 2013;23 1531-1543.

[39] Winqvist, C., Bengtsson, J., Aavik, T., Berendse, F., Clement, L.W., Eggers, S., Fischer, C., Flohre, A., Geiger, F., Liira, J. Mixed effects of organic farming and landscape complexity on farmland biodiversity and biological control potential across Europe. Journal of Applied Ecology. 2011;48 570-579.

[40] Krauss, J., Gallenberger, I., Steffan-Dewenter, I. Decreased Functional Diversity and Biological Pest Control in Conventional Compared to Organic Crop Fields. Plos One. 2011;6.

[41] Gosme, M., de Villemandy, M., Bazot, M. Jeuffroy, M.H. Local and neighbourhood effects of organic and conventional wheat management on aphids, weeds, and foliar diseases. Agriculture Ecosystems and Environment. 2012;161 121-129.

[42] Chateil, C., Goldringer, I., Tarallo, L., Kerbiriou, C., Le Viol, I., Ponge, J.F., Salmon, S., Gachet, S., Porcher, E. Crop genetic diversity benefits farmland biodiversity in cultivated fields. Agriculture Ecosystems and Environment. 2013;171 25-32.

[43] Geiger, F., Bengtsson, J., Berendse, F., Weisser, W.W., Emmerson, M., Morales, M.B., Ceryngier, P.,; Liira, J., Tscharntke, T., Winqvist, C. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic and Applied Ecology. 2010;1 97-105.

[44] Power, E.F., Kelly, D.L., Stout, J.C. Organic Farming and Landscape Structure: Effects on Insect-Pollinated Plant Diversity in Intensively Managed Grasslands. Plos One. 2012;7.

[45] Andersson, G.K.S., Ekroos, J., Stjernman, M., Rundlof, M., Smith, H.G. Effects of farming intensity, crop rotation and landscape heterogeneity on field bean pollination. Agriculture Ecosystems and Environment. 2014;184 145-148.

[46] Batary, P., Matthiesen, T., Tscharntke, T. Landscape-moderated importance of hedges in conserving farmland bird diversity of organic vs. conventional croplands and grasslands. Biological Conservation. 2010;143 2020-2027.

[47] Rundlof, M., Edlund, M., Smith, H.G. Organic farming at local and landscape scales benefits plant diversity. Ecography. 2010;33 514-522.

[48] Winqvist, C., Ahnstrom, J., Bengtsson, J. Effects of organic farming on biodiversity and ecosystem services: taking landscape complexity into account. Year in ecology and conservation biology (ed. Ostfeld, RS; Schlesinger, WH) Annals of the New York Academy of Sciences. 2012;1249 191-213.

[49] Boyce, J.K. A Future for Small Farms? Biodiversity and Sustainable Agriculture. Working paper series. 2004: No 86. http://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1071&context=peri_workingpapers (accessed 24 April 2014).

[50] European Union Agriculture and rural development. Facts and figures on organic agriculture in the European Union. 2013. http://ec.europa.eu/agriculture/markets-and-prices/more-reports/pdf/organic-2013_en.pdf (accessed 24 April 2014).

[51] IFOAM press release. Highlights the Plight of Smallholder Farmers on Earth Day. http://www.ifoam.org/ sites/default/files/pr_earth_day_0.pdf (accessed 25 April 2014).

[52] Berhan, T. Egziabher, G., Edwards, S. Knowledge of Africa's rich plant biodiversity as a basis for the ecological intensification of agriculture and protecting biodiversity. Acta Universitatis Upsaliensis Symbolae Botanicae Upsalienses. 2011;35 229-250.

[53] Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005. http://ec.europa.eu/digital-agenda/en/news/regulation-eu-no-13052013-european-parliament-and-council (accessed 24 July 2014).

[54] von Haaren, C. Kempa, D; Vogel, K; Ruter, S. Assessing biodiversity on the farm scale as basis for ecosystem service payments. Journal of environmental management. 2012;113 40-50.

[55] Agriculture and biodiversity. 2014. http://ec.europa.eu/agriculture/envir/biodiv/index_en.htm (accessed 24 July 2014).

[56] Kelemen, E., Nguyen, G., Gomiero, T., Kovacs, E., Choisis, J.P., Choisis, N., Paoletti, M.G., Podmaniczky, L., Ryschawy, J., Sarthou, J.P. Farmers' perceptions of biodiversity: Lessons from a discourse-based deliberative valuation study. Land use policy. 2013;35 318-328.

[57] Power, E.F., Kelly, D.L., Stout, J.C. Impacts of organic and conventional dairy farmer attitude, behaviour and knowledge on farm biodiversity in Ireland. Journal for nature conservation. 2013;21 272-278.