# Biodiversity and Organic farming: What do we know?

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**Abstract**

The number of studies on organic farming and biodiversity increased significantly within the last years. Meanwhile organic farming has been recognised as a field with scientific relevance. About 19,000 publications were found in the Web of Science (www.isiknowledge.com) using Endnote® software with the wording "organic farming", and out of these about 1,200 were published by German scientists (6 %). In total 766 publications of these papers contained also the word "biodiversity" (3.5 %). Half of them were published during the last five years, and are mostly authored by Europeans. A meta-data analysis of these 766 scientific papers has been carried out to answer the question whether organic farming has an advantage for biodiversity in comparison to conventional farming systems.

327 out of 396 relevant results found a higher degree of biodiversity in organic farming when compared to conventional farming. In 56 papers (14 %) no difference was verified, and in 13 contributions (3 %) organic farming yielded less biodiversity (7 of them for soil invertebrates).

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. In addition, more information is required about biodiversity of farming systems in non-European regions, particularly in the tropics and sub-tropics.

*Keywords: Agri-environmental schemes, organic farming, biodiversity, integration, long-term field studies, segregation*

**Zusammenfassung:**

**Biodiversität und Ökologischer Landbau – Was wissen wir?**

In den letzten Jahren sind eine Vielzahl von neuen Studien zum Ökologischen Landbau und Biodiversität veröffentlicht worden. Der Ökologische Landbau hat als wissenschaftliches Objekt an Bedeutung gewonnen. Im web of science (www.isiknowledge.com) wurden mit dem Quellenrechercheprogramm Endnote® unter dem Stichwort "organic farming" 19.000 Quellen gefunden, davon 1.200 (6 %) aus Deutschland. Mit der ergänzenden Einschränkung "biodiversity" waren es immer noch 766 Quellen (3,5 %), wovon die Hälfte erst in den letzten fünf Jahren veröffentlicht wurde, vorwiegend aus Europa. In einer Metaanalyse wurden diese 766 Quellen auf ihre Aussagen bezüglich der Bedeutung des Ökologischen Landbaus für die Biodiversität untersucht.

Es konnten 396 Bewertungen verwendet warden. 327 (83 %) der Bewertungen stellten fest, dass der Ökologische Landbau mehr Biodiversität aufweisst als der konventionelle Landbau. Weitere 56 (14 %) der Bewertungen waren indifferent und nur 13 (3 %; davon 7 alleine im Bereich des Bodenlebens) stellten fest, dass die Biodiversität im Ökologischen Landbau niedriger als im konventionellen Landbau ist.

Zusammenfassend kann aus dieser Metaanalyse geschlossen werden, dass der Ökologische Landbau förderlich für die Biodiversität ist. Die wissenschaftliche Arbeit sollte sich verstärkt um die Lücken des Wissens zur funktionellen Biodiversität und landwirtschaftliche Systeme kümmern. Das Bodenleben, die Landschaft (Ökosystem, Habitate) sowie die genetische agro- und natürliche Biodiversität sind dabei hervorzuheben. Auch fehlt es an Wissen über die Wirkung des Ökolandbaus auf die Biodiversität tropischer oder sub-tropischer Agrozonen (vor allem außerhalb von Europa).

*Schlüsselworte: Agrarumweltmaßnahmen, Ökologischer Landbau, Biodiversität, Integration, Langzeit Feldstudien, Segregation*

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## 1 Introduction

Biodiversity is one of the most important resources on earth, and human activities endanger the total number of species. Large numbers are already extinct or close to being erased. At the Rio-conference 1992, the United Nations agreed to reduce biodiversity losses to zero in 2010. The goals have not been reached. Farming (intensification and land use change) are main reasons for biodiversity losses, but agriculture can also protect and enhance biodiversity. Several strategies have been developed to produce food and protect biodiversity. Organic farming is considered an environmentally-friendly form of food production and receives agri-environmental payments for the protection of biodiversity. But does organic farming live up to this expectation? A lot of scientific efforts have been made to answer this question. The presented meta-data analysis was made to give an up-to-date evaluation of the state of the art.

## 2 The background

Biodiversity is defined as the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (Reference). This biodiversity is threatened by human activities. Land use changes, degradation, pollution, climate change, and desertification and last but not least human population growth enforced the loss of biodiversity by factor 100 to 1,000 when compared to natural extinction. In 1992, the United Nations agreed to rescue the world's biodiversity. The Convention of Biological Diversity (CBD: 192 countries and the European Union) is one of the three Rio conventions. "The target agreed by the world's Governments in 2002 [Rio+10 summit in Johannesburg; GR], "*to achieve by 2010 a* significant *reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth",* has not been met. This disappointing conclusion is the introduction of the "Global Biodiversity outlook 3 of the United Nations in 2010", the year of biodiversity. This fatal situation needs to be faced though more than 170 countries (87 % of the Parties to the Convention, including Germany and the European Union) implemented national biodiversity strategies and action plans (Convention of Biological Diversity (CBD), 2010).

It is a fact that the world's biodiversity is still decreasing. The global Living Planet Index (LPI)[1] (WWF, 2010) has declined by more than 30 % since 1970. While the Tropical LPI declined by almost 60 %, the Temperate LPI [including Germany] increased by 15 %. Obviously, the efforts to protect environment and nature in temperate climates (mainly developed countries of the western world) have been successful after substantial declines in the past. About 1.75 million species are described worldwide but they are probably only a small share of the true total number (estimates provide a number of up to 13 million species; CBD, 2010).

In Germany, 48,000 animal species are described (Anonymous, 2011a), and 3,600 different plants can be found of which 2,800 are indigenous (Bundesamt für Naturschutz (BfN) ,2007). These figures include 77 tree species; 111 shrubs; 33,305 insects; 4,000 bacteria (estimations are 1 million bacteria species exist); 703 vertebrates with 100 mammals; 256 bird species; 14 reptiles, and 21 amphibians. Most of the 3001 higher plant and animal species are endangered because of land use changes and land use intensification (Rahmann, 2000). Among the European countries, losses in biodiversity are highest in Germany. About 28 % of the flora species and even more animal species (44 % of the birds, 51 % of the mammals, 61 % of ants, and 52 % of bees) are extinct or endangered (Anonymous, 2011b; BfN, 2008).

Agro-biodiversity is an important part of the world biodiversity. From the 250,000 worldwide described plant species, about 30,000 are edible, and about 7,000 are currently used for consumption. Not more than 30 species comprise more than 95 % of the food composition. And it is only three species (rice, wheat, corn) which supply more than 50 % of today's human food (Bundesanstalt für Landwirtschaft und Ernährung (BLE-BEKO), 2008). About 75 % of the genetic diversity of cultivated plants is already extinct (genetic erosion). Particularly fruits and vegetables species and varieties are endangered (Anonymous, 2011c). Crop production dominates the land use of many countries of the world. In Germany more than 50 % of the land surface is used for agriculture. Only a small number of different crop species are planted: A total of 27 % of the arable land is used for wheat, 17 % for barley, 15 % for corn, 12 % for oilseed rape, 4 % for rye so that only a quarter of the land is cultivated with any other plant. Counterproductive in terms of biodiversity is that crops are regularly cultivated in monoculture. The use of pesticides causes a change of the habitat and reduce/eradicate wild plants and wild animal biodiversity on a regional scale.

A similar trend can be observed in pens. More than 25 animal species are domesticated but only 11 of them are of economic relevance. Human selection has created a large number of different breeds. Many livestock breeds are endangered, especially sheep and goat breeds (Sambraus, 1999; www.g-e-h.de).The FAO registered more

[1] The Living Planet Index tracks nearly 4,000 populations of 241 fish, 83 amphibian, 40 reptile, 811 bird and 302 mammal species (WWF, 2010).

than 7,600 different breeds worldwide (FAO, 2007), and more than 1,500 of them are endangered.

The protection and backing of biodiversity is one of the main challenges of farming. Even before public laws enforced protection of wild plants and animals, organic farming had declared the aim to protect the environment and biodiversity in the first version of principles (IFOAM, 1980; www.ifoam.org).

One of the four principles of organic farming is defined by the International Federation of Organic Agricultural Movement (IFOAM, 2007): "*The Principle of Ecology: Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. […] Organic agriculture should attain ecological balance through the design of farming systems, establishment of habitats and maintenance of genetic and agricultural diversity. Those who produce, process, trade, or consume organic products should protect and benefit the common environment including landscapes, climate, habitats, biodiversity, air and water.*"

The preamble of the EU regulation 834/2007 confirms the IFOAM principle: "Organic production is an overall system of farm management and food production that combines best environmental practices, a high level of biodiversity, the preservation of natural resources, the application of high animal welfare standards and a production method in line with the preference of certain consumers for products produced using natural substances and processes." In Article 3 (Objectives and principles for organic production) is fixed that "Organic production shall pursue the following general objectives: (a) establish a sustainable management system for agriculture that: (i) respects nature's systems and cycles and sustains and enhances the health of soil, water, plants and animals and the balance between them; (ii) contributes to a high level of biological diversity;" This includes soil and aquatic biodiversity (article 5 (a) (n) as well as farm crop and livestock diversity (889/2008 introduction (8)).

In contrast to the segregation strategy of conventional farming (production or protection), biodiversity is an integral component of organic farming (production and protection) (Rahmann et al 2006; Schnug et al., 2008). Therefore wild plants, livestock and agricultural biodiversity are found as co-products of the farming activity. The use of herbicides (but also other pesticides) is prohibited which protects the natural flora and fauna. Only manual, mechanical and heat measures are permitted for weed control. Wild fauna such as insects, snails, beetles, and spiders can be controlled through biotechnological measures (traps, lime, etc.) and natural insecticides (Annex II of 889/2008/EU) (Kühne et al., 2006).

Organic farming is based on norms which are in force worldwide (IFOAM, 2005). Organic production is expanding continuously and is practiced in more than 160 countries (of a total of 195 countries; in the year 2000 only 86 countries were documented with organic production). In 2007, more than 1,800,000 farms (677,000 organic farms only in India) manage about 38 million hectares farmland organically with certification (0.9 % of total agricultural farmland; plus 42 million hectare wild collection area). 2/3 of the world's organic farmland is grassland (Willer et al., 2011).

Europe was and is the most driving continent in the development and establishment of organic farming. One quarter of the world's organic farm land is in Europe (200,000 farms, 7.8 million hectares, 1.9 % share of total farmland). In the European Union (EU27) about 180,000 farms manage 7.2 million hectares land organically (4 % of the total farmland; 2007) and generate produce worth 16.8 billion Euros (2008). With 5.9 billion Euros (2010), Germany has the biggest organic market in Europe. The market share of organic products in the German food market is about 3 %, about half of the Danish market share with 6.7 %, and Austria with 5.7 %. The world organic purchases are 6 Euro per capita and year (2009). In the USA, about 50 Euro $c^{-1}\,yr^{-1}$ were spent in 2008 per capita. With 26 Euro $c^{-1}\,yr^{-1}$ the organic purchases are less in the EU27. Danish citizens purchase about 132 Euro $c^{-1}\,yr^{-1}$, while Germany is in the middle field with about 71 Euro $c^{-1}\,yr^{-1}$ (AMI, 2010). 94 % of the German consumers buy organic food but only 3 % of all German consumers are relevant for 39 % of all organic sales. These intensive buyers spend about 730 Euro per year and household on organic food products. This is 39 % of total food purchase of these households (BÖLW, 2011). The Second National Nutrition Study of Germany (MRI, 2008) found that organic frequent consumers have a healthier lifestyle compared with non-organic consumers.

Currently the German farmers deliver about 50 % of the organic products for the German market, the other half is imported, mainly from other EU countries (BÖLW, 2011). The farmers get about 20 % of the market sales. That means, that 80 % of the value of organic products (final consumer spending) is earned in transport, processing and trade. This is comparable to conventional famers (AMI, 2010).

The implementation of official standards and regulations in the EU in 1992 (2092/91/EEC, 834/2007/EC and related regulations; http://ec.europa.eu/agriculture/organic/home_en) and the political support – European action plan for organic food and farming (since 2004) and national programmes like the German Bundespropgramm Ökologischer Landbau (www.bundesprogramm-oekolandbau.de) with more than 75 million Euro R&D fund since 2002 – were and are the main driving forces. The German speaking countries (DE, CH, AT) comprise the most relevant organic farming research in the world.

At the end of 2010, more than 21,000 German farms (5.6 % of total German farms) managed more than one million hectares farmland organically (5,6 % of total farmland) (BMELV, 2011). About 50 % of the German organic farmland is grassland, while total farmland comprises only 30 % in Germany. Grassland is important for biodiversity and has severely decreased in the last decades (Soussana and Duru, 2007), particularly in the last years in Germany in areas of biomass encroachment. The question is: Does organic farming fulfil the promise to protect the biodiversity better than non-organic (conventional) farming? A meta-data analysis was performed to answer this question.

## 3 Material and methods

The term "biodiversity" has many facets: It is commonly interpreted as species richness, only occasionally as the richness of varieties, cultivars or genetic expressions (e.g. micro-organisms) (Buchs, 2003; Buchs et al., 2003; Kasperczyk and Knickel, 2006). Not all papers gave clear answers on how to measure biodiversity. Classical ecology indexes were used to determine richness (S), but biodiversity (H') and dominance (D) were sometimes missing in the studies (Crowder et al., 2010). The impact of alpha (within-field level), beta (between-field level) and gamma diversity (landscape-level) is an important criterion (Rundlof et al., 2008). Here, it is necessary to evaluate and compare cultivation intensities, landscapes, micro-climate and agro-environments to respect the sensitivity of the biodiversity as an indicator of management.

The meta-data analysis was performed on the basis of scientific publications listed in the Web of Science and 'grey literature' in March 2011. The scientific papers are identified through a online database check in the Web of Science (www.isiknowledge.com), using Endnote® as the search and citation software, the online publication and project database organic eprints (http://orgprints.org) and grey literature in google (www.google.com), all under the search words "organic farming," "biodiversity", "[year]" and "[country]" in March 2011 (Table 1). In addition, the proceedings of the main scientific conferences of the organic sector in German speaking countries have been assessed as these papers are not listed in ISI.

Table 1:
Results of the web search "Organic farming", "biodiversity", "[year]", "[country]"

| **Results** | **Web of Science** (Endnote® search March 2011) | **Organic eprints** (March 2011) | **Google** (x1.000) |
|---|---|---|---|
| "biodiversity" | 97,215 | n.a. | 16,700 |
| "Organic farming" | 19.158 | 10.876** | 8.860 |
| "Organic farming", "Germany": | 1.276 | 2.923** | 7.740 |
| "Organic farming", "biodiversity": | 766 | 96*** | 3.390 |
| - Year of publication: | | | |
| < 1991 | 0 | 0 | 142 |
| 1991 – 1995 | 17 | 1 | 145 |
| 1996 – 2000 | 78 | 3 | 142 |
| 2001 – 2005 | 250 | 37 | 530 |
| 2006 – 2011 | 421 | 55 | 2.010 |
| - selected countries, continents: | | | |
| Germany | 44 | 35 | 672 |
| European Union | 287* | 83 | 1.978 |
| USA, Canada | 38+14 | 3+0 | 497 |
| India | 31 | 3 | 161 |
| China | 10 | 1 | 155 |
| Australia, New Zealand | 10+6 | 0 | 188 |
| Africa | 15 | 1 | 166 |
| Country not specified | 311 | 5 | n.a. |

* EU27 including Germany
** Including projects and institutions as dataset beside publication
*** Only publications

## 4 Results

### *4.1 The search results*

In the last years the number of studies on organic farming and biodiversity increased significantly (Table 1). Despite the relatively new serious recognition of the organic system as a field of scientific relevance in the scientific world, about 19,000 publications were found in the Web of Science (www.isiknowledge.com) under the word of "organic farming". Out of these papers 1,200 were from Germany (6 %). 766 publications were found with the second search word "biodiversity" (3.5 %); half of them were published in the last five years by European researchers. This data set includes papers of the main international organic farming conferences.

In contrast to ISI listed data banks in the Web of Science it is usually hard to find grey literature. These papers may well meet scientific standards but miss a scientific platform for publication (e. g. diploma thesis, reports). The data bank http://orgprints.org was established in 2001 by the Danish DARCOF (today ICROFS) and joint by FiBL and BÖL to give grey organic farming papers a web-based source. All international and European organic conferences use the web platform for submission of papers (Table 2). Nowadays this organic farming databank has more than 10,000 entries. The majority of papers is from Europe, with about one third from Germany. A total of 1,154 submissions deal with environmental aspects, but only 526 publications focus on the subject "biodiversity and ecosystem service." 96 publications concentrate exclusively on biodiversity (1 %). The main activities of organic farming research are in the field of development of organic farming, while less attention has been paid to enhancing and strengthening sustainability (10 %). One reason is topic of the organic farming conference.

The Google search brought too many results without relevance to this study. This source was not considered for further analysis. However, it gives an impression about the importance of this topic in the web. The proceedings of the most important scientific conferences of organic farming proved to be the best source to get an overview of main research topics and the relevance of biodiversity in scientific studies. At the moment biodiversity is still a minor topic as only 105 papers dedicated their research to thus field of research (Table 1). This equals 4 % of all papers.

### *4.2 Meta-analysis of ISI listed papers*

The meta-data analysis tried to answer the question, whether organic farming benefits biodiversity. From 766 studies found with Endnote® in Web of Science using the key words "organic farming" and "biodiversity," nearly half of the references (343) could be used for the assessment, 423 had to be rejected (Table 3). Because some studies have assessed more than one species, multiple answers were given. Thus some studies are cited more than once (total citations = 396). Not all studies made clear comparisons between organic and conventional farming systems (Pimentel et al., 2005; Pimpini et al., 2005). Nevertheless, the meta-data analysis comes to the unequivocal conclu-

Table 2:
Proceedings of the scientific conferences of organic farming in the last 10 years, published under http://orgprints.org

| Selected scientific Organic Farming conferences | Place | Year | Papers total | Papers Biodiversity |
|---|---|---|---|---|
| 13st International IFOAM Scientific conference | Basel, CH | 2000 | 500 | 19 |
| 6. Wissenschaftstagung Ökologischer Landbau[1] | Freising, DE | 2001 | 116 | 10 |
| 14th IFOAM Organic World Congress | Victoria, CA | 2002 | 294 | 13 |
| 7. Wissenschaftstagung Ökologischer Landbau[1] | Wien, AT | 2003 | 214 | 7 |
| 1st ISOFAR conference[1] | Adelaide, AU | 2005 | 141 | 5 |
| 8. Wissenschaftstagung Ökologischer Landbau[1] | Kassel, DE | 2005 | 215 | 6 |
| Joint Organic Conference | Odense, DK | 2006 | 275 | 1 |
| 9. Wissenschaftstagung Ökologischer Landbau[1] | Hohenheim, DE | 2007 | 245 | 19 |
| 2nd ISOFAR conference | Modena, IT | 2008 | 385 | 15 |
| 10. Wissenschaftstagung Ökologischer Landbau[1] | Zürich, CH | 2009 | 287 | 10 |
| 11. Wissenschaftstagung Ökologischer Landbau[1] | Gießen, DE | 2011 | 209 | 6 |
| Total | | | 2,881 | 111 |

[1] The papers of the biannual German speaking organic farming conferences are not found with Endnote® in web of science (ISI). The papers of these conferences have been assessed additionally because of their relevance on a global scale.

sion that biodiversity is higher in organic farming than in conventional farming. 327 citations backed this result, 56 were not clear and only 13 suggested that biodiversity was lower under organic farming management (Table 3).

Table 3:
Impact of organic farming[1] on biodiversity in comparison to conventional farming (no. of citations in ISI listed publications[2])

| Subject | More biodiversity | Unclear, indifferent | Less biodiversity |
|---|---|---|---|
| Landscape | 28 | 5 | 0 |
| Flora on arable land | 61 | 3 | 0 |
| Flora on grass land | 20 | 5 | 0 |
| Flora perennial land use[3] | 12 | 1 | 2 |
| Invertebrates | 77 | 12 | 7 |
| Vertebrates | 26 | 5 | 0 |
| Bacteria, yeast, pests | 6 | 2 | 1 |
| Soil biota | 38 | 15 | 0 |
| Agro-biodiversity | 28 | 2 | 0 |
| Biodiversity in general | 31 | 6 | 3 |
| Total | 327 | 56 | 13 |

[1] This includes organic farming, wild plant collection, traditional farming under organic standards (without certification).
[2] Multiple citations of 343 used papers are possible due to different conclusions for different species.
[3] Perennial land use: vineyards, orchards, special biotopes are for example: orchards, hedges, ponds, farm buildings, paths, fences, forests or stone heaps, special buildings, plantation or facilities for nature (e. g., herb loops). They are assessed in the context of adjacent farming systems.
Source: Web of Science search using Endnote® in March 2011; see Annex 1)

Most of the 396 citations were from Europe (80 %; only EU27 72 %), North-America (6 %) and Latin-America (5 %) (Table 4). Important countries for comparative studies on biodiversity were UK (65 citations; 20 %), DE (51; 16 %), SE (30; 9 %), CH (27; 8 %), IT (24; 7 %), FR (23; 7 %), NL (21; 6 %), US (20; 6 %) and ES (18; 6 %) (McLaughlin and Mineau, 1995).

Table 4:
Origin of the citations[1] about comparative studies of organic and conventional farming on biodiversity in different land use systems

| Region | more | unclear | less | Total |
|---|---|---|---|---|
| Europe (from EU27) | 258 (228) | 48 (47) | 11 (11) | 317 (286) |
| North America | 20 | 4 | 1 | 25 |
| Latin America | 16 | 3 | 0 | 19 |
| Asia | 11 | 0 | 0 | 11 |
| Africa | 4 | 0 | 0 | 4 |
| Oceania | 9 | 1 | 1 | 11 |
| miscellaneous | 9 | 0 | 0 | 9 |
| Total | 327 | 56 | 13 | 396 |

[1] Multiple citations of 343 used papers are possible due to different conclusions for different species.
Source: web of science search using Endnote® in March 2011; see Annex 1)

Organic farming was in favour for all species. The restricted use of pesticides and low nutrient input in organic farming were identified as main factors for a higher biodiversity of flora and fauna was usually (Frost and Ardeshir, 2004). Agro-biodiversity and landscape architecture were less often identified as key parameters for biodiversity. Some flora and fauna have adapted on intensive conventional farming (high nutrient level in soils and high crop yields etc.): epigaeic spiders, birds, plants like *Urtica dioica* (Nettel) (Rydberg and Milberg, 2000). Usually these flora and fauna is not endangered.

### *4.3 Long term trials*

It seems safe to assume that the influence of the land use management is best reflected and assessed in long-term field experiments. And all long-term field studies (BMELV, 2005) with the topic "organic versus conventional farming" (Raupp, 2009) confirm the advantage of organic farming to improve biodiversity (soil biota, flora, arthropods): Glenlea long-term rotation study in Canada (Entz et al., 2005); the DOC-trial in Switzerland (Pfiffner, 1996; Fliessbach et al., 2000; Mader et al., 2002); State Research Institute at Osiny in Poland (Feledyn-Szewczyk, 2008); Rodale Institute Farming Systems Trial (Hepperly et al., 2006); Ekhaga Experimental Farm in Sweden (Lundkvist et al., 2008); Trenthorst organic farming system comparison study in Germany (Rahmann et al., 2006); Mediterranean Arable Systems Comparison Trial (MASCOT) and (MOLTE) in Italy (Migliorini and Vazzana, 2006; Mazzoncini et al., 2010).

### *4.4 Other meta-analysis*

Pfiffner (1996) compiled 44 studies related to fauna richness of different land use management systems (Table 4). They concluded that fauna is more diverse on organic compared to conventional farm land. Bartram and Perkins (2003) found an advantage of organic farming in biodiversity in 33 UK studies, too. Lynch (2009) analysed studies from Canada and the USA and concluded that organic farming contributes to diversity of cropping, flora and habitat.

Bengtsson et al. (2005) found in their meta-data analysis of literature, published before December 2002 that organic farming increases species richness in general. Species richness was on average 30 % higher than in conventional farming systems. However, the results were variable among studies, and 16 % of them actually showed a negative effect of organic farming on species richness. On average, organisms were 50 % more abundant in organic farming systems, but the results were highly variable between studies and organism groups. Birds, predatory in-

Table 5:
Significant impact of organic farming on selected fauna

| | Abundance of fauna No. of studies[1], where ... | | | Diversity of fauna species No. of studies[1], where ... | | |
|---|---|---|---|---|---|---|
| Fauna group[2] | Organic more than conventional | Organic like conventional | Organic less than conventional | Organic more than conventional | Organic like conventional | Organic less than conventional |
| Earth worms | 17 | 1 | 0 | 4 | 3 | 0 |
| Ground beetles | 13 | 2 | 0 | 6 | 2 | 0 |
| Spiders | 6 | 1 | 0 | 0 | 0 | 0 |
| Millipedes | 4 | 0 | 0 | 1 | 1 | 0 |
| Bugs | 2 | 1 | 0 | 1 | 1 | 0 |
| Mites | 2 | 0 | 1 | 1 | 1 | 0 |
| Birds | 5 | 0 | 0 | 1 | 1 | 0 |
| Total | 49 | 5 | 1 | 15 | 7 | 0 |

[1] Results of 44 studies; multiple answer possible.
[2] Most of these groups have important functions in agro-eco-systems.
Source: Pfiffner, 1996

sects, soil organisms and plants responded positively to organic farming, while non-predatory insects and pests did not. The positive effects of organic farming on abundance were verified at plot and field scale, but not on farm level.

Bugg (2002) found in studies conducted in the USA (Pennsylvania and North Dakota), UK (Wales and England) and Canada (Saskatchewan and Ontario) that organic farming and minimum tillage systems support a higher bird diversity and abundance than do conventional systems.

Mondelaers et al. (2009) performed a meta-data analysis of the peer reviewed literature comparing the environmental impacts of organic and conventional farming. They concluded that soils in organic farming systems have, on average, a higher content of organic matter and that organic farming contributes positively to agro-biodiversity (breeds used by the farmers) and natural biodiversity (wild life).

### *4.5 Agro-biodiversity*

Biodiversity is not only defined for wild flora and fauna but also for cultivated crops (Mondelaers et al., 2009). While a higher diversity of cultivated and wild plants and associated fauna is found on grassland, arable land usually lacks biodiversity due to pesticide applications (Geiger et al., 2010). More than one third of the German surface is arable land and very often the cultivated crops are the only plants on these areas. There are about 40 different crops/crop groups cultivated on organic and conventional farms. These crops have different importance (abundance) and are not equally distributed over the area. Some crop species dominate, while others have only a very small share Table 5). The impact on agro-biodiversity can be measured through the inequality of the distribution. Using the statistical data from the cropping in organic farming, this is less equal than on conventional farming. The Gini coefficient[2] for organic farming is 0.69 and for conventional 0.82. The higher equality of organic farming can be easily explained. The crop rotation is broader than in conventional farming (a minimum of six versus a maximum of three different crops in the rotation).

## 5 Conclusions

In the presented comprehensive meta-data analysis, publications were assessed to prove whether organic farming has an advantage for biodiversity or not. This and other meta-analyses (Pfiffner, 1996; Bartram and Perkins, 2003; Bengtsson et al., 2005; Chamberlain et al., 2010) provide evidence that organic farming enhances and conserves biodiversity. A total of 766 ISI-listed publications were found with the search words "organic farming" and "biodiversity", 83 % from Europe. Half of them were published in the last five years. 396 papers could be used for the answer and 327 (83 %) of the citations (multi citations of the 343 papers were possible) found an advantage of organic farming for more biodiversity compared with conventional farming. 56 (14 %) citations were not sure or they found no difference and only 13 (3 %) came to the conclusion that organic farming has less biodiversity (7 of them for soil invertebrates).

[2] The Gini coefficient is defined as a ratio of the area on the Lorenz curve diagram and can be from "0" (very equal: all crops are cultivated on the same number of hectares) up to "1" (very unequal: nearly all hectares are used for only one crop).

Table 6:
Statistical data on cultivated crops in relation to the land use system in Germany (2008)

| Crop | Organic (x1,000 ha) | % of organic | Conventional (x1,000 ha) | % of conventional | Percentage organic (%) |
|---|---|---|---|---|---|
| Farmland (utilised) | 908 | 100.00 | 16,926 | 100,00 | 5.09 |
| Cropland | 385 | 42.40 | 12,103 | 71,50 | 3.08 |
| Grassland | 490 | 54.00 | 4,789 | 28,30 | 9.28 |
| Mixed orchard/pasture | 13 | 1.43 | 300 | 1,77 | 4.15 |
| Permanent culture | 12 | 1.32 | 200 | 1,18 | 5.66 |
| Grain | 188 | 20.70 | 6,518 | 38,50 | 2.80 |
| Winter wheat | 40 | 4.41 | 3,164 | 18,70 | 1.25 |
| Summer wheat | 7 | 0.72 | 43 | 0,25 | 13.10 |
| Rye | 52 | 5.73 | 737 | 4,35 | 6.59 |
| Triticale | 21 | 2.31 | 399 | 2,36 | 5.00 |
| Winter barley | 9 | 0.94 | 1,418 | 8,38 | 0.60 |
| Summer barley | 13 | 1.43 | 544 | 3,21 | 2.33 |
| Dinkel | 18 | 1.98 | 0 | 0,00 | 100.00 |
| Oat | 23 | 2.53 | 179 | 1,06 | 11.49 |
| Maize (corn) | 5 | 0.50 | 515 | 3,04 | 0.87 |
| Maize (silage) | 8 | 0.88 | 1,672 | 9,88 | 0.48 |
| Mixed feed crops | 9 | 0.99 | 126 | 0,74 | 6.67 |
| Legume feed | 76 | 8.37 | 206 | 1,22 | 26.95 |
| Cultivated grassland | 24 | 2.64 | 392 | 2,32 | 5.77 |
| Pulses | 24 | 2.64 | 84 | 0,50 | 22.22 |
| Faba beans | 6 | 0.66 | 11 | 0,06 | 35.29 |
| Lupine | 9 | 0.99 | 20 | 0,12 | 31.03 |
| Peas | 9 | 0.99 | 48 | 0,28 | 15.79 |
| Potatoes (fresh) | 7 | 0.77 | 109 | 0,64 | 6.03 |
| Potatoes (industry) | 1 | 0.08 | 73 | 0,43 | 0.95 |
| Sugar beets | 1 | 0.12 | 369 | 2,18 | 0.30 |
| Feeding beets | 0 | 0.01 | 4 | 0,02 | 2.44 |
| Rape | 2 | 0.25 | 1,371 | 8,10 | 0.17 |
| Sunflowers | 2 | 0.18 | 25 | 0,15 | 6.02 |
| Soy beans | 1 | 0.06 | | 0,00 | 100.00 |
| Flax | 0 | 0.04 | 4 | 0,02 | 8.70 |
| Medical plants | 1 | 0.07 | 6 | 0,04 | 9.77 |
| Cannabis | 0 | 0.04 | | 0,00 | 100.00 |
| Hops | 0 | 0.01 | 18 | 0,11 | 0.55 |
| Carrots | 1 | 0.15 | 10 | 0,06 | 12.30 |
| Cabbage | 0 | 0.03 | 7 | 0,04 | 3.45 |
| Onions | 0 | 0.04 | 9 | 0,05 | 3.54 |
| Red beet | 0 | 0.03 | 2 | 0,01 | 13.33 |
| Salad | 0 | 0.01 | 10 | 0,06 | 1.31 |
| Asparagus | 1 | 0.07 | 18 | 0,11 | 3.49 |
| Strawberry | 0 | 0.04 | 13 | 0,08 | 2.66 |
| Flowers | 0 | 0.01 | 34 | 0,20 | 0.36 |
| Apples | 3 | 0.30 | 32 | 0,19 | 7.83 |
| Wine yards | 4 | 0.48 | 102 | 0,60 | 4.14 |
| Tree nursery | 0 | 0.05 | 22 | 0,13% | 2.08 |

Source: AMI 2010 using the basis of the test farm net data of the BMELV.

Long-term field studies on "organic versus conventional farming" confirm the advantage of organic farming to improve biodiversity for soil biota, flora, arthropods (Pfiffner, 1996; Mader et al., 2002; Entz et al., 2005; Feledyn-Szewczyk, 2008) and contribute to a better understanding of functional biodiversity (Wolfe, 2002; Zhong et al., 2005). The impact can be found on the farm land and attached areas such as hedges. Herbaceous field boundaries are rich in biodiversity and can be used as a separation between organic and conventional fields (Moonen et al., 2006; Gardarin et al., 2007). If the local biodiversity is already poor due to intensive farming in the surrounding area, organic farming can not compensate the loss of biodiversity. This was for instance shown for flower visiting insects (Hopkins and Feber, 1997; Brittain et al., 2010). Seed banks were not influenced by management (Hawes et al., 2010). It is no suitable political solution to define preference areas for organic (remote and low productive soils) and conventional farming (high potential soils) as every region should have a mixture of organic and conventional farming systems (Taube et al., 2006).

Conventional farming can have similar results in the case of compulsory set-aside farm land (segregation). Mac Donald et al. (2007) and Nemecek et al. (2006, 2011a, b) found advantages of organic farming in alpha-diversity but state that set-aside land on conventional farms can equalize this advantage. But on-farm segregation like set-aside land can be a risk for long-term biodiversity protection. As the EU set the obligation for set-aside farm land to zero in 2008, conventional farmers have converted set-aside land into crop land (Rundlof et al., 2010). This has been followed by losses of biodiversity on conventional farms.

Agri-environmental schemes (AES) have a high importance in biodiversity protection (Purtauf et al., 2005; Rund-lof et al., 2008; Taylor and Morecroft, 2009). This can be carried out as organic farming (paid under the agri-environmental schemes) or as a part of conventional farming (nature protection areas) (Schader et al., 2008). Good farming practice becomes more important to enhance and improve biodiversity in organic and conventional farming (Rydberg and Milberg, 2000; Strasser and Ryffel, 2010). Biodiversity assessment is not part of the inspection process (889/2008/EC) so that it is possible that it depends on the organic farm manager whether biodiversity will be promoted or repelled.

The main question is the antagonism between food security and biodiversity. One options to solve this problem is segregation (conventional) and integration (organic) (Gabriel et al., 2009). Differences in biodiversity have a positive and a negative impact: For example, weeds, pests and parasites dominate in organic farming (more biodiversity), are, however, negative for crop yield, product quality and animal welfare (Poetsch et al., 2005; Meyling et al., 2010). This has to be considered in the analysis of the impact of biodiversity (Letourneau and Goldstein, 2001; Letourneau and Bothwell, 2008; Ryan et al., 2010). Biodiversity needs equilibrium between biodiversity and food production (Vandana, 2000; Crowder et al., 2010; Chappell and LaValle, 2011). Biomass production is a new challenge for biodiversity protection, particularly if maize is encroaching as a monoculture (Fritsche, 2004). In addition, it should be decided, if "organic-herbicides" are a strategy (additional to mechanical and temperature weed control measures). A strong argument against such procedure is that organic farming would start to go conventional with the risk of loss of biodiversity and loss of consumer confidence (Darnhofer et al., 2010).

Hole et al. (2005) came to the conclusion, that *"(1) It remains unclear whether a 'holistic' whole-farm approach (i.e. organic) provides greater benefits to biodiversity than carefully targeted prescriptions applied to relatively small areas of cropped and/or non-cropped habitats within conventional agriculture (i.e. agri-environment schemes); (2) Many comparative studies encounter methodological problems, limiting their ability to draw quantitative conclusions; (3) Our knowledge of the impacts of organic farming in pastoral and upland agriculture is limited; (4) There remains a pressing need for longitudinal, system-level studies in order to address these issues and to fill in the gaps in our knowledge of the impacts of organic farming, before a full appraisal of its potential role in biodiversity conservation in agro-ecosystems can be made"*

The presented meta-data analysis confirms the conclusions of Hole et al. (2005). However, it is important to emphasise the fact that numerous studies favour organic farming for improving biodiversity in comparison to conventional farming. Yet, it needs to be taken into account that farming systems (including organic) and farm functions change rapidly. Energy farming and agri-environmental schemes force science to understand the impact more rapidly than in previous years. For example, biomass production can have a negative impact on biodiversity (maize domination) and biogas-facilities are installed for many decades. In future, the aspects of food security and food safety will gain increasing importance irrespective of the land use system. Putative solutions towards more biodiversity is the use of set aside farm land for segregation as it can have the same or even better impact on biodiversity than integrated measures such as organic farming. A mixture of intensive farming with set aside, non-farm land, agri-environmental schemes and organic farms may deliver a high range of biodiversity throughout all landscapes (Holland et al., 2007). A separation of these systems into specific farming areas (intensive/conventional and extensive/organic) is counter-productive.

## 6 Annex

Annex 1:
Comparison of Organic farming[1] (OF) and Conventional farming (CF) on biodiversity (by countries[2])

| Subject | More biodiversity | Unclear, indifferent | Less biodiversity |
|---|---|---|---|
| Landscape, whole farm approach on biodiversity | BE: (Beider et al., 2007); CA: (Lynch, 2009); CH: (Schader et al., 2008; Steiner and Pohl, 2009); CR: (Blanco-Metzler and Diaz Porras, 2008); DE: (Haas and Wetterich, 2000; Holzschuh et al., 2010); DK: (Tybirk and Fredshavn, 2003; Tybirk et al., 2004); ES: (Mena et al., 2009; Jose-Maria et al., 2010); FR: (Gardarin et al., 2007); IT: (Ronchi and Nardone, 2003; Moonen et al., 2006; Lazzerini et al., 2007); SE: (Weibull, 2002; Rundlof and Smith, 2006; Rundlof et al., 2008; Rundlof et al., 2008; Rundlof et al., 2010); UK: (Norton et al., 2006; Watson et al., 2006; Gibson et al., 2007; Watson et al., 2008; Norton et al., 2009; van der Gast et al., 2011); US: (Smukler et al., 2008; Lynch, 2009; Smukler et al., 2010) | DE: (Holzschuh et al., 2007); NL: (Manhoudt and Snoo, 2003); SE: (Weibull, 2002); UK: (Hole et al., 2005; Holland et al., 2007) | |
| Flora on arable land | AT: (Kaar and Freyer, 2008); AU: (Macfadyen et al., 2009); CA: (Lynch, 2009); CH: (Mader et al., 2002; Nemecek et al., 2006; Hiltbrunner et al., 2008; Wyss and Pfiffner, 2008; Nemecek et al., 2011); CZ: (Tyser et al., 2008); DE: (Albrecht, 2005; Roschewitz et al., 2005a; Glemnitz et al., 2006; Himstedt and van Elsen, 2006; Clough et al., 2007a; Albrecht, 2008); DK: (Aude et al., 2003; Aude et al., 2004); ES: (Romero et al., 2005; Caballero-Lopez et al., 2010; Jose-Maria et al., 2010); EU: (Albrecht, 2003); FI: (Hyvonen et al., 2003; Ekroos et al., 2010); FR: (Bochu et al., 2004; Mesleard et al., 2005; Chateil et al., 2007); HU: (Glemnitz et al., 2006); IT: (Caporali et al., 2003; Migliorini and Vazzana, 2007; Mazzoncini et al., 2010); LT: (Balezentiene, 2008; Balezentiene, 2009); NL: (Alebeek et al., 2003; Manhoudt et al., 2007); PL: (Feledyn-Szewczyk and Duer, 2006; Feledyn-Szewczyk, 2008; Krawczyk, 2009; Krawczyk et al., 2010); SE: (Mattsson, 1999; Rydberg and Milberg, 2000; Belfrage et al., 2005; Bengtsson et al., 2005; Lundkvist et al., 2008; Rundlof et al., 2010); UK: (Cobb et al., 1999; Leake, 2002; Bartram and Perkins, 2003; Asteraki et al., 2004; Turner, 2004; Fuller et al., 2005; Hole et al., 2005; Gibson et al., 2007; Brandao et al., 2010; Hawes et al., 2010); US: (Hepperly et al., 2006; Lynch, 2009; Ryan et al., 2010; Wortman et al., 2010); ZA: (Baudron et al., 2009); No specific country: (Leifert et al., 2007; Mondelaers et al., 2009; Ulber et al., 2009) | CH: (Aavik and Liira, 2010); FI: (Hyvonen, 2007); SE: (Mattsson, 1999) | |
| Flora on grass land | AT: (Matthes et al., 2002; Poetsch et al., 2005); BR: (Aroeira, 2003; Aroeira and Paciullo, 2004); CH: (Schmid et al., 2001; Britschgi et al., 2006); DE: (Elsasser, 2000; Haas et al., 2001; Mayer et al., 2008; Muller-Lindenlauf et al., 2010); DK: (Petersen et al., 2006); EE: (Geherman and Viiralt, 2004); ES: (Mena et al., 2009); NL: (Baars, 2002); PT: (Crespo et al., 2004); UK: (Adamson et al., 2004; Fuller et al., 2005; Hole et al., 2005; Younie and Baars, 2005); | CA: (Brandt et al., 2010); CZ: (Sarapatka and Cizkova, 2007); EE: (Geherman and Ellermae, 2001); FR: (Benoit et al., 2005; Fiorelli et al., 2008) | |
| Flora on perennial crop land[3] | BR: (Batista et al., 2002); CR: (Somarriba and Harvey, 2003; Somarriba et al., 2003); DE: (Ammer et al., 1995; Geier et al., 2000); DK: (Boutin et al., 2008); ES: (Cotes et al., 2009; Minarro et al., 2009; Cotes et al., 2010); US: (Reganold et al., 2001; Nicholls et al., 2008); ZA: (Gaigher and Samways, 2010) | ES: (Minarro et al., 2009) | ES: (Minarro et al., 2009); IT: (Bruggisser et al., 2010) |
| Invertebrates: insects, spiders, beetles, parasites, earth worms, nematodes | AT: (Matthes et al., 2002); AU: (Macfadyen et al., 2009); AR: (Zalazar and Salvo, 2007; Fernandez et al., 2008); BG: (Andreev et al., 2001); CA: (Lynch, 2009); CH: (Pfiffner, 1996; Mader et al., 2002; Britschgi et al., 2006; Nemecek et al., 2006; Nemecek et al., 2011); CN: (Zhong et al., 2005; Chen et al., 2010; Yuan et al., 2010); DE: (Clough et al., 2005; Roschewitz et al., 2005b; Schmidt et al., 2005; Humann-Ziehank and Ganter, 2006; Clough et al., 2007a; Clough et al., 2007b; Clough et al., 2007c; Hallmann et al., 2007; Holzschuh et al., 2007; Holzschuh et al., 2008; Bates and Harris, 2009; Diekotter et al., 2010; Holzschuh et al., 2010); DK: (Boutin et al., 2009; Meyling et al., 2010); ES: (Cotes et al., 2009; Caballero-Lopez et al., 2010; Cotes et al., 2010); FR: (Garcin et al., 2004; Viaux and Rameil, 2004; Mesleard et al., 2005); FI: (Salonen et al., 2001a; Salonen et al., 2001b; Salonen et al., 2005; Ekroos et al., 2008; Ekroos et al., 2010); IN: (Suthar, 2009); IT: (Benvenuti et al., 2007; Migliorini and Vazzana, 2007; Peverieri et al., 2009; Mazzoncini et al., 2010); IR: (Hutton and Giller, 2003); NI: (Ottonetti et al., 2010); NL: (Mulder et al., 2003; Postma-Blaauw et al., 2010); NZ: (Bowie et al., 2003; Moller et al., 2007); PK: (Siddiqui et al., 2005); PT: (Santos et al., 2007); SE: (Belfrage et al., 2005; Bengtsson et al., 2005; Oberg, 2007; Rundlof et al., 2008; Rundlof et al., 2008); UK: (Cobb et al., 1999; Leake, 2002; Asteraki et al., 2004; Wickramasinghe et al., 2004; Fuller et al., 2005; Hole et al., 2005; Birkhofer et al., 2008; Eyre et al., 2009; Mondelaers et al., 2009; Hodgson et al., 2010; Eyre and Leifert, 2011); US: (Nicholls et al., 2008); ZA: (Carvalheiro et al., 2010; Gaigher and Samways, 2010); No country specified: (Boisclair and Estevez, 2006; Crowder et al., 2010) | DE: (Doring et al., 2003; Irmler, 2003; Purtauf et al., 2005); DK: (Boutin et al., 2009); FR: (Ricard et al., 2007; Pelosi et al., 2009); SE: (Weibull et al., 2000; Weibull, 2002; Weibull and Ostman, 2003); UK: (Feber et al., 1998; Feber et al., 2007; Birkhofer et al., 2008) | DE: (Clough et al., 2007a); BE: (Albert et al., 2003); IT: (Boisclair and Estevez, 2006; Bruggisser et al., 2010); FR: (Garcin et al., 2004); SE: (Oberg, 2007; Oberg, 2009) |

| Subject | More biodiversity | Unclear, indifferent | Less biodiversity |
|---|---|---|---|
| Birds, mammals, aquatic fauna | DE: (Batary et al., 2010); CA: (Freemark and Kirk, 2001; Bugg, 2002); IT: (Ciani, 1997; Genghini et al., 2006); FR: (Mesleard et al., 2005; Ondine et al., 2009); PA: (Bael et al., 2007); NL: (Kragten and de Snoo, 2007; Kragten and de Snoo, 2008); SE: (Belfrage et al., 2005; Bengtsson et al., 2005; Danhardt et al., 2010; Smith et al., 2010); UK: (McLaughlin and Mineau, 1995; Bugg, 2002; Leake, 2002; Potts, 2002; Wickramasinghe et al., 2003; Wickramasinghe et al., 2004; Fuller et al., 2005; Hole et al., 2005; McKenzie and Whittingham, 2009; Mondelaers et al., 2009; Chamberlain et al., 2010); US: (Bugg, 2002) | NL: (Kragten and de Snoo, 2007; Kragten and de Snoo, 2008); FR: (Ondine et al., 2009); SE: (Danhardt et al., 2010); UK: (Chamberlain et al., 2010) | |
| bacteria, yeast, pests | AU: (Bissett et al., 2006; Bissett et al., 2007; Macfadyen et al., 2009); ES: (Escudero et al., 2007; Cordero-Bueso et al., 2011); US: (Letourneau and Goldstein, 2001; Letourneau and Bothwell, 2008) | BE:(Coorevits et al., 2008); US: (Letourneau and Bothwell, 2008) | FR: (Benoit et al., 2005) |
| Soil biota | AU: (Bruggen and Termorshuizen, 2003; Bell et al., 2004); BR: (Lal, 2005); CH: (Fliessbach et al., 2000; Mader et al., 2002; Oehl et al., 2004; Nemecek et al., 2006; Oehl et al., 2009; Nemecek et al., 2011); DE: (Poveda et al., 2006; Diekotter et al., 2010); CL: (Peredo et al., 2009); DK: (Hansen et al., 2001); FR: (Peres et al., 2008); GR: (Tsiafouli et al., 2006); HR: (Custovic and Tvica, 2004); IN: (Tilak et al., 2005); IT: (Cardelli et al., 2004; Migliorini and Vazzana, 2007; Mocali and Benedetti, 2008; Campaneili et al., 2010; Mazzoncini et al., 2010; Paoletti et al., 2010); JP: (Nakamura et al., 2000); NL: (Mulder et al., 2003; Breure et al., 2004; van Diepeningen et al., 2006; Verbruggen et al., 2010); PK: (Rana et al., 2010); UK: (Leake, 2002; Shannon et al., 2002; Mondelaers et al., 2009; Stockdale and Watson, 2009; van der Gast et al., 2011); US: (Wander et al., 1995; Tu et al., 2006; Reeve et al., 2010); No country specified: (Creamer et al., 2010) | CL: (Peredo et al., 2009); DE: (Schrader et al., 2006; Chirinda et al., 2008); FR: (Peres et al., 2008; Pelosi et al., 2009); IT: (Bedini et al., 2008; Paoletti et al., 2010); NL: (Zanen et al., 2008; Galvan et al., 2009); NZ: (Parfitt et al., 2005); UK: (Shannon et al., 2002; Brussaard et al., 2004; Orr et al., 2011); US: (Bossio et al., 1998; Sanchez-Moreno et al., 2008) | |
| Agro-biodiversity | AT: (Vogl and Vogl-Lukasser, 2003); CA: (Scott, 2000; Lynch, 2009); CH: (Freyer, 1997); DE: (Muller et al., 2000; Wolff et al., 2002; Buchs, 2006); EU: (Bocci and Chable, 2009); ES: (Correal et al., 2006; Mena et al., 2009; Cordero-Bueso et al., 2011); FR: (Tronel and Codarin, 2010); HU: (Birol et al., 2005; Birol et al., 2006); IT: (Ronchi and Nardone, 2003); IN: (Vijayalakshmi and Arumugasamy, 2004); HR: (Lotti et al., 2008; Matotan et al., 2008); NL: (Bueren and Osman, 2001; Bueren et al., 2002); SE: (Rydberg and Milberg, 2000); UK: (Leake, 2002; Hole et al., 2005; Gibson et al., 2007; McKenzie and Whittingham, 2009; Mondelaers et al., 2009); US: (Lynch, 2009); No specific country: (Shiva, 1997) | DE: (Langer and Frederiksen, 2008) | |
| General and not species-specified comments concerning organic farming and biodiversity, farm assessments | AT: (Loidl, 2007); BE: (Baltus, 1997); BH: (Aziz and Al-Barakah, 2005); BR: (Alvarenga et al., 2002); CH: (Fliessbach et al., 2000; Wolfe, 2002; Nemecek et al., 2006; Strasser and Ryffel, 2010; Nemecek et al., 2011); CN: (Wang et al., 2007; Wang et al., 2009); CR: (Somarriba and Harvey, 2003; Somarriba et al., 2003; Dahlquist et al., 2007); DE: (Ammer et al., 1995; Elsen, 2000; Stein-Bachinger et al., 2005; Gabriel et al., 2006; Gabriel and Tscharntke, 2007; Stein-Bachinger and Fuchs, 2008; Gabriel et al., 2009; Gabriel et al., 2010; Muller-Lindenlauf et al., 2010); DK: (Porter and Petersen, 1997; Noe et al., 2005; Vaarst, 2010); ES: (Calero Castillo, 2003; Parra-Lopez et al., 2007); EU: (Bandarra, 2001); FR: (Chable et al., 2002; Dron and Ferron, 2003; Lamine and Bellon, 2009); GE: (Adl et al., 2006); HU: (Toth and Baldi, 2006); IN: (Ayyappan and Jena, 2003; Singh, 2005a; Singh, 2005b; Singh et al., 2007; Singh and Satapathy, 2007; Dubey and Sharma, 2008; Subhasis et al., 2008); IT: (Pacini et al., 2003; Ronchi and Nardone, 2003; Migliorini and Vazzana, 2007); MX: (Bray et al., 2002; Escamilla et al., 2005); NL: (Smis and Meijerink, 2006); NO: (Olsson and Rnningen, 1999); PO: (Link, 2004); UK: (McLaughlin and Mineau, 1995; Cobb et al., 1999; Atkinson et al., 2002; Dabrowski and Abanowska-Bury, 2005; Firth et al., 2006; Norton, et al. 2006; Watson et al., 2006; Watson et al., 2008; Norton et al., 2009; Taylor and Morecroft, 2009); US: (Altieri, 1999; Lotter, 2003; Snapp et al., 2010; Chappell and LaValle, 2011); No specific country: (Mansvelt and Lubbe, 1999; Leake, 2002; Scialabba et al., 2003; Xie et al., 2003; Kairo, 2005; Pimentel et al., 2005; Leifert et al., 2007; Briggs, 2008; Schnug et al., 2008) | AT: (Darnhofer et al., 2010); MX: (Philpott et al., 2007); NL: (Bueren and Osman, 2001; Ammann, 2007; Ammann, 2008; Ammann, 2009) | US: (Avery, 1996); SE: (Kirchmann and Thorvaldsson, 2000); NZ: (Rowarth, 2008) |

343 papers were assessed. Multiple citations are possible due to different conclusions for different species.
[1] This includes organic farming, wild plant collection, traditional farming under organic standards (without certification).
[2] ISO country codes are used.
[3] Perennial crop land: e.g., agro-forestry, orchards, vineyards.
Source: web of science search using Endnote® in March 2011)

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