Environmental impacts of organic management

Part of this review has been published by the EU Commission with its external evaluation of the EU organic regulation.

A6.1 General environmental impact

The impacts reviewed below may be a direct result of the regulation requirements, e.g. more biodiversity due to restrictions on biocide use, or indirect, e.g. more farmland birds due to more overwintering stubbles due to more spring cereals sown due to need to alternate sowing periods to control weeds due to non-use of herbicides. Indirect impacts, while important, are less easy to verify. Impacts will also vary according to the type (e.g. horticulture, dairy) and intensity (e.g. more intensive lowland or less intensive hill/mountain) of the organic farming system.

Review of scientific literature: Bound to strict rules regarding nutrient cycling and input avoidance, organic agriculture guides farmers to establish agro-ecosystem management and other progressive management practices, and thus implements a system approach to farming (Lampkin, 1990, Niggli et al., 2008). This system approach may induce synergetic environmental effects. Indeed, several authors found that pest control measures of organic farming significantly support the provision of ecosystem services (Crowder et al., 2010; Krauss et al., 2011; Zehnder et al., 2007) or pollination (Holzschuh et al., 2008). The promotion of high nature value elements on farms like hedgerows, beetle banks and habitats for other beneficial insects in grass or wildflower strips along field margins becomes ecologically and agronomically much more attractive in combination with a ban on pesticides (Niggli et al., 2008).

A6.2 Biodiversity

Analysis of provisions: The EU Organic Regulation does not address biodiversity through dedicated rules. However, Article 12 of Regulation (EC) 834/2007 mentions that organic production shall use cultivation practices that enhance soil biodiversity. Whereas such practices are not clearly defined, the Regulation provides a list of rules that indirectly protect or contribute to high levels of biological diversity (see Table 7.2)

Review of scientific literature: Scientific evidence for the positive impact of organic production on biodiversity is substantial. Many studies have concluded that holdings with less use of inputs are very important to preserve biodiversity (The Soil Association, 2000; Bengtsson *et al*., 2005; Hole *et al*., 2005, Smith et al., 2011). This is especially the case of organic holdings that combine cultivation of a wide variety of crops, complexity of landscapes and reduced environmental disruption. Bengtsson *et al.* (2005) analysed 63 studies and concluded that the species diversity is on average 30 % higher on organic than conventional land. Of the studies analysed by Bengtsson, 84 % found a positive impact of organic farming on the species richness, whereas 16 % did not. Fuller et al (2005) showed that organic fields can support 68-105% more plant species, and 74-153% greater abundance, compared with conventional fields. Roschewitz et al (2005) concluded that as organic systems are characterised by diverse seed banks, organic fields could be viewed as self-sufficient ecosystems for plants, therefore not relying on immigration from surrounding habitats to maintain species pools.

Looking in more detail, organic farming practices are most beneficial for birds. Kragten et al. (2008a, b) found the home range density of skylarks and vulnerable lapwings on organic farms to be three times of that on conventional farms. Gabriel et al (2010) recorded higher overall bird diversity on conventional farms, but generalist species and members of the crow family were found in higher densities on organic farms. (There is anecdotal evidence that the use of untreated seed attracts some bird species from neighbouring farms.)

On organic arable land, the floral diversity (Gabriel et al., 2006; Gabriel et al., 2007) and the diversity of predatory insects (Pfiffner und Luka, 2003) is higher than on conventional arable land. Boutin et al. (2008) identified higher species richness in semi-natural habitats on organic farms compared with conventional. The differences in the biodiversity performance between organic and conventional farming systems are more pronounced on arable land than on grassland (Niggli et al. 2008). There is evidence that organic farms can extend their biodiversity benefits beyond the farm boundary into surrounding landscapes and farms (e.g. Gabriel et al. 2010; Hodgson et al. 2010; Rundlöf et al. 2008). The species richness is however largely depending on landscape type (Tscharntke et al. 2005) (see figure below). Whereas in simple landscapes (and mainly in arable cropping) the differences in species richness are mostly significant, in more complex landscapes, in particular when non-organic low-input farming systems are compared with more intensive organic farming systems, only few or no significant differences are found (Gomiero et al. 2011). Similar conclusions were reached in recently finished EU project "Bio-Bio.[1]

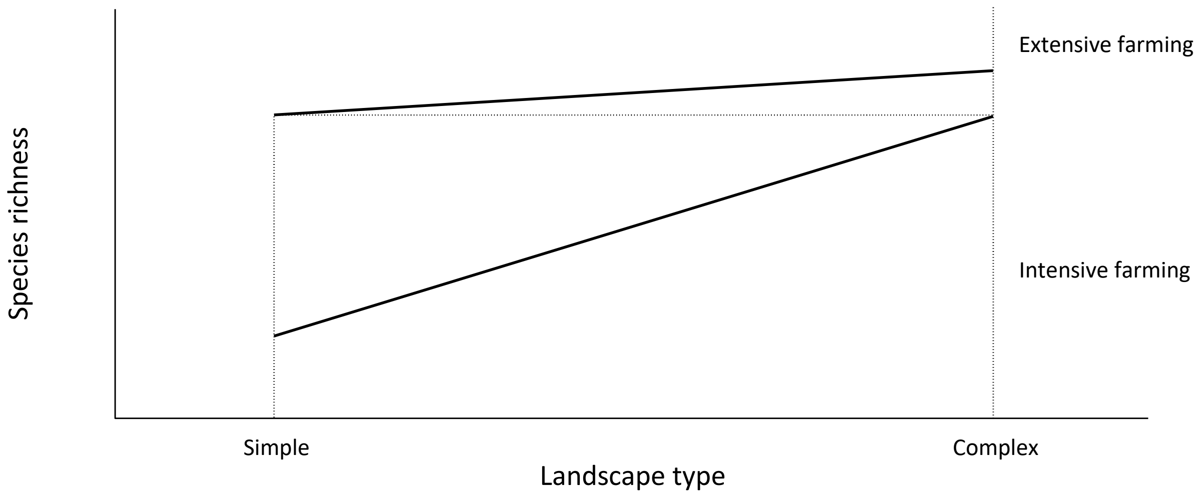

Figure A6-1: Compensation of local land-use intensity by landscape complexity

Source: Tscharntke et al. (2005).

The prevalent high biodiversity found on organic farms significantly supports ecosystem services such as natural pest control (Crowder et al., 2010; Krauss et al., 2011; Zehnder et al., 2007) or pollination (Holzschuh et al., 2008). Ulber et al (2009) observe that the increased plant diversity on organic farms arose from the complexity of the system including crop rotation, absence of herbicides and other synthetic pesticides. Concerning landscape diversity, organic farming may perform better because of more diverse crop rotations (Norton et al. 2009) and higher implementation rates of structural elements such as hedges and fruit trees (Schader et al. 2009). However, landscape effects are very farm and site specific. Therefore, no general trend can be determined (Steiner 2006).

The positive impacts of organic production on biodiversity assessed in the scientific studies (e.g. Bengtsson et al., 2005; Fuller et al., 2005; Hole et al., 2005; Smith et al., 2011; Schader et al. 2012) derive from:

i) directly related aspects from the organic farming regulations: ban of synthetic mineral fertilisers, use of organic fertilisation, lower stocking density, no use of herbicides and chemical pesticides, more diverse rotation, etc.

[1] See website: http://www.biobio-indicator.org/scientific-publications.php

ii) and general organic production practices: use of cover crops, use of legumes, less tillage, higher presence of semi-natural habitats in total UAA such as hedges, trees or grass strip corridors.

A6.3 Energy

Analysis of provisions: The EU Organic Regulation does not provide explicit rules regarding the responsible use of energy. However, the provision of rules has some possible indirect impact (see Table 7-2) and particularly limiting the use of chemically synthesised inputs has a significant impact on energy consumption. Yet the regulation does not include any direct provision on use of fossil energy, transport, packaging, heating, energy saving measures, etc.

Review of scientific literature: The energy use in agriculture essentially comes from direct consumption of fossil energy (e.g. fuel and oil) as well as indirect energy consumption resulting from the production of synthetic fertilisers and pesticides, transport of imported feedstuffs and from investment goods such as buildings. Because of the very limited use of synthetic mineral fertilisers (in particular the ban of chemically synthesised nitrogen fertilisers) and pesticides (no use of chemically synthesised pesticides except pheromones and a few products for insect traps), several studies have proven that energy consumption is lower in organic than in conventional farming (ITC-FiBL (2007); Stolze et al. (2000); Lampkin (2007). This is a positive side effect that can thus be attributed to the EU Organic Regulation. However, for certain crops (e.g. potatoes broccoli, lettuce), organic farming can sometimes offset the reduced usage of man-made chemical inputs by increased mechanical labour, increasing the amount of fuel used compared to conventional farming (Venkat, 2012, Williams et al. 2006, Pimentel et al. 1983). Thomassen et al. (2008) found that the energy efficiency of organic milk production was significantly higher compared to conventional production. They concluded that the use of concentrate feed in particular is a major driver and has potential for reducing energy use. Nemecek et al. (2005) demonstrated on the basis of long-term field experiment data a lower energy use per ha and per product unit overall in organic systems for all major crops in Switzerland (with an exception to this, potatoes, where a slightly higher energy use was calculated per ton of organic potatoes).Therefore for most crops the energy use, both land-related or product-unit related is generally lower. This is a positive side effect that can thus be attributed to the EU Organic Regulation.

An exception to this is potatoes, where a slightly higher energy use was calculated per t. In addition, Williams et al. (2006) found higher energy use per kilogram of product within organic tomato production as a result of reduced yields but similar levels of fossil-fuel inputs. Yet, some other studies have shown that the positive impacts resulting from the non-use of synthetic nitrogen/pesticides may therefore be mitigated and might or even be reversed, depending on the practices and crops (De Backer et al., 2009; Azeez and Hewlett, 2008, Gomiero et al., 2011), especially for crops. However for most crops the energy use, both land-related or product-unit related is generally lower, with some exceptions like potatoes or tomatoes, where disease pressure in organic farming is high and organic yields relatively low. While milk and beef production is more efficient on organic farms, as a result of greater energy efficiency in forage production though the use of grass-clover leys, organic poultry production has been shown to have a slightly lower energy efficiency due to higher feed conversion ratios (Schader et al., 2012, Leinonen et al., 2012a &b).

A6.4 Water (quality and quantity)

Analysis of provisions: Regarding water quality and limiting pollution, there are several direct and indirect effects in organic agriculture resulting from specifications in the rules. Regarding water use, the Organic Regulation does not provide any direct requirements, but organic production uses potentially less water because of individual choices and cultivation practices[2].

Review of scientific literature: Thanks to the strict limitation of chemically synthesized inputs in plant production, organic farming significantly helps reduce residues of plant protection products and chemical fertilisers in water thus improving water quality (Mahé and Portet, 2012). Rotations including legumes and green manure crops, the use of manure as fertiliser and limitation of the total amount of livestock manure (as well as the according stocking density) reduce the input of rapidly soluble and mineralisable nitrogen, therefore reducing leaching of nitrates. Several studies show that nitrogen leaching can be reduced by 40–64% through organic farming (e.g. Edwards et al., 1990; Younie and Watson, 1992; Eltun, 1995; Condron et al., 2000; Goulding, 2000; Haas et al., 2001; Kirchmann and Bergström, 2001; Mäder et al., 2002; Stopes et al., 2002; Auerswald et al., 2003; Pacini et al. 2003; Shepherd et al., 2003; Osterburg and Runge, 2007). Based on a statistical comparison of 12 studies, Mondelaers et al. (2009) conclude that the nitrates leaching is on average 9kg/ha in organic production versus 21kg/ha in conventional agriculture. In contrast, looking at the impact per kg output, Nemecek et al. (2005) found higher eutrophication impacts per unit output for some organic crops compared to conventional. In some places, these higher nutrient loads on arable land are attributed to the greater use of organic fertilisers in the organic system, because the life cycle assessments used by Nemecek et al. (2005) assume relatively high fertilisation rates for organic farms. Taking the data by Nemecek et al. (2005) and projecting them at sector level, using statistical data and an economic model, Schader (2009) found on average 35% lower eutrophication rates on organic farms per hectare.

Muller et al. (2012) conclude that due to the fact that organic farming practices commonly increase and stabilize soil organic matter (e.g. Mäder et al., 2002; for more details see section below), soils under organic management can capture and store more water than soils of conventional cultivation (Reganold *et al.*, 1987). Organic production is thus less prone than conventional cultivation to extreme weather conditions, such as drought, flooding, and water-logging (El-Hage et al., 2010).

Nevertheless significant differences are noted among the studies due to differences in soil, regions, fertilisation practices and measurement protocols. In some comparative crop rotation experiments nitrate leaching has been at the same levels in organic and conventional rotations (Korsaeth and Eltun, 2000), especially if calculated per kilogram of harvest (Mondelaers et al., 2009). Looking at the impact per kg output, Nemecek et al. (2005) found higher eutrophication impacts for some organic crops compared to conventional. Following facts underline the lower eutrophication potential of organic farming found in literature (Schader et al., 2012):

- Organic farming systems have lower nutrient levels, which reduces the absolute quantity of nutrient loads that can be emitted from the system due to lower stocking rates and the ban of mineral nitrogen fertilisers.
- The quantity of directly available nitrogen is much lower in organically managed soils.
- Because nutrients cannot be imported easily into the systems, the opportunity cost of nitrogen losses is higher for organic farms than for conventional farms (Stolze et al., 2000). This implies a need for more efficient nutrient management in organic systems, although this does not

[2] Stanhill (1990) and Lotter (2003) found that organic crops show higher ability to cope with drought than conventional ones, mainly due to better soil properties. More recently, a French study comparing 151 organic holdings to 281 conventional ones (Caplat, 2006) revealed that only 8 % of the organic areas were irrigated, whereas it reached 33 % in conventional holdings.

eliminate losses. In addition, nitrate leaching can be high at the point of transition from the fertility building phase of the rotation to the cropping phase.

In animal husbandry, outdoor production of pigs and poultry (not specifically organic but access to pasture is required) increases the risk of nitrate losses if the livestock is allowed to concentrate their excrements and deteriorate the vegetation cover (Eriksen et al., 2002, 2006; Degre´ et al., 2007; Salomon et al., 2007; Halberg et al., 2010). The EGTOP report on poultry (European Commission- EGTOP, 2012) has indeed pointed out that the minimum outside area for laying hens of 4 m^2 can sometimes lead to a pressure of nitrogen that exceeds 170 kg/ha/year. For herbivores, the maximum stocking density (related to the limit of 170 kg N/ha) is being implemented, at the farm level, but not for any specific parcel.

There could be a positive impact of organic production practices in relation to **water use,** partly related to production rules. For example, Stanhill (1990) and Lotter (2003) found that organic crops show higher ability to cope with drought than conventional ones, mainly due to better soil properties; more recently, a French study comparing 151 organic holdings to 281 conventional ones (Caplat, 2006) revealed that only 8% of the organic areas were irrigated, whereas it reached 33% in conventional holdings.

A6.5 Soil and soil organic matter

Analysis of provisions: Extended crop rotations, incorporating grass-clover and forage legumes, the application of organic fertiliser (e.g. slurries and manure) and avoiding bare soils are all practices that have been shown to have the potential to prevent soil carbon losses and build soil carbon stocks (Freibauer *et al.*, 2004; Smith *et al.*, 2007; Lal, 2008; Smith *et al.*, 2008; Diacono and Montemurro, 2011). These practices, although desirable, are not commonly found in modern agricultural systems, whereas they are a core element of organic production systems (Gattinger, 2012). In addition, there are certain sets of rules which have a direct and positive impact on soil and its organic matter content. In particular, good soil management practices and mandatory rotations including legumes and other green manure crops and organic fertilisation practices using only products listed in Annex I (especially manure and compost), which contribute to high level of organic matter.

Review of scientific literature: Organic agriculture encompasses a number of different activities within the system approach, which aim at increasing the organic matter content in the soil. Most important is the ban of mineral fertilisers, which necessitates meeting the nutrient demand of the crops with organic fertilisers (Mäder et al., 2002). Furthermore, the importance of a crop rotation including short-term clover grass leys supports the development of fertile soils (Pimentel et al., 2005). There is also clear scientific evidence that soils under organic management have higher biological activity, both in terms of species and general biomass. Results from the Swiss long-term DOC trial show that organic soils contains 20 to 30 % more microbial biomass, 30 to 40 % more earthworms, 90 % more spiders (with high diversity) and 40 % more mycorrhizae[3] (Mäder et al., 2002; Pfiffner and Luka, 2007, Fließbach et al., 2007). Moreover, the content of organic matter improves the soil characteristics. Tuomisto et al. (2012) found in their meta-analysis a 7% higher soil organic matter content on organic farms compared to conventional farms. Organic soils thus show improved water retention properties and allow the crops to cope better with drought. Investigation of five plots in Rutzendorf/Weinviertel Lower Austria, differing in soil quality as well as in fertilising methods (cover crops, compost, dung, conventional fertiliser), revealed a significant increase of saturated hydraulic conductivity in organic tilled soils compared to

[3] Pimentel et al. (2005) have shown that organic matter content is higher in a organic system (+28 % with legumes and organic fertilizers and + 15 % with legumes) with regard to a conventional ones (+9 %)

conventional tilled soils. Best effects were obtained with compost, followed by dung and green manure/cover crops (Lunzer 2009). The positive effects of organic farming practices on soil structure results in beneficial effects on soil erosion (Siegrist et al., 1998; Shepherd et al., 2002). Gattinger *et al.* (2012) also performed a meta analysis of 74 pairwise comparisons of organic and non-organic farming systems, finding significantly higher soil organic carbon concentrations in soils under organic management.

A6.6 Air

Analysis of provisions: There is no provision regarding the prevention of air pollution in the organic regulation. However, some rules stated in the regulation can have indirect effects, e.g. the restrictive use of chemical inputs and on direct gaseous emissions from pesticides and ammonia.

Review of scientific literature: Air contamination risk by pesticide spray is minimal in organic farming due to the ban of synthetic pesticides (Stolze et al., 2000, Schader et l. 2012). Nevertheless, the application of powdered and fluid substances permitted by organic standards may cause a short-time impairment of air (Stolze et al., 2000).

A6.7 Greenhouse gas (GHG) emissions

Analysis of provisions: There is no provision regarding the prevention of GHG emissions in the organic regulation. However, some rules stated in the regulation can have indirect effects.

Review of scientific literature: Due to lower stocking rates per hectare, organic farming performs better with respect to methane emissions (Schader et al, 2012). Hörtenhuber et al. (2010, 2011) showed that, when considering deforestation due to growing feed concentrates for imports and inclusion of carbon sequestration, the soil's carbon footprints per unit of product clearly may be in favour of organic production. When considering the impact per unit of product, some have highlighted that increasing milk yield, through feeding increased amounts of concentrates can decrease greenhouse gas (GHG) emissions per kg of milk produced (Lovett *et al.*, 2005; Lovett *et al.*, 2006; Garwes, 2009; Zehetmeier *et al.*, 2012), and that as milk production is estimated to be 20% lower on organic dairy farms methane emissions per kg milk will be higher (Piorr and Werner (1998) in Stolze *et al.* (2000). However, a more recent study by Lampkin (2007) highlights that average yield per cow on organic dairy farms is typically only about 10% lower than conventional, and there is no significant difference in the meat output per animal, so this effect may be outweighed by other, farm or sector level considerations such as stocking rates and reliance on bought in feeds from off farm. Increased milk yields can also lead to a decrease in animal fertility and health and to an increase in the overall replacement rate. This may, paradoxically, involve an increase in herd size, resulting in greater emissions overall, due to a greater number of replacements/young stock on the farm (Novak and Fiorelli, 2009). Others have suggested that increasing the roughage content of the diet will result in an increase in methane emissions under organic management (de Boer, 2003), however Cederberg and Mattson (2000) found that the nitrous oxide emissions associated with synthetic fertiliser manufacture more than offsets the greater amounts of methane released by organic dairy cattle, as illustrated in Figure A6.2 below.

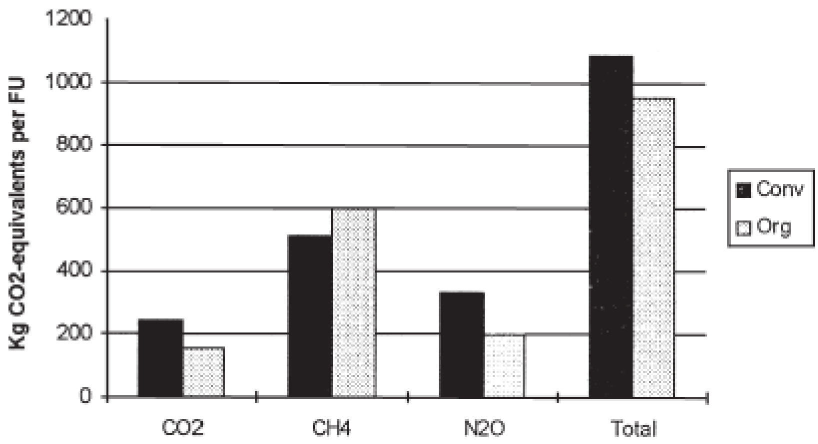

Figure A6-2: Global Warming Potential per t of milk from contrasting production systems

Source: Cederberg and Mattson (2000)

Diets high in tannins (e.g. diets with a high clover/legume content) may also produce less methane than grass-only diets through a suppression of fibre degradation in the rumen, which may then be degraded in the hindgut, resulting in lower methane emission (Hess *et al.*, 2006). In this sense, Lampkin (2007) highlights that the use of legumes could represent a potential “triple-gain” for climate change: reducing methane emissions from animals, building soil organic matter and reducing reliance on synthetic nitrogen fertilizers. The increasing popularity in the use of legumes on non-organic farms can result in savings for the agriculture sector overall.

In addition, organic farms try to maintain a closed production system as far as possible. Assessments of greenhouse gas emissions within beef and dairy production by Schader (2009) and Haas et al. (2001) found that this approach manifests through a reliance on home grown sources of feed for livestock. Lower emissions associated with concentrate feed have also been reported in comparisons of organic and conventional dairy production in Sweden, Denmark and the Netherlands (Cederberg and Mattsson, 2000; Jørgensen et al., 2005; Thomassen et al., 2008). Within an assessment of the environmental impacts of a 1996 ‘baseline’ and a number of 100% organic conversion scenarios in Denmark, Dalgaard et al. (2001) also found that domestically produced, organic grass/clover has less impact than conventional forage, due to a lack of fertiliser application, with the increased efficiency contributing to lower energy use, and associated emissions, per livestock unit.

A recent literature review also compared the total Global Warming Potential (GWP) of organic products, finding no significant differences overall between the greenhouse gas emissions resulting from the production of conventional and organic products (Knudsen et al., 2011). As may be seen from Figure , the variation between studies for the same product types is considerable. Figure A6.3 also shows the relative importance of farming system (organic vs. conventional) and product type (plant vs. meat products) for greenhouse gas emissions.

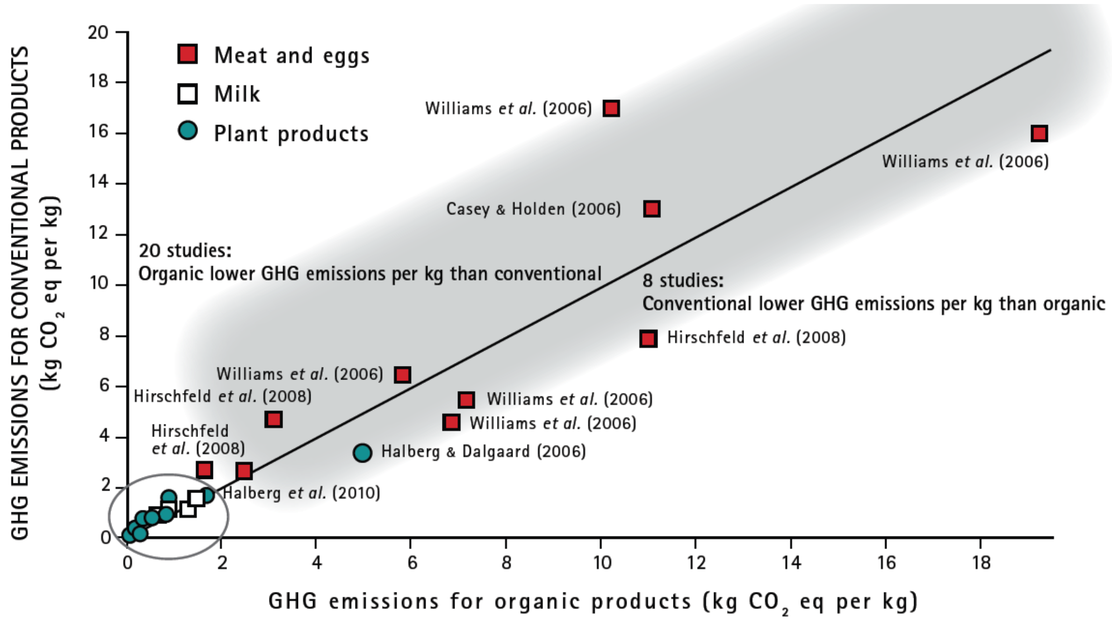

Figure A6-3: Literature review of conventional and organic products. Organic performs better above the line, worse below the line. Source: Knudsen *et al.* (2011)

Organic systems also avoid the N_2O emissions associated with mineral nitrogen fertiliser, as the main source of N is biological nitrogen fixation, within the fertility building ley period of the crop rotation. Despite this, there are only a few studies available which compare N_2O-emissions from organic and conventional farming systems. Chirinda et al. (2010) found no differences in N_2O-emissions between farming systems. Flessa et al. (2002) and Sehy (2003) found lower N_2O-emissions in organic farming systems per ha, and calculated N_2O-emissions per output weight to be equal to Swiss non-organic farming systems. A Life Cycle Assessment by Nemecek et al., (2005) showed lower N_2O-emissions in organic farming systems for both area and product output (36 or 18% respectively) than conventional. Gattinger et al. (2010) conclude that organic farming systems have a lower N_2O-emission potential than conventional farming systems, because in general, there is a linear relationship between N-Input und N_2O release and in organic farming systems N-supply is up to 50% lower than conventional. In summary, data uncertainty concerning N_2O emissions from different fertilisers and from the soil does not allow general conclusions to be drawn on the impact of organic farming.

Since the performance of organic agriculture regarding CO_2 emissions is highly correlated to energy use, the same arguments apply as for the discussion of energy use in the section above. Unlike the energy use though, net emissions of CO_2 (i.e. gross emissions subtracted by the sequestration rate) need to be taken into account. There are indications that organic farming performs better regarding carbon sequestration due to the incorporation of fertility building grass-clover leys and the use of livestock manures within diverse crop rotations (Olesen et al., 2006; Niggli et al., 2009, Smith et al., 2011). Several long-term trials from the United States, Germany, and Switzerland (Mäder et al., 2002) show that organic farming systems are able to sequester more carbon from the atmosphere than the best performing conventional counterparts. A meta-analysis of 74 studies conducted by Gattinger et al. (2012) confirms higher soil organic carbon concentrations and stocks in top soils under organic farming management compared to conventional. These differences seemed to be mainly influenced by elements of mixed farming (livestock plus crop production), such as organic matter recycling and forage legumes in the crop rotation.

The main finding is that GHG emissions are 48 to 66 %generally lower per hectare in organic farming than conventional[4]. However, related to the quantities produced, GHG emissions remain equivalent or sometimes higher for organic production, although the differences between the two systems are often marginal. Important factors which influence the product-related greenhouse gas emissions are yield, land use change due to the production of feed concentrates (deforestation), the method of production, the intensity of cultivation (pesticides, fertilisers) as well as carbon sequestration (Schmid et al., 2012).

A6.8 Animal health and welfare

Analysis of provisions: The EU Organic Regulation provides very detailed rules in terms of health care, feeding and housing (Council Regulation (EC) 834/2007 Article 14 and Regulation (EC) 889/2008 Article 7 to 25). Some transitional and exceptional rules exist in Regulation (EC) 889/2008, such as tethering for small holdings under certain conditions which is directly linked to animal welfare. It requires regular exercise, access to bedded areas, good management and additional control visits, but it is not clear to what extent the control visits are take the animal welfare outcome into account. Similarly for exceptions related to housing conditions and stocking densities, farmers had to present a plan to the competent authority and control body how they ensure compliance after this period (until end of 2013). To which extent the animal welfare was affected is difficult to judge.

Review of scientific literature: In the EU funded project EconWelfare, organic rules were compared with general animal welfare standards and private non-organic welfare standards for farm animals. The project concluded that animal welfare is already on a high level compared with the requirements of the general EU Legislation (Ferrari et al. 2010). In contrast, in the introduction to the proceedings of the 2nd Organic Animal Husbandry Conference of IFOAM[5], some practices in organic animal husbandry were highlighted which are considered not adequately respecting animal welfare. Some of them are directly authorised in the regulation (mainly under transitional or exceptional rules), such as temporary tethering of cows, and dehorning or castration without anaesthesia. Other examples include the use of conventional breeds that are not robust enough and not adapted to organic farming conditions (e.g. hybrid poultry bred for intensive systems), high mortality rates of piglets, meat quality problems due to non-appropriate feeding, killing of male chicks in poultry due to the lack of multi-purpose lines, large poultry flocks with difficulties to ensure a sufficient and adequate outdoor runs, short life expectancy of organic dairy cows in some countries, and high reliance of the milk production on concentrate feeds (cereal and soy) instead of strong roughage basis. Schmid and Knuti (2012) compared the main added requirements of EU organic production rules with other welfare standards, and found differences related to the prohibition of certain housing systems (e.g. fully slatted floors for cattle) and improvements in existing ones (e.g. access to bedding). To develop organic standards to become more adequate to highest welfare standards, it is suggested to provide more space indoors for all species of animal and to include measures for transport and slaughter where there are almost no measures at present.

Some studies investigate health and welfare on different types of farms. For example, Kilbride et al. (2012) concluded that enterprises participating in organic or farm assurance inspections were more likely to comply with welfare legislation in animal health inspections and that such membership could be included in the risk-based selection of farms for inspection. In contrast, in

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[4] "Les enjeux de la production d'agriculture biologique en France" http://www.agreste.agriculture.gouv.fr/IMG/pdf/analyse501207.pdf, *Biblio AB_enviro_RMT_DevAB*

[5] Rahmann and Godinho (Ed.) 2012 Proceedings of 2nd Organic Animal Husbandry Conference, September 2012, in Hamburg, by IFOAM, VTI, Senat Bundesforshung and ISOFAR.

study of 40 organic farms paired with 40 non-organic farms for housing type and herd size, Langford et al (2008) found no significant differences in building dimensions between conventional and organic in other aspects of cow housing and health. Referring to same study of 80 paired dairy farms, Rutherford et al. (2008) found lameness to be less prevalent on organic farms whereas Haskell et al (2009) found no difference in somatic cell counts of dairy cows. Similarly, Fall et al (2009) and Müller et al (2010) found no difference in udder health in paired farm studies in Sweden and Germany respectively. No studies that directly compare welfare also for other species could be identified.

A6.9 Food safety/quality

Analysis of provisions: In relation to the aim of high quality products the EU Organic Regulation does not define specific quality attributes. Outside the context of the EU rules quality is often defined by characteristics expected from the product with respect to consumer needs/demands (health, taste and safety). Various rules are likely to impact on the quality of raw organic products, addressing different stages in the process of production, storage or transport that confer properties to the products:

- Food safety and nutrition: No use of chemical plant protection and fertilizers, limitation of allopathic treatment of animals, controlled composition of organic processed food [6]
- Taste: slow growing strains, open-air access, feed requirements[7].
- Traceability: Organic animals and seeds[8].

Food safety: The production rules forbid the use of chemical pesticides and limit allopathic treatment for animals, but does not specify maximum threshold of the residue content in organic production. The number of permitted inputs is considerably lower than for conventional agriculture, which is the major impact of the production rules on food safety. The EU funded study on quality and safety of organic and low input foods in the context of cost efficiency and sound environment (QLIF, 2009) showed that "organic production methods resulted in (a) higher levels of nutritionally desirable compounds (e.g. vitamins/antioxidants and poly-unsaturated fatty acids such as CLA and omega-3 and (b) lower levels of nutritionally undesirable compounds such as heavy metals, mycotoxins, pesticide residues and glycol-alkaloids in a range of crops and milk." A Dutch literature review on food quality, safety and health impact of organic production (Van der Vijver et al., 2009) comes to similar conclusions but expresses some reservations about livestock products[9]. Thus, food safety of crop based products is improved mainly thanks to the prohibition

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[6] E.g. Mineral nitrogen fertilizers shall not be used (Article. 12.1(e) of Reg. 834/2007), plant protection products must be authorized by the regulation and use in case of established threat (Article 12.1 (h), chemically synthesised allopathic veterinary medicinal products including antibiotics may only be used under strict conditions (Article 14.1(e ii) of Reg. 834/2007).

[7] E.g. appropriate breeds shall be chosen (Article 14.1 (c iv) of Reg. 344/2007; in the choice of breeds or strains, account shall be taken of the capacity of animals to adapt to local conditions, their vitality and their resistance to disease (Art 8 of Reg. 889/2008); animals must have permanent access to open air (Article 14.1 (b) iii of Reg. 834/2007), prohibition of landless livestock production (Article 16 of Reg. 889/2008), use of certain products and substances in feed (Article 22 of Reg. 889/2008)

[8] E.g. Animals must be born and raised on organic holdings (with few exceptions) (Article 14.1 (a) of Reg. 834/2007), only organically produced seed and propagating material shall be used (Article 12. 1 (i) of Reg. 834/2007) and other consumers' expectations on environmental value, animal welfare, no GMO, etc.).

[9] The literature review leads the author to conclude that a number of well-conducted studies show clear evidence of the following: in the plant sector, organic products contain less rather than more fungal toxins, the nitrate content of organic crops is generally lower than for conventional crops (occasionally some result show the opposite), there are a limited number of comparative studies showing that conventional products contain more pesticides residues than organic; regarding animal production, there are clear indications that eggs from free-range hens contain more dioxins, that the prevalence of antibiotic resistant bacteria in organic

of chemical pesticides and the non-use of mineral fertilizers. For animal-based products, the obligation to use roughage in the diet and limitation on allopathic treatment are likely to have a positive effect; however, for monogastrics the obligation of access to pasture (free-range) and restrictions on the use of allopathic treatment require good management abilities of the holder (e.g. Vaarst et al 2008). For several potential food safety risk factors not only direct restrictions in the EU organic rules but also indirect measures can play a potential role (Schmid, 2002, AFFSA, 2003). A recent review a recent systematic review (concluded that organic food consumption may reduce exposure to pesticide residues and antibiotic resistant bacteria (Smith- Spangler et al 2012).

Traceability: The regulation intends to prevent fraud and contamination of organic products; in terms of production rules, several obligations apply to the producers to keep documentation traces in order to prove the use of inputs, some husbandry operations like veterinary treatment, the use of non-organic feed or seeds, etc.[10] Mostly the traceability insurance relies on the control system (see also Evaluation Question 3).

Nutritional value and health: There is very little evidence of an impact of organic practices on the nutritional value of products and even less regarding health. According to a study conducted in 2003 by the French Food Agency (AFSSA, 2003) the fact that organic crops are more exposed to environmental stress would slightly increase the content of the following micronutrients: iron, magnesium, vitamin C and antioxidants (these molecules intervene in the defence system of plants). According to Raiffaud (2010), promoting grazing for ruminants improves the flavour and the nutritional composition of products like milk or cheese, because of the abundance and the varieties of meadow wildflowers. Comparison of nutritional quality between conventional and organic dairy products (Palupi et al., 2012) also conclude to premium nutritional quality[11] of organic milk, probably related to difference in feeding regime (higher level of fresh forage encouraged by the regulation in the case of organic production). Similarly, the meta-analysis of results related to organic milk production (Kahl et al. 2011) shows that organic dairy products contain significantly higher levels of protein or total omega-3 fatty acid. Some studies (QLIF, 2009; van der Vijver et al., 2009) concluded that it was premature to draw conclusions in the field of health, whereas the systematic review of Smith Spangler et al (2012) concluded that there is no strong evidence of the higher nutritional value of organic products compared to conventional ones, but pointed to the limitations of their study in terms of the number of studies and their heterogeneous nature. In contrast, Brandt et al. (2011) concluded that the content of secondary metabolites is approximately 12 % higher in organic produce resulting from the different fertility management system between both systems**.**

Organoleptic value: According to Raiffaud (2010), the numerous scientific studies on the impact of organic practices on the taste of products have not shown significant difference to conventional ones. Various production parameters (e.g. varieties and species used, the duration of rearing or the crop conditions) may influence the flavour making rigorous comparison more difficult. In the

pigs and chickens is lower than with conventional bred animals and that the prevalence of Campylobacter is higher in organic broilers.

[10] Organic operators shall keep documentary evidence: of the need to use fertilisers and soil conditioners referred to in Annex I (Article 3), of the need to use pesticides referred to in Annex II (Article5), of the provision regarding simultaneous production of organic and non-organic livestock (Article 17), of the period animals runs are left empty (Article 23), of the occurrence of veterinary treatments (Article 24), of transport (Article 32), of the use of non organic feed (Article 43), of the use of exceptions for catastrophic circumstances (Article 47).

[11] Significantly higher amounts of protein, ALA, n-3, CLA9, VA, EPA and DPA in organic dairy products than in conventional products, as well as a higher ratio of n-3 to n-6 (approximately twofold) and _9-desaturase index, indicate that the organic dairy product may have a premium nutritional quality."

EU funded research project ECROPOLIS, a comparative analysis of relevant sensory related requirements in regulations and standards for mainly processed organic products was made using an impact matrix (Schmid, 2009). The empirical verification of product qualities through consumers and sensory laboratory testing showed significant standards-related impacts for oil and salami, but no impact for apples, biscuits and tomato sauce. These effects were related to processing rules, such additives (non-use of nitrates/nitrites for meat products) and restrictions on extraction methods and heat treatment of plant oils that are found in some private standards but not in the EU regulation for organic production (Espig et al., 2011).

A6.10 Rural economic development/vitality

The financial viability of organic farming relies on utilisation of specialist markets to generate premium prices as well as policy support through agri-environment schemes. Evidence in the UK and other European countries is that organic farms generate similar or higher levels of incomes and employment (Offermann and Nieberg, 1999; Moakes et al., 2011). There is also evidence that organic farming businesses engage more women, younger people and new entrants (Janssen, 2000; Lobley et al., 2005).

In general terms, the rural economic development/vitality impacts of organic farming are an indirect consequence of the use of the specialist organic market, rather than directly a consequence of organic production standards/regulations themselves. Specialist markets and organic food products create opportunities for adding value to farm products and consequent rural employment generation.

A6.11 References

AUERSWALD K, KEINZ M, FIENER P (2003) Soil erosion potential of organic versus conventional farming evaluated by USLE modelling of cropping statistics for agricultural districts in Bavaria, Soil use and Management, 19: 305-311

AZEEZ GSE, HEWELLETT KL (2008) The comparative energy efficiency of organic farming, in IFOAM organic world congress, cultivate the future? 8-29 June 2008, Modena, Italy

BATARY P, BÁLDI A, KLEIJN D, TSCHARNTKE T (2010) Landscape-moderated biodiversity effects of agri-environmental management: a meta-analysis. Proc. R. Soc. B 22 June 2011 Vol. 278 No. 1713 1894-1902

BECK A, KAHL J, LIEBL B (Eds.) (2012) Analysis of the current state of knowledge of the processing and quality of organic food and of consumer protection, Frick: FIBL.

BENGTSSON J, AHNSTRÖM J, WEIBULL AC (2005). The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology, 42: 261-269

BOUTIN, C., BARIL, A., MARTIN, P. A. 2008. Plant diversity in crop fields and woody hedgerows of organic and conventional farms in contrasting landscapes. Agriculture Ecosystems and Environment, 123: 185-193

CAPLAT J., Mise en place et analyse d'une collecte de données agro-environnementale sur les pratiques de l'agriculture biologique, FNAB, 2006.

CEDERBERG, C., MATTSSON, B., 2000. Life cycle assessment of milk production — a comparison of conventional and organic farming. Journal of Cleaner Production 8, 49-60.

CHIRINDA, N., CARTER, M.S., ALBERT, K.R., AMBUS, P., OLESEN, J.E., PORTER, J.R. and PETERSEN, S.O. 2010. 'Emissions of nitrous oxide from arable organic and conventional cropping systems on two soil types. ', Agriculture, Ecosystems and Environment 136: 199-208.

COLÉNO F. C. 2008. Simulation and evaluation of GM and non-GM segregation management strategies among European grain merchants. Journal of Food Engineering 88 (3): 306-314.

CONDRON, L.M., CAMERON, K.C., DI, H.J., CLOUGH, T.J., FORBES, E.A., MCLAREN, R.G. AND SILVA, R.G. 2000, 'A comparison of soil and environmental quality under organic and conventional farming systems in New Zealand', New Zealand Journal of Agricultural Research, 43: 443-466.

CROWDER, D.W., NORTHFIELD, T.D., STRAND. M., SNYDER, W.E. 2010. Organic agriculture promotes evenness and natural pest control. Nature, 46:109-112.

DALGAARD, T., HALBERG, N., PORTER, J.R., 2001. A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. Agriculture, Ecosystems & Environment 87, 51-65.

DE BOER, I.J.M., 2003. Environmental impact assessment of conventional and organic milk production. Livestock Production Science 80, 69-77.

DE BACKER E., AERTSENS, J. VERGUCHT, S. STEURBAUT,W. 2009., Assessing the ecological soundness of organic and conventional agriculture by means of life cycle assessment - a case study of leek production. British Food Journal, 111 (10): 1028 – 1061.

DEGRÉ A., DEBOUCHE C., VERHÈ D. 2007. Conventional versus alternative pig production assessed by multicriteria decision analyses. Agron. Sustain. Dev. 27 (9): 185-195.

DIACONO, M., MONTEMURRO, F., 2011. Long-term effects of organic amendments on soil fertility. Sustainable Agriculture Volume 2. Springer, pp. 761-786.

EDWARDS, C.A., LAL, R., MADDEN, P., MILLER, R.H. and HOUSE, G. 1990. 'Research on integrated arable farming and organic mixed farming in the Netherlands', Sustainable agricultural systems, Ankeny, Iowa, Soil and Water Conservation Society, pp. 287-296.

El-HAGE, N., SCIALABBA, N., MÜLLER-LINDENLAUF, M., 2010. Organic agriculture and climate change. Renewable Agriculture and Food Systems 25(Special issue2): 158-169.

ELTUN, R. 1995 Comparisons of nitrogen leaching in ecological and conventional cropping systems', Biological Agriculture and Horticulture, 11, pp. 103-114.

LUNZER, E. 2009. Investigation of organic farming on saturated hydraulic conductivity of the soil. Dissertation BOKU, Vienna. https://zidapps.boku.ac.at/abstracts/search_abstract.php?paID=3&paLIST=0&paSID=7569

ERIKSEN J., PETERSEN S.O., SOMMER S.G. 2002. The fate of nitrogen in outdoor pig production. Agronomy 22: 863-867.

ERIKSEN J., HERMANSEN J.E., STRUDSHOLM K., KRISTENSEN K. 2006 Potential loss of nutrients from different rearing strategies for fattening pigs on pasture. Soil Use and Management 22: 256-266.

FALL, N., EMANUELSON, U., MARTINSSON, K. JONSSON, S. 2008 Udder health at a Swedish research farm with both organic and conventional dairy cow management. *Preventive* Veterinary Medicine 83 (2): 186-195.

FERRARI P. et al. (2010). Report on (dis-) advantages of current animal welfare standards for animals, based on the main findings of EU and national research projects. EconWelfare project report D2.3. www.econwelfare.eu

FLESSA, H., RUSER, R. DÖRSCH, P. KAMP, T. JIMENEZ, M.A. MUNCH, J.C. BEESE, F. 2002. Integrated evaluation of greenhouse gas emissions from two farming systems in southern Germany: Special consideration of N2O emissions. Agriculture Ecosystems and Environment 91:175–199.

FLIESSBACH, A., OBERHOLZER, H.-R., GUNST, L., MÄDER, P. 2007. Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture, Ecosystems and Environment, 118: 273-284.

FLYSJÖ, A., CEDERBERG, C., HENRIKSSON, M., LEDGARD, S. 2012. The interaction between milk and beef production and emissions from land use change - critical considerations in life cycle assessment and carbon footprint studies of milk. Journal of Cleaner Production 28: 134-142.

FREIBAUER, A., ROUNSEVELL, M.D.A., SMITH, P., VERHAGEN, J., 2004. Carbon sequestration in the agricultural soils of Europe. Geoderma 122, 1-23.

FULLER, R.J., NORTON, L.R., FEBER, R.E., JOHNSON, P.J., CHAMBERLAIN, D.E., JOYS, A.C., MATHEWS, F., STUART, R.C., TOWNSEND, M.C., MANLEY, W.J., WOLFE, M.S., MACDONALD, D.W. FIRBANK, L.G. 2005. Benefits of organic farming to biodiversity vary among taxa. Biology Letters, 1: 431-434.

GABRIEL D, SAIT SM, HODGSON JA, SCHMUTZ U, KUNIN WE, BENTON TG. 2010. Scale matters: the impact of organic farming on biodiversity at different spatial scales. Ecology Letters 13 (7):858-869.

GABRIEL, D. and TSCHARNTKE, T. 2007. Insect pollinated plants benefit from organic farming. Agriculture, Ecosystems and Environment 118: 43-48.

GABRIEL, D., ROSCHEWITZ, I., TSCHARNTKE, T., THIES, C. 2006. Beta diversity at different spatial scales: plant communities in organic and conventional agriculture. Ecological Applications 16: 2011-2021.

GARWES, D., 2009. Grazed Livestock are Good news for the UK. Practice with Science Extract 2: Reducing Emissions from Livestock.

GATTINGER, A., MULLER, A., HAENI, M., SKINNER, C., FLIESSBACH, A., BUCHMANN, N., MADER, P., STOLZE, M., SMITH, P., SCIALABBA, N.E.-H., 2012. Enhanced top soil carbon stocks under organic farming. Proceedings of the National Academy of Sciences 109, 18226-18231.

GATTINGER, A., MÜLLER, A., HÄNI, M., OEHEN, B. AND NIGGLI, U. 2010. Klimaleistungen des Biolandbaus - Fakten und Hintergründe Frick.

GOMIERO, T., PIMENTEL, D. AND PAOLETTI, M. G. 2011. Environmental Impact of Different Agricultural Management Practices: Conventional vs. Organic Agriculture, Critical Reviews in Plant Sciences, 30: 95-124

GOULDING, K.W.T. 2000.Nitrate leaching from arable and horticultural land', Soil Use and Management, 16: 145-151.

GREENE C., K. SMITH 2010. Can Genetically Engineered and Organic Crops Coexist? http://farmdoc.illinois.edu/policy/choices/20102/2010214/2010214.pdf

GRÖNROOS, J., SEPPÄLÄ, J., VOUTILAINEN, P., SEURI, P., KOIKKALAINEN, K. 2006. Energy use in conventional and organic milk and rye bread production in Finland. Agriculture, Ecosystems and Environment, 117(2-3): 109-118.

HAAS, G., F. WETTERICH, and KÖPKE, U. 2001. Comparing intensive, extensified and organic grassland farming in southern Germany by process life cycle assessment. Agriculture, Ecosystems and Environment 83:43–53.

HALBERG, N., HERMANSEN, J.E., KRISTENSEN, I.S., ERIKSEN, J., TVEDEGAARD, N., PETERSEN, B.M., 2010. Impact of organic pig production systems on CO2 emission, C sequestration and nitrate pollution. Agronomy for Sustainable Development 30:721-731.

HASKELL, M., LANGFORD, F., JACK, M., SHERWOOD, L., LAWRENCE, A. RUTHERFORD, K. 2009. The effect of organic status and management practises on somatic cell counts on UK dairy farms. Journal of Dairy Science, 180: 3775-3780.

HESS, H., TIEMANN, T., NOTO, F., CARULLA, J., KREUZER, M., 2006. Strategic use of tannins as means to limit methane emission from ruminant livestock. International Congress Series 1293, 4.

HODGSON, J. A., KUNIN, W.E., THOMAS, C.D., BENTON, T.G., GABRIEL, D., (2010). Comparing organic farming and land sparing: optimizing yield and butterfly populations at a landscape scale. Ecology Letters 13(11): 1358-1367.

HOEPPNER, J.W., M.H. ENTZ, B.G. MCCONKEY, R.P. ZENTNER, NAGY C.N. 2005. Energy use and efficiency in two Canadian organic and conventional crop production systems. Renewable Agriculture and Food Systems 21(1): 60–67.

HOLE, D.G., PERKINS, A.J., WILSON, J.D., ALEXANDER, I.H., GRICE, P.V., EVANS, A.D. 2005. Does organic farming benefit biodiversity? Biological Conservation, 122: 113-130.

HOLZSCHUH, A., STEFAN-DEWENTER, I., TSCHARNTKE, T. 2008. Agricultural landscapes with organic crops support higher pollinator diversity. Oikos 117: 354-361.

HOLZSCHUH, A., STEFAN-DEWENTER, I., KLEIJN, D., TSCHARNTKE, T. 2007. Diversity of flower-visiting bees in cereal fields: effects of farming system, landscape composition and regional context. Journal of Applied Ecology 44: 41-49.

HÖRTENHUBER, S., LINDENTHAL, T., AMON, B., MARKUT, T., KIRNER, L. AND ZOLLITSCH, W. 2010. Greenhouse gas emissions from selected Austrian dairy production systems—model calculations considering the effects of land use change. Renewable Agriculture and Food Systems 25 (04): 316-329.

HÖRTENHUBER, S.J., LINDENTHAL, T. AND ZOLLITSCH, W. (2011). Reduction of greenhouse gas emissions from feed supply chains by utilizing regionally produced protein sources: the case of Austrian dairy production. Journal of the Science of Food and Agriculture 91(6): 1118-1127.

JANSEN, K. 2000. Labour, livelihoods, and the quality of life in organic agriculture. Biological Agriculture and Horticulture 17(3): 247-278.

JØRGENSEN, U., DALGAARD, T., KRISTENSEN, E.S., 2005. Biomass energy in organic farming—the potential role of short rotation coppice. Biomass and Bioenergy 28, 237-248.

KNUDSEN, M., HERMANSE, J., HALBERG, N., ANDREASEN, L., WILLIAMS, A., 2011. LIfe Cycle Asssessment of Organic Food and Farming Systems: Methodological Challenges Related to Greenhouse Gas Emissions and Carbon Sequestration. Organic Agriculture and Climate Change Mitigation: A Report of the Round Table on Organic Agriculture and Climate Change.

LAL, R., 2008. Carbon sequestration. Philosophical Transactions of the Royal Society 363, 15.

LAMPKIN, N., 2007. Organic Farming's Contribution to Climate Change and Agricultural Sustainability. Welsh Producer Conference, Builth Wells,.

LOBLEY, M., REED, M. et al. 2005. The Impact of Organic Farming on the Rural Economy in England. Report to Defra, London.

LOVETT, D.K., SHALLOO, L., DILLON, P., O'MARA, F.P., 2006. A systems approach to quantify greenhouse gas fluxes from pastoral dairy production as affected by management regime. Agricultural Systems 88:156-179.

LOVETT, D.K., STACK, L.J., LOVELL, S., CALLAN, J., FLYNN, B., HAWKINS, M., O'MARA, F.P., 2005. Manipulating Enteric Methane Emissions and Animal Performance of Late-Lactation Dairy Cows Through Concentrate Supplementation at Pasture. Journal of Dairy Science 88, 2836-2842.

MAGDELAINE P., RIFFARD C. 2010 Analyse comparée des dynamiques des filières avicoles biologiques au sein de l'Union Européenne, Rapport de synthèse, projet avibio: ITAVI.

NOVAK, S.M., FIORELLI, J.L., 2009. Greenhouse gases and ammonia emissions from organic mixed crop-dairy systems: a critical review of mitigation options. Agronomy for Sustainable Development, 22.

KILBRIDE, A. L., MASON, S. A., HONEYMAN, P. C., PRITCHARD, D. G., HEPPLE, S. AND GREEN, L. E. 2012. Associations between membership of farm assurance and organic certification schemes and compliance with animal welfare legislation. *Veterinary Record* 170 (6): 152-158.

KIRCHMANN, H., BERGSTRÖM, L. 2001. Do organic farming practices reduce nitrate leaching? Communications in Soil Science and Plant Analysis 32(7): 997–1028.

KRAGTEN, S., DE SNOO, G.R. 2008a. Field-breeding birds on organic and conventional arable farms in the Netherlands. Agriculture, Ecosystems and Environment, 126 (3-4): 270-274.

KRAGTEN, S., TRIMBOS, K.B., DE SNOO, G.R. 2008b. Breeding skylarks (Alauda arvensis) on organic and conventional arable farms in The Netherlands. Agriculture, Ecosystems and Environment, 126 (3-4): 163-167.

KRAUSS, J., GALLENBERGER, I., STEFFAN-DEWENTER, I. 2011. Decreased functional diversity and biological pest control in conventional compared to organic crop fields. Plos One 6: 1-9.

KRISTENSEN, T., MOGENSEN, L., KNUDSEN, M.T., HERMANSEN, J.E. 2011. Effect of production system and farming strategy on greenhouse gas emissions from commercial dairy farms in a life cycle approach. Livestock Science 140, 136-148.

KORSAETH A. and ELTUN R., 2008 Nitrogen mass balances in conventional, integrated and ecological cropping systems and the relationship between balance calculations and nitrogen runoff in an 8-year field experiment in Norway, Agriculture, Ecosystems and Environment, 79 (2–3): 199-214.

LAMPKIN, N.H. 1990, Organic Farming, Ipswich, UK, Farming Press Books.

LAMPKIN, N.H. 2007. Organic farming's contribution to climate change and agricultural sustainability. Paper presented at the Welsh Organic Producers Conference, 18th Oct 2007.

LANGFORD, F. M., RUTHERFORD, K. M. D., SHERWOOD, L., JACK, M. C., LAWRENCE, A. B. HASKELL, M. J. 2011 Behavior of cows during and after peak feeding time on organic and conventional dairy farms in the United Kingdom. Journal of Dairy Science94 (2): 746-753.

LEINONEN, I., WILLIAMS, A.G., WISEMAN, J., GUY, J., KYRIAZAKIS, I., 2012a. Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Broiler production systems. Poultry Science 91: 8-25.

LEINONEN, I., WILLIAMS, A.G., WISEMAN, J., GUY, J., KYRIAZAKIS, I., 2012b. Predicting the environmental impacts of chicken systems in the United Kingdom through a life cycle assessment: Egg production systems. Poultry Science 9: 26-40.

LOTTER D.-W. 2003. Organic Agriculture, *Journal of Sustainable Agriculture*, 21 (4): 59-128.

MÄDER, P.,. FLIESSBACH A, DUBIOS, D. GUNST, L. FRIED, P. NIGGLI, U. 2002. Soil fertility and biodiversity in organic farming. Science 296: 1694–1697.

MAHE T., PORTET F. (2012), Les enjeux de la production d'agriculture biologique en France, Centre d'études et de Prospectives, No.50. Available at http://www.agreste.agriculture.gouv.fr/IMG/pdf/analyse501207.pdf

MOAKES, S., LAMPKIN, N., GERARD, C. 2011. Organic Farm Incomes in England and Wales 2010/11. Report to Defra. Aberystwyth University.

MONDELAERS K., AERTSENS J., VAN HUYLENBROECK G. 2009, A meta-analysis of the differences in environmental impacts between organic and conventional farming, *British Food Journal* 111: 1098-1119.

MULLER, A., OLESEN, J.E., DAVIS, J., DYTRTOVA, K., GATTINGER, A., LAMPKIN, N. AND NIGGLI, U. 2012: Reducing Global Warming and Adapting to Climate Change: The Potential of Organic Agriculture. Working Paper, Forschungsinstitut für biologischen Landbau (FiBL), CH Frick.

MÜLLER, U. SAUERWEIN, H. 2010. A comparison of somatic cell count between organic and conventional dairy cow herds in West Germany stressing dry period related changes. Livestock Science, 127: 30-37.

NEMECEK, T., O. HUGUENIN-ELIE, D. DUBOIS, GAILLARD, G. 2005. Ökobilanzierung von Anbausystemen im schweizerischen Acker- und Futterbau , FAL Schriftenreihe, Vol. 58. Reckenholz: Eidgenössische Forschungsanstalt für Agrarökologie und Landbau (FAL).

NIGGLI, U., FLIESSBACH, A.. STOLZE M, SANDERS, J., SCHADER, C, WYSS, G, BALMER, O. . PFIFFNER, L, WYSS, E. 2008. Gesellschaftliche Leistungen der biologischen Landwirtschaft. Frick: Forschungsinstitut für Biologischen Landbau (FiBL).

NIGGLI, U., FLIESSBACH, A., HEPPERLY, P. SCIALABBA, N. 2009. Low Greenhouse Gas Agriculture: Mitigation and Adaptation Potential of Sustainable Farming Systems', Rome, Food and Agriculture Organization of the United Nations (FAO).

NORTON, L., P. JOHNSON, A. JOYS, R. STUART, D. CHAMBERLAIN, R. FEBER, L. FIRBANK, W. MANLEY, M. WOLFE, HART, B. 2009. Consequences of organic and non-organic farming practices for field, farm and landscape complexity. Agriculture, Ecosystems and Environment 129(1–3): 221–227.

OFFERMANN. F., NIEBERG, H. 1999. Economic performance of organic farms in Europe. Organic farming in Europe: Economics and Policy, Volume 5, Universität Hohenheim, Stuttgart-Hohenheim.

OLESEN, J.E., SCHELDE, K., WEISKE, A., WEISBJERG, M.R., ASMAN, W.A.H. AND DJURHUUS, J. 2006. Modelling greenhouse gas emissions from European conventional and organic dairy farms. Agriculture, Ecosystems and Environment, 112 (2-3): 207-220.

OSTERBURG, B., RUNGE, T. (eds.) 2007. Maßnahmen zur Reduzierung von Stickstoffeinträgen in Gewässer - eine wasserschutzorientierte Landwirtschaft zur Umsetzung der Wasserrahmenrichtlinie, Braunschweig.

PACINI, C., WOSSINK, A., GIESEN, G., VAZZANA, C., HUIRNE, R. 2003. Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis, Agriculture, Ecosystems and Environment, 95(1): 273-288.

PFIFFNER, L., LUKA, H. 2003. Effects of low-input farming systems on carabids and epigeal spiders – a paired farm approach. Basic and Applied Ecology 4: 117-127.

PFIFFNER, L., LUKA, H., 2007. Earthworm populations in two low-input cereal farming systems. Applied Soil Ecology 37: 184-191.

PIMENTEL, D., BERARDI, G., FAST, S. 1983. Energy efficiency of farming systems: Organic and conventional agriculture. Agriculture, Ecosystems and Environment 9: 359-372.

PIMENTEL, D., HEPPERLY, P., HANSON, J., DOUDS, D. SEIDEL, R. 2005. Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems', Bioscience, 55 (7): 573-582.

REGANOLD, J., ELLIOTT, L., UNGER, Y., 1987. Long-term effects of organic and conventional farming on soil erosion. Nature 330, 3.

ROSCHEWITZ I, GABRIEL D, TSCHARNTKE T, THIES C. 2005. The effects of landscape complexity on arable weed species diversity in organic and conventional farming. Journal of Applied Ecology 42:873-882.

RUNDLÖF, M., BENGTSSON, J., SMITH, H.G. 2008. Local and landscape effects of organic farming on butterfly species richness and abundance. Journal of Applied Ecology 45: 813-820.

RUTHERFORD, K. M. D., LANGFORD, F. M., JACK, M. C., SHERWOOD, L., LAWRENCE, A. B. HASKELL, M. J. 2009 Lameness prevalence and risk factors in organic and non-organic dairy herds in the United Kingdom The Veterinary Journal 180: 95-105.

SALOMON, E., ÅKERHIELM, H., LINDAHL, C. LINDGREN, K. (2007) Outdoor pig fattening at two Swedish organic farms—Spatial and temporal load of nutrients and potential environmental impact. Agriculture, Ecosystems and Environment 121 (4): 407-418.

SCHADER, C. 2009. Cost-effectiveness of organic farming for achieving environmental policy targets in Switzerland, Dissertation, Institute of Biological, Environmental and Rural Sciences, Aberystwyth, Aberystwyth University, Wales.

SCHADER, C., L. PFIFFNER, C. SCHLATTER, AM. STOLZE. 2009. Umsetzung von Agrarumweltmassnahmen auf bio- und konventionellen Betrieben der Schweiz. In: Mayer, J., Alföldi, T., Leiber, F., et al. (eds) Werte – Wege - Wirkungen: Biolandbau im Spannungsfeld zwischen Ernährungssicherung, Markt und Klimawandel. Beiträge zur 10. Wissenschaftstagung Ökologischer Landbau, 11–13.

SCHADER, C., STOLZE, M., GATTINGER, A. 2012. Environmental performance of organic farming. In Boye, J.I. and Arcand, Y. (eds) Green Technologies in Food Production and Processing, pp. 183-210, Food Engineering Series Part 3, Springer New York, Dordrecht, Heidelberg, London.

SCHADER, C., 2009. Cost effectiveness of organic farming for achieving environmental policy targets in Switzerland. PhD thesis. University of Wales: Aberystwyth.

SCHMID et al (2012) Climate relevance and sustainability of Bavarian agricultural businesses: http://orgprints.org/20986/1/Schmid_et_al_2012_Klimawirksamkeit.pdf

SCHMID, O., KNUTI, S. 2012. Outcome-oriented approaches for regulating animal welfare in organic farming. Paper in Workshop 6.3. at the 10th European IFSA Symposium, "Producing and reproducing farming systems. New modes of organization for sustainable food systems of tomorrow." 1-4 July 2012 in Aarhus, Denmark available http://www.ifsa2012.dk/downloads/WS6_3/Otto_Schmid.pdf

SEHY, U. 2004. N2O-Freisetzungen aus Ackerböden. PhD Thesis. Technical University Munich.

SHEPHERD, M., PEARCE, B., CORMACK, B., PHILIPPS, L., CUTTLE, S., BHOGAL, A., COSTIGAN, P., UNWIN, R. 2003. An assessment of the environmental impacts of organic farming', DEFRA, ADAS, Elm Farm, IGER.

SIEGRIST, S., SCHAUB, D., PFIFFNER, L., MÄDER, P. 1998. Does organic agriculture reduce soil erodibility? The results of a longterm field study on loess in Switzerland. Agriculture, Ecosystems & Environ. 69:253-265.

SMITH, J., WOLFE, M., WOODWARD, L. PEARCE, B. AND LAMPKIN, N. (2011)a: Organic Farming and Biodiversity: A review of the literature. Organic Centre Wales, Aberystwyth.

SMITH, L., PADEL, S. AND PEARCE, B. (2011)b: Soil Carbon Sequestration and Organic Farming: An overview of current evidence. Organic Centre Wales, Aberystwyth.

SMITH, P., MARTINO, D., CAI, Z., GWARY, D., JANZEN, H., KUMAR, P., MCCARL, B., OGLE, S., O'MARA, F., RICE, C., SCHOLES, B., SIROTENKO, O., 2007. Agriculture. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

SMITH, P., MARTINO, D., CAI, Z., GWARY, D., JANZEN, H.H., KUMAR, P., MCCARL, B., OGLE, S., O'MARA, F., RICE, C., SCHOLES, R.J., SIROTENKO, O., HOWDEN, M., MCALLISTER, T., PAN, G., ROMANENKOV, V., SCHNEIDER, U., TOWPRAYOON, S., WATTENBACH, M., SMITH, J.U., 2008. Greenhouse gas mitigation in agriculture. Philosophical Transactions of the Royal Society.

SOIL ASSOCIATION. 2000. The Biodiversity Benefits of Organic Farming. Soil Association: Bristol.

STANHILL G., 1990. The comparative productivity of organic agriculture, Agricultural Ecosystems and Environment, 30 1-26.

STEINER, R. S. 2006. Landnutzungen prägen die Landschaft. Dissertation ETH Zürich.

STOLZE, M., A. PIORR, A. HÄRING, DABBERT, S. 2000. Environmental and resource use impacts of organic farming in Europe. Organic farming in Europe: Economics and Policy, Volume 6, Stuttgart.

STOLZE, M., PIORR, A., HÄRING, A., DABBERT, S., 2000. The Environmental Impacts of Organic Farming in Europe. In: Dabbert, S., Lampkin, N., Michelsen, J., Nieberg, H., Zanoli, R. (Eds.), Organic Farming in Europe: Economics and Policy. University of Hohenheim, Stuttgart-Hohenheim.

STOPES, C., LORD, E.I., PHILIPPS, L., WOODWARD, L. 2002. Nitrate leaching form organic farms and conventional farms following best practice, Soil Use and Management, 18: 301-308.

THOMASSEN, M.A., VAN CALKER, K.J.,. SMITS, M.C.J, IEPEMA, G.L., de Boer, I.J.M. 2008. Life cycle assessment of conventional and organic milk production in the Netherlands. Agricultural Systems 96: 85–107.

THOMASSEN, M.A., VAN CALKER, K.J., SMITS, M.C.J., IEPEMA, G.L., DE BOER, I.J.M., 2008. Life cycle assessment of conventional and organic milk production in the Netherlands. Agricultural Systems 96, 95-107.

TSCHARNTKE, T., KLEIN, A.M., KRUESS, A., STEFFAN-DEWENTER, I., THIES, C., 2005. Landscape perspectives on agricultural intensification and biodiversity– ecosystem service management. Ecololgy Letters 8: 857–874.

TUOMISTO, H.L., HODGE, I.D., RIORDAN, P., MACDONALD, D.W., 2012. Does organic farming reduce environmental impacts?--a meta-analysis of European research. Journal of Environmental Management 112: 309-320.

ULBER L., STEINMANN H-H. LIMEK S., ISSELSTEIN J. 2009. An on-farm approach to investigate the impact of diversified crop rotations on weed species richness and composition in winter wheat. Weed Research 49:534-543

VENKAT, K., 2012. Comparison of Twelve Organic and Conventional Farming Systems: A Life Cycle Greenhouse Gas Emissions Perspective. Journal of Sustainable Agriculture 36: 29-.

WILLIAMS, A.G., AUDSLEY, E., SANDARS, D.L., 2006. Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. Defra Research Project IS0205. IS0205, D.R.P.

YOUNIE, D., WATSON, C.A. 1992. Soil nitrate-N levels in organically and intensively managed grassland systems', Aspects of Applied Biology, No. 30 Nitrate and Farming Systems, pp. 235-238.

ZEHNDER, G., GURR, G.M., KÜHNE, S., WADE, M.R., WRATTEN, S.D.,WYSS, E. 2007. Arthropod pest management in organic crops. Annual Review of Entomology, 52: 57-80.

ZEHETMEIER, M., BAUDRACCO, J., HOFFMANN, H., HEIßENHUBER, A., 2012. Does increasing milk yield per cow reduce greenhouse gas emissions? A system approach. animal 6, 154-166.