Comparison between organic and conventional crop farming in regards to greenhouse gas emission, biodiversity, yield and nitrogen leaching

What measures could increase sustainability in crop farming nationally in Sweden and regionally in Scania?

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Abstract

Advantages and disadvantages with organic production have been studied in the scientific community and is greatly debated. Demands for organic products have risen the past years in Sweden and the objective in one of the governments environmental goal is to reach a 20 % organic production. But is organic production increasing sustainability in the agriculture sector? This study aims to compare organic and conventional crop farming with the parameters of greenhouse gas, biodiversity, yield and nitrogen leaching. As well there is an aim to analyze on a national level in Sweden and on a regional level in Scania if a conversion to organic farming of crops would increase sustainability in the agriculture sector. The study is based on both a qualitative literature review and a quantitative statistical element. The literature survey analyzed comparative studies of organic and conventional crop farming and as well what effects crop farming have regionally in Scania and nationally in Sweden. The results showed that conventional crop farming produced a higher yield, had lower greenhouse gas emissions and nitrogen leaching per unit product, whilst organic crop farming had a higher amount of biodiversity. In total conventional crop farming is superior to organic crop farming but with an integrated system more environmental benefits could be sustained.

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1. Introduction

1.1 Background

The main aspects of organic farming is that inorganic fertilizers, genetically modified products and pesticides are not used in the production (Council Regulation, 2007). European Union (EU) has a common agricultural policy (CAP) which sets the standards for all the member states regarding organic production and certification (European Commission, 2014b). Besides the EUs certification for organic production, Sweden has a national organic certification called KRAV which has more requirements than the EUs certification (KRAV, 2015a). If farmers get an organic certification they can have environmental support, e.g. economic compensation, which is distributed to the farmer and is funded by the EU and the Swedish government (Jordbruksverket, 2015). Today the Swedish government is supporting organic production with about 500 million Swedish kronor per year (Kirchmann et al., 2014).

Sweden's government has had as an environmental goal to reach a 20 % organic production by 2010 (Miljömål, 2015a) but in 2014 the amount of organically grown farmland in Sweden was 17 % (Statistiska centralbyrån, 2015a). The demand for organic products in Sweden has increased between 2012 and 2013 with almost 12 % (Fagerberg et al., 2014) but the conversion to organic farming has decreased (Statistiska Centralbyrån, 2015a). Scania (Skåne), a region where half of the land is farmland (Hall et al., 2014), has 6 % organic farming which is the lowest amount compared to other regions in Sweden (Statistisk Centralbyrån, 2015a).

Organic farming was first developed from natural philosophy, not science, with the assumptions that certain organic farming methods would lower the negative impacts on the environment without it being tested or proven scientifically (Kirchmann et al., 2014). Today it is stated that organic production is built on science but Kirchmann et al. (2014) discuss that there still is certain assumptions about environmental benefits in organic production that is not scientifically based which is a subject greatly debated in the scientific community.

1.2 Purpose and aims

The purpose of this study is to compare how sustainable organic and conventional farming of crops are in relation to greenhouse gas (GHG) emissions, yield, biodiversity and nitrogen leaching with focus on environmental effects from crop farming in Sweden and Scania. Based on how sustainable organic and conventional crop farming are in relation to these four parameters will measures on how to increase sustainability in the different farming techniques be identified and discussed.

- How much farmland in Sweden and Scania have been organic certified and what main aspects does a organic certification from EU and KRAV constitutes of?
- Is conventional or organic farming of crops more sustainable in relation to GHGs emissions, yield, biodiversity and nitrogen leaching?
- What measures could increase sustainability in crop farming nationally in Sweden and regionally in Scania?

2. Methodology

2.1 Literature study

A qualitative literature study has been performed to examine and compare studies which analyzed organic and conventional crop farming. Articles were found using the databases Google, LubSearch and Google Schoolar or directly via websites of relevant institutions.

To compare the parameters of GHG emissions, nitrogen leaching, yield and biodiversity in the different farming techniques have the meta-analyzes Kirchmann et al. (2014), Toumisto et al. (2012), and Zikeli et al. (2014) been examined. The articles De Ponti et al. (2012), Kremen et al. (2014), Gliessman (2007) have been reviewed in regards to yield and the articles Hall et al. (2015) and Gomiero et al. (2008) have been reviewed in regards to GHG emission. In regards of biodiversity have the articles Gliessman (2007), Tscharntke et al. (2014), Geiger et al. (2010) and Bengtsson et al. (2005) been analyzed. Many of the articles have been examined as well in regards to identifying measures that could increase sustainability in the different farming techniques.

Studies regarding crop farmings environmental effects in Sweden and Scania were also analyzed to get an understanding of the situation on a national and a regional level. Data of the amount of yield and amount of organic certified farmlands in Sweden and Scania have been collected from Statistiska Centralbyrån (2015a), Statistiska Centralbyrån (2013) and KRAV (2014). Information regarding national environmental goals in Sweden and measures to reach the environmental goals have been taken from Miljömål (2015a), Miljömål (2015b), Miljömål (2015c), Miljömål (2014), Miljömål (2013a). Information about Sweden's and Scania's environmental issues in relation to crop farming and measures to decrease the impact have been taken from the articles Hall et al. (2015), Sveriges Lantbruksuniversitet et al. (2012), Greppa Näringen (2015), Jordbruksverket (2015), Jordbruksverket et al. (2012), Skånes Länsstyrelse (2015), Skånes Länsstyrelse (2008), Skånes Länsstyrelse (2004), Naturvårdsverket (2015), Naturvårdsverket (2010) and Därnhardt et al. (2013).

To analyze what it requires to get an organic certification have the article Council Regulation (EC) No 834/2007 on organic production and labelling of organic products and repealing of Regulation (EEC) No 2092/91 and KRAV's regulations in Crop Production: Rules 2015 (Växtodling: Regler 2015) been examined. Information regarding organic certification have also been distributed from the articles European Commission (2014a), European Commission (2014b), Jordbruksverket (2012), Jordbruksverket (2015), and KRAV (2015b).

Many non academic literature, articles that have not been peer-reviewed, have been chosen since institutions such as Statistics Sweden (Statistiska Centralbyrån), The Swedish Board of Agriculture

(Jordbruksverket), The Federation of Swedish Farms (Lantbrukarnas Riksförbund), Scanias County Government (Skånes Länsstyrelse), Sweden's Agricultural University (Sveriges Lantbruksuniversitet) and the Swedish Environmental Protection Agency (Naturvårdsverket), have produced a lot of reports which have related to the the aim and purpose of this study. Non peer-reviewed articles such as what it requires to get an organic certification, what kind of environmental supports there is for having an organic production and the governments environmental goals that is related to this study's purpose and aims have been analyzed.

2.2 Databases

Databases were used in this study to find literature, reports and scientific articles on the subjects. The databases that were used were Google, Google Schoolar and LubSearch.

2.3 Search words

General search words were used in the beginning to get an understanding of the concepts of organic and conventional farming where search words as for example *organic farming AND conventional farming* were used. To get more specific studies related to *Sweden* and *Scania* the words were added with a AND or +. In regards to finding information about the different parameters regarding organic and conventional farming the words *greenhouse gas emissions, nitrogen leaching, biodiversity* and *yield* were added separately to sentences mentioned above.

2.4 Statistical tests

Quantitative elements such as a paired t-test has been performed in the study to see if there is any significant correlation between yield in organic and conventional crop farming. The t-test were performed on 14 crops in Sweden, 9 crops in Scania and on Spring Barley which is a crop grown in 15 out of 21 regions in Sweden. The t-test on Spring Barley were performed to see if there were any regional difference between yield in organic and conventional crop farming. The hypothesis was that conventional grown crops would give higher yields and the null hypothesis was that there would be no difference in the amount of yields. The data used in the tests have been collected from Statistics Sweden.

Spearman's rank correlation test was also performed on Spring Barley to see if the yield differed between organic and conventional crop farming in relation to geographic placement such as south to north and west to east. These northerly and easterly ranks were estimated using the approximate spatial centroids of each administrative region within Sweden. Statistical differences were considered significant when $p < 0.05$.

2.5 Selection criteria, irrelevance, delimitations

Due to the study's broad purpose and aims the study contains several subjects such as for example, scientific reports that compare yield, biodiversity, nitrogen leaching and GHG emissions in organic and conventional crop farming. Focus has been given to find scientific meta-analyzes where many parameters in organic and conventional crop farming have been studied.

Many articles were not relevant for the study and in this study that means studies with titles that was not relatable to the studies purpose and aims.

Scientific studies that have examined organic and conventional crop production have been selected for this study with focus on the parameters of GHG emissions, yield, biodiversity and nitrogen leaching. Studies about how crop farming in Sweden and Scania are affecting the environment have been reviewed with focus on the same four parameters. In regards to GHG emissions a comparison of how much carbon dioxide, nitrous oxide and methane the different farming methods emits have been analyzed with focus on what causes the differences between the systems. Differences in yield, biodiversity and nitrogen leaching have been examined and why these differences occur have been analyzed. The parameters GHG emissions, yield, biodiversity and nitrogen leaching have been chosen to get a overview of the impact the different farming techniques have on the environment. The relation between crop farming and environmental issues related to these four parameters are great whereas a comparison between organic and conventional crop farming can enlighten how the different methods causes environmental issues. Due to the lack of time more parameters could not be analyzed whereabout for example phosphorus was eliminated even though phosphorus causes environmental issues such as overfertilization and have an important role when it comes to productivity.

2.6 Selection

When relevant titles were found in scientific studies the abstract was read to see if the report examined subjects that was in the aim and purpose of this study. Due to the large range of parameters, and the difficulties in measuring some of them, some articles could be eliminated due to that the result was only valid for very particular geographic conditions and crops or that the specific parameters that had been chosen for this study had not been examined.

2.7 Limitations

Since organic crop production is almost always interconnected with livestock production, strict delimitations have been difficult to determine but when possible studies which compared organic and conventional livestock production have been eliminated from this study.

Several meta-analyzes have been chosen for this study and these meta-analyzes have summarized several studies on organic farming. In the meta-analyzes, the mean of different parameters are generally discussed but due to the difficulties to get a complete understanding of all the specific studies that have been concluded, such as for example, if organic livestock have been a part of the study, this would give a result that may not be exactly relatable to organic crop production in Sweden and Scania. Studies on crop production is very dependent on the specific geographic conditions and what type of crops were grown and where in the world that the organic production was examined, which will effect the result.

Due to the delimitations to only review the parameters of yield, biodiversity, GHG emissions and nitrogen leaching it is not possible to get a complete overview of how organic crop farming relates to conventional crop farming. For example the role of phosphorus in crop farming was eliminated which have a great impact on the crops growth production and which contributes to overfertilization as well.

3. Result

3.1 Organic production in Sweden and Scania

Farmers decision to convert from conventional production to organic production in Sweden and Scania is affected by several aspects such as for example environmental support, geographic context, information and customer requests. If a conversion is done the farmer needs to follow the EU regulations for an organic certification and farmers can as well choose to certify their production with the national organic certification KRAV. Several aspects affect the farmers decision to convert from conventional to organic production which have been shown in the amount of farmland in Sweden and Scania that have been organic certified.

Sweden had in 2014 about 17 % organic farmland that was certified by the Council Regulation (EC) 834/2997 and 13 % were also certified by KRAV (KRAV, 2014). The farmland that has been converted to organic production is 15 % while 2 % is still under conversion to organic production (Statistiska Centralbyrån, 2015a). The amount of area which is farmed using organic methods have been increasing the last couple of years, but during 2013 and 2014 have it been almost unchanged (Statistiska Centralbyrån, 2015a).

The Swedish government have 16 environmental goals which should be reached 2020 (Miljömål, 2013a) and one of the indicators is the amount of organic farmland where the objective is to reach 20 % by 2010 (Miljömål, 2015a), which has still not been met.

Scania accounts for 16 % of Sweden's farmland and about 6 % of Scania's farmland is certified as organic production which is the lowest amount of organic certified farmland in comparison to other regions (Statistiska Centralbyrån, 2015a). The amount of farmland that has been converted to organic production is 5.6 % and farmland that is under conversion to organic production is 0.7 % (Statistiska Centralbyrån, 2015a). Almost 90 % of the organic producers were also certified by KRAV (Statistiska Centralbyrån, 2015a). According to Hall et al. (2015) one reason for Scania's low amount of organic production could relate to that certain crops give less yield when growing organically and crops that are very common in Scania are sugar beets and potatoes which have quite great losses of yield when grown organically. As a result, the environmental support is too low to compensate the loss in yields for those crops (Hall et al., 2015).

3.1.1 EU certification of organic production

The CAP that has been set by EU concern all farmers that are part of the member states of the EU. The purpose of CAP is to set the conditions so the farmers can fulfill their objectives to produce food (European Commission, 2014a). A new CAP has begun to be implemented for the years 2014-2020 in the EU (European Commission, 2014a). According to the European Commission (2014b) the new CAP has become greener and it should promote organic farming with for example support that will help farmers to apply organic methods.

To get an organic certification in the EU the farmers need to follow the regulations in *Council Regulation (EC) No 834/2007 on organic production and labelling of organic products and repealing of Regulation (EEC) No 2092/91* (Jordbruksverket, 2012). According to Council Regulation (EC) 834/2007 an organic production for example cannot use inorganic fertilizers, genetically modified products, pesticides; an organic production should as well minimize the use of non renewable energy sources. If approved for organic certification a farmer can apply for environmental support for organic production or conversion to organic production (Jordbruksverket, 2015). All or parts of the economic compensation are retrieved from the EU and the rest is from the Swedish government (Jordbruksverket, 2015).

3.1.2 KRAV certification of organic production

Sweden has a national certification of organic products called KRAV where the foundation for the certification relies on national regulation such as animal protection- and environmental legislation (KRAV, 2015a). A KRAV certification also fulfill all standards in Council Regulation (EC) 834/2007 with added regulations regarding for example a need of an environmental policy and vegetated, unfertilized areas by water zones to minimize nitrogen leaching (KRAV, 2015b). According to KRAV (2015b) there is also more consideration minimizing the effect on the climate such as that the producers need to drive their machines sparingly to reduce the use of fuel and that the electricity that the farmer uses should be 100 % from renewable sources (KRAV, 2015a).

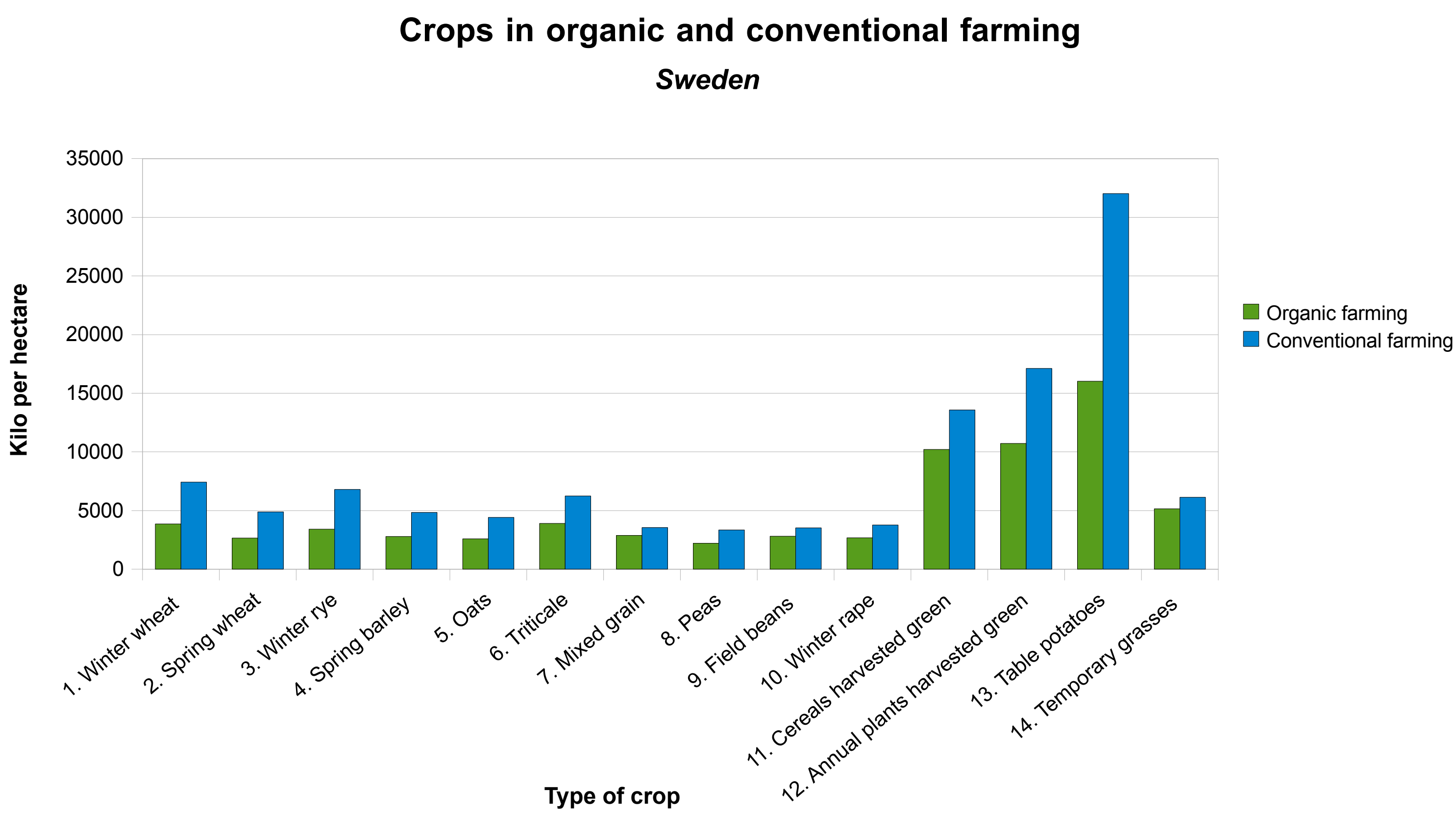
3.2 Comparison between conventional and organic crop farming

Yield in organic crop farming is generally known to be lower in comparison to yield in conventional crop farming. Three statistical tests have been performed to analyze if the yield in Sweden and Scania differ between conventional and organic crop farming.

3.2.1 Yield

3.2.1.1 Sweden

Graph 1. Difference between organic and conventional crop farming in regards of yield in 2014 from 14 different crops in Sweden (Statistiska Centralbyrån, 2015b).

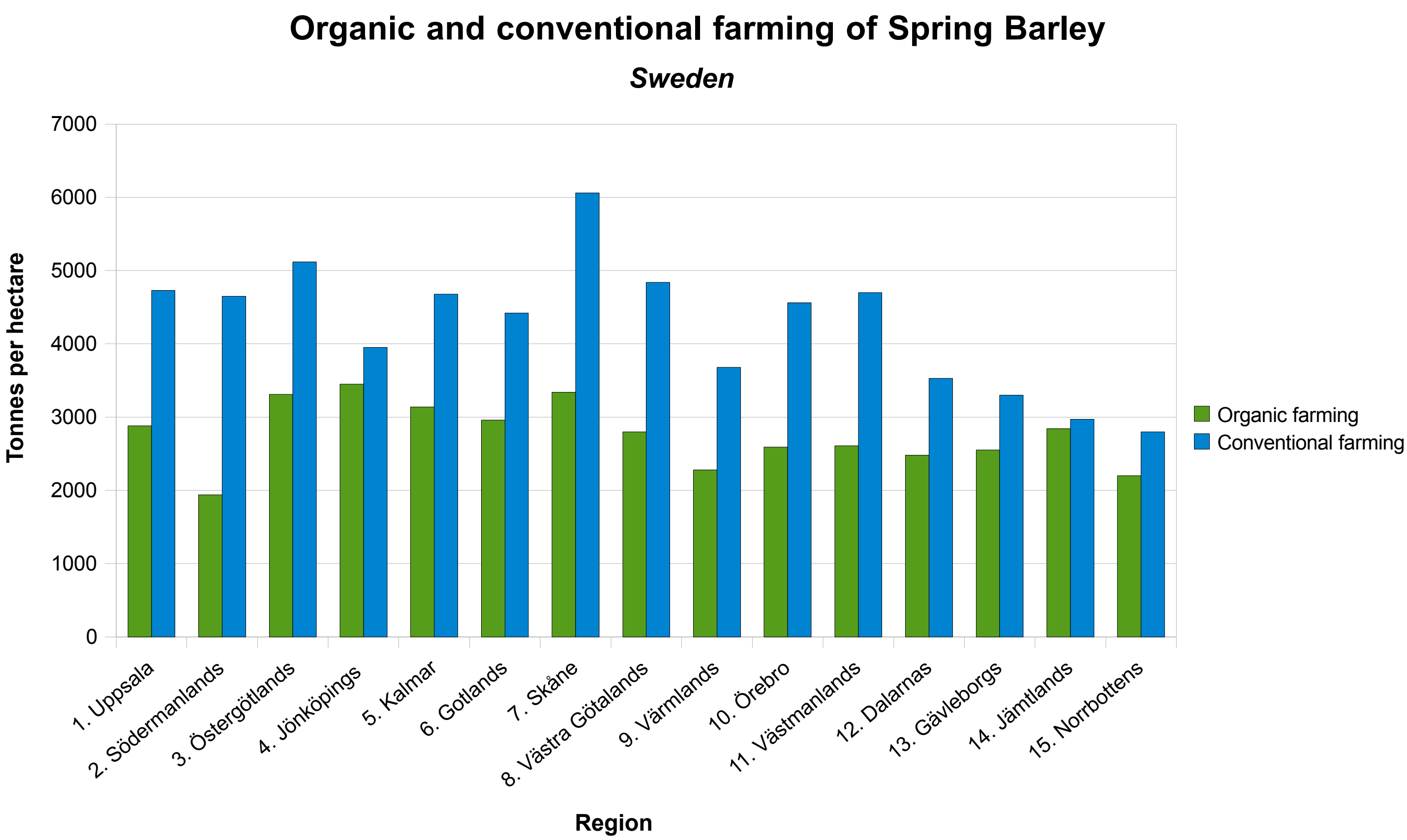


Average difference was 35 % lower yield in organic crop farming in comparison to conventional crop farming in Sweden. The t-test showed a significant difference (t = 3.08, p = 0.009) showing that conventional crop farming produces a higher yield than organic crop farming in these cases.

3.2.1.2 Regional comparison of Spring Barely

Spring Barley is compared on a regional level since it is a crop that is broadly spread in Sweden and is produced conventionally and organically in 15 out of 21 regions.

Graph 2. Regional comparison of Spring Barley yield in conventional and organic farming (Statistiska Centralbyrån, 2015b).

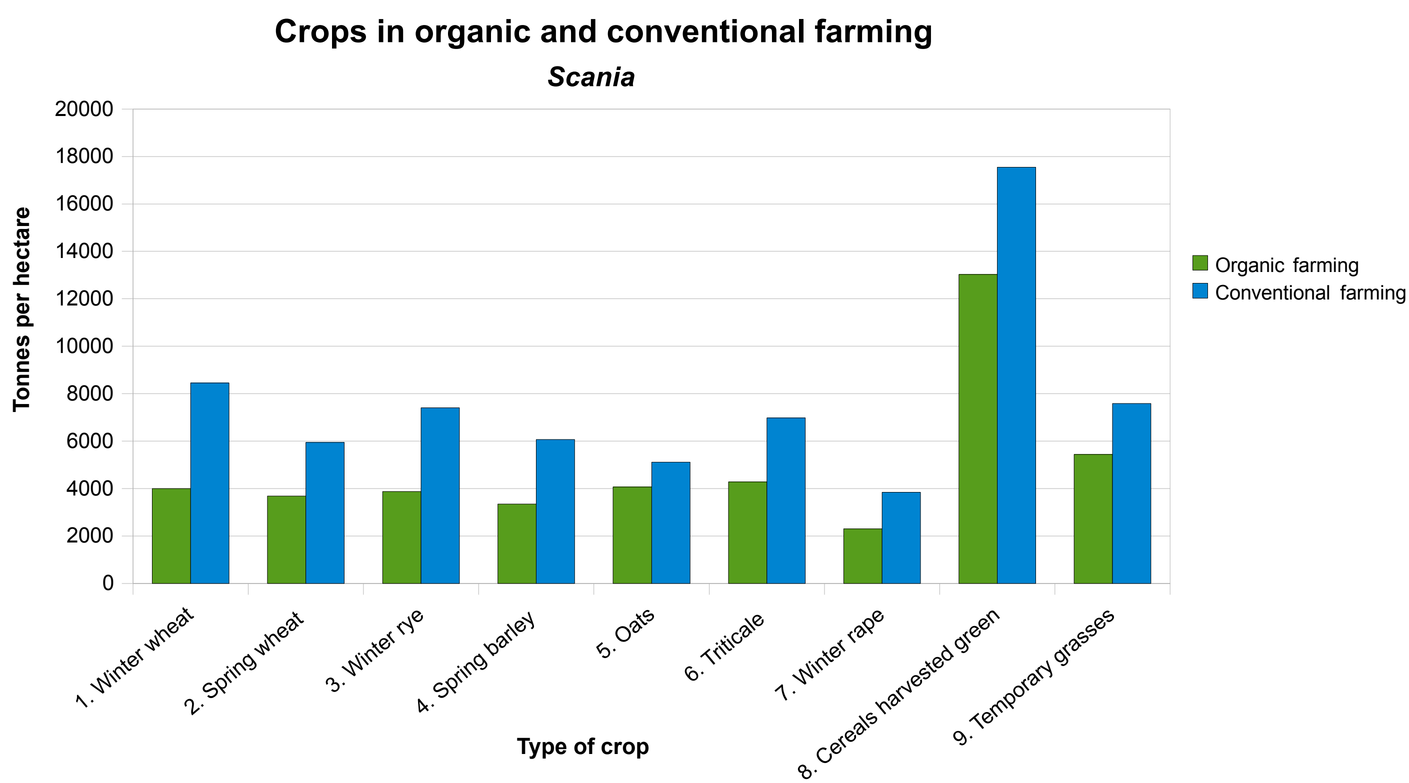


The average difference regionally of Spring Barley was 33 % lower yield in organic farming in comparison to conventional farming. The paired t-test also confirmed a significant difference ($t = 7.49$, $p < 0.001$), hence showing that conventional crop farming consistently produces a higher Spring Barley yield than organic crop farming in these Swedish regions.

The Spearman's test showed that there was a negative but not significant correlation (Spearman's*rho*: 0.36, p = 0.184) between Spring Barley yield differences and northerly regional location within Sweden. A similar result was found when looking at easterly locations where there also were negative but non-significant correlations (Spearman's *rho* = -0.22, p = 0.259).

3.2.1.3 Scania

Graph 3. Difference between organic and conventional crop farming in regards to yield in 2014 from 9 different crops in Scania (Statistiska Centralbyrån, 2015b).



The average difference was a 37 % lower yield in organic crop farming in comparison to conventional crop farming in Scania.The t-test showed a significant difference (t = 6.89, p = 0.00012) showing that conventional crop farming produces a higher yield than organic crop farming in these cases.

3.2.1.4 Conventional vs Organic

3.2.1.4.1 Situation

It is generally known that organic crop farming produces less yield than conventional crop farming but how much lower yield is produced differ between studies as well as measures on how to increase productivity. Reasons for lower yields in organic crop farming are due to the *lack of use of inorganic nitrogen fertilizer* which is easily taken up by the crops and increases the production (Kirchmann et al., 2014). Another aspect that results in lower yields in organic farming is that *weeds can spread more easily* since there is no use of pesticides and the weeds take up space and nitrogens that could have been used for the crops (Kirchmann et al., 2014).Kirchmann et al. (2014) states that when growing organically the yields decreases by 40 % compared to conventional farming. If including the loss of yields when the farmlands is in land-lay and/or when growing nitrogen fixing crops the yield in organic farming would be 50 % lower (Kirchmann et al., 2014). But Kirchmann et al. (2014) mentions that there are studies that show that organic farms can produce equally or a higher yield than conventional farms. This is often due to added plant nitrogens, both inorganic and organic, from outside the farm such as easily soluble minerals, animal manure or straw which is allowed in organic farming (Kirchmann et al., 2014). De Ponti et al. (2012) stated that in an organic farm the average outcome is about 80 % of the yields in comparison to a conventional farm but the difference varied greatly in relation to regions and between types of crops. A study by Kremen et al. (2014) came to similar conclusions that organic farms produces 19.2 % lower yields in comparison to conventional farms.

3.2.1.4.2 Measures

Toumisto et al. (2012) discussed benefits with biofuel technology such as an incorporating anaerobic digestion technology where the digestate make organically bound nitrogen into ammonium. The ammonium is easier to absorb for the crops which may have a positive effect on the yields and be an alternative for inorganic nitrogen fertilizers. The process is based on that cover crops, crop residues and animal manure for example can be used to produce biogas and the digestate that is created can be used as fertilizers afterwards. Kirchmann et al. (2014)

have another suggestion that incorporates inorganic nitrogen fertilizers which have been produced using renewable energy. This process would lower the negative environmental impacts and have positive effects on yield but this process will be further discussed in section 3.5.3.3.

According to Gliessman (2007) there is a great challenge with removing pesticides from conventional farms and there is a risk for a large increase of weeds and pests. One way to deal with weed without pesticides is according to Gliessman (2007) is to implement a niche organism, such as Wild Mustard, which have little negative effect on the crop but more so on other weeds, but it is not mentioned how much this procedure would affect the yield. Another idea discussed by Gliessman (2007) to increase yield is the possibilities with intercropping (using two or more crops) where one study done on corn-bean-squash resulted in a lower yield for two crops, but in total the yield was higher in comparison to a monoculture (one crop) had been grown on the land during similar conditions.

3.2.2 Nitrogen leaching

Both organic- and conventional crop farming are dealing with nitrogen leaching issues and both farming methods are contributing to overfertilization of inland waters and oceans in Sweden and Scania. Due to different farming methods organic and conventional crop farming contributes to overfertilization in different ways and unequally much.

3.2.2.1 Sweden

Overfertilization is one of Sweden's greatest environmental problem according to Sveriges Lantbruksuniversitet et al. (2012) and the agricultural sector is the greatest source of nutrient leaching. Nitrogen is needed for the crops growth production but also causes eutrophication of fresh and marine water ecosystem, causing severe effects on biodiversity and water quality (Sveriges Lantbruksuniversitet et al., 2012).

During 2011 there was an excess of nitrogen by 34 kilo per hectare, 103 000 tonnes total, which is an increase of 6 % since 2009 (Statistiska Centralbyrån, 2013). Nitrogen contributes greatly to the overfertilization of coast and oceans (especially the Northern Sea), and the excess of nitrogen from farmland was estimated in 2009 to contribute by 43 % of the runoff in Sweden (Sveriges Lantbruksuniversitet et al, 2012).

Measures to stop overfertilization have been implemented in Sweden. The project Greppa Näringen (Grab the nutrients) is a collaboration with the Swedish Board of Agriculture (Jordbruksverket), the Federation of Swedish Farmers (Lantbrukarnas Riksförbund), the County Governments (Länsstyrelser) and several agricultural companies where the objectives amongst others is to minimize overfertilization (Greppa Näringen, 2015). Greppa Näringen provides knowledge and guidance about nitrogen leaching and the project is funded by the CAP and relocated environmental taxes (Greppa Näringen, 2015).

During 2013 there were about 11 558 hectares *protective zones* and *catch crops* had been implemented on about 58 753 hectares in Sweden. Both measures have positive effects on nitrogen leaching and according to Miljömål (2014) catch crops are the most important measures to decrease nitrogen leaching. *Wetlands* have the possibility to trap nitrogen and between 2000 and 2011, 5 700 hectare wetlands had been landscaped (Miljömål, 2015b). Even though these measures have been taken to stop nitrogen leaching the problems is still severe in Sweden.

In the new CAP there are some uncertainties if environmental support will continue to be granted for some of these measures that can minimize nitrogen leaching (Milömål, 2015c). According to Jordbruksverket (2015) there is still environmental support for having or landscaping wetlands but there are uncertainties regarding catch crops and protective zones. In 2016 it *may* be possible to apply for environmental support for measures that are called *reduced nitrogen leaching* and *protective zones* (Jordbruksverket, 2015).

3.2.2.2 Scania

Overfertilization is severe in Scania and the greatest source is from the agricultural sector (Skånes Länsstyrelsen, 2015). Tests that have been taken of the ground water in Scania have showed high amounts of nitrogen (Skånes Länsstyrelse, 2015).

Over 50 % of Scania's farmland was connected to Greppa Näringen during 2010 according to Skånes Länsstyrelse (2015) and 253 hectares of new wetlands have been financed between 2013 and 2014 (Miljömål, 2015c). Farmland using catch crops have been decreasing since 2010 and during 2013 about 34 100 hectare of farmland had catch crops according to Miljömål (2015c). Protective zones have as well been decreasing a bit since 2013 to about 1 189 hectares (Skånes Länsstyrelse, 2015). Scania as a region will as well be effected by the new CAP where there is some uncertainties if environmental support will still be granted for some of the measures that would minimize nitrogen leaching (Milömål, 2015c).

3.2.2.3 Conventional vs Organic

3.2.2.3.1 Situation

Kirchmann et al. (2014) argues that during the same conditions studies have shown that nitrogen leaching is greater in organic crop farming than in conventional crop farming per unit product. Zikeli et al. (2014) have come to the same conclusion but have also stated that when compared per unit area organic farming has lower nitrogen leaching than conventional farming. But, organic farming has higher nitrogen leaching per unit product due to the use of organic nitrogen fertilizers (stable manure, green manure and slaughterhouse waste) where the nitrogen is mainly organically bonded whereas inorganic nitrogen is soluble, hence easier to absorb for the plants (Kirchmann et al., 2014). Both inorganic and organic nitrogen fertilizer are dealing with nitrogen leaching but with organic nitrogen fertilizer the nitrogen can leach also after harvest since the organic nitrogen fertilizers are being decomposed whereas the nitrogen can be released during the Fall when there is generally more precipitation which could result in more runoff (Kirchmann et al., 2014). Easily absorbed inorganic nitrogen fertilizers have the ability to easily run through the soil and this happen when the amount have exceeded the needs of the crops or with large amount of precipitation during spring planting but this is according to Kirchmann et al. (2014), very rare. According to Kirchmann (2014) it is easier to control inorganic nitrogen fertilizers which results in lower leaching and when compared per unit product conventional farming results in substantially less nitrogen leaching (Kirchmann et al., 2014). When growing crops with nitrogen fixing crops there is even greater nitrogen leaching per unit product in organic farms according to Kirchmann et al. (2014) if compared to the use of animal manure or slaughterhouse waste. This is due to that every third or fourth year there will only be a harvest of nitrogen fixing plants and no yield which have a great impact when calculating per unit product (Kirchmann et al., 2014).

3.2.2.3.2 Measures

Kirchmann et al. (2014) discuss the benefits with increasing protective zones, wetlands and catch crops to reduce nitrogen leaching and that such measures would be more cost effective than general environmental support for organic production. As mentioned before Toumisto et al. (2012) discusses benefits of incorporating an anaerobic digestion technology on farms. Through a digestion process ammonium will be formed and since ammonium is more easily absorbed by the crops it may reduce the runoff from the farmlands (Tuomisto et al., 2012). The idea of Kirchmann et al. (2014) regarding the production of inorganic nitrogen fertilizers with renewable energy would also be a practice that would have a lower environmental impact than inorganic nitrogen fertilizers produced on fossil fuels and result in lower nitrogen leaching if compared to organic nitrogen fertilizers. The process of using renewable energy when producing inorganic nitrogen fertilizers will be discussed further in section 3.5.3.3. Another measure could be to use crops that can grown more than one year (perennial crops) since a lot of nitrogen leaching problems is due to that the soil is bare during the winter after plowing (Kirchmann et al., 2014). Perennial crops would decrease nitrogen leaching since living roots would be able to take up the nitrogens in the soil and weed would also have more difficulties to spread but no studies have been done on the shift from annual crops (only lives one year) to perennial crops (Kirchmann et al., 2014). Cover cropping have the same positive effect as perennial crops (Zikeli et al., 2014) but is often not used as food which decreases the amount of yield in comparison to perennial crops.

3.2.3 GHG emissions

It is impossible to avoid GHG emissions from crop farming in both organic and conventional systems and crop farming in general contributes to a great deal of GHG emissions in Sweden and Scania. But how much GHG emissions organic and conventional crop farming contributes with differ and the amount of GHG emissions differ also within each system.

3.2.3.1 Sweden

According to Naturvårdsverket (2015), the main direct emissions from Sweden's agricultural sector is the greenhouse gas carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In 2013, 12 % (6,9 million tonnes CO_2-eq) of Sweden's total GHG emissions came from the agricultural sector whereas the emissions constitute of 50 % nitrous oxide, 49 % methane and 1 % carbon dioxide (Naturvårdsverket, 2015). Not included in the 12 % of Sweden's GHGs from the agriculture sector is the working machineries and off road vehicles in the agricultural sector that emitted almost 0.8 million tonnes CO_2-eq in 2013 (Naturvårdsverket, 2015).

Methane emissions from livestock manure is estimated to be 7 % (0,5 million tonnes CO_2-eq) of the total amount of methane emissions in Sweden (Naturvårdsverket, 2015).

Nitrous oxide emissions result from microbial nitrification-denitrification processes in the soil which is a natural process but is often enhanced due to that large amounts of fertilizers that are added to farmlands (Naturvårdsverket, 2015). According to Naturvårdsverket (2015) the main emission of nitrous oxide come from inorganic nitrogen fertilizers, cultivation of histosols and manure from livestock.

Carbon dioxide emits from application of lime and urea to the farmland (Naturvårdsverket, 2015). Due to acidification of the soil due to erosion and nitrogen leaching, liming is used to neutralize the soils pH and produced 87 thousand tonnes carbon dioxide in 2013 (Naturvårdsverket, 2015). Urea is a product used for fertilization and is contributing a small part to the CO_2 emissions with 0.9 thousand tonnes (Naturvårdsverket, 2015).

3.2.3.2 Scania

According to Hall et al. (2015) the agriculture sector in Scania accounted for 1.5 million tonnes (15 % of Scania's GHG emission) of CO_2-eq (only calculating methane and nitrous oxide). Some calculations show that the GHG emissions from the agricultural sector in Scania constitutes of about 1/2 from nitrous oxide, 1/3 from methane and 1/10 from carbon dioxide (Skånska Länsstyrelsen, 2008). Every year 44 000 tonnes of nitrogen is spread over Scania's farmland and the production of inorganic nitrogen fertilizers creates 0.2 million tonnes carbon dioxide emissions and since the tax for inorganic fertilizers was removed in 2012 the use has increased which is believed to have contributed to greater emissions of nitrous oxide (Hall et al., 2015). Drained peat soils (former wetlands that were drained due to an increased need for farmland in the 1900^{h} century) is also a large emitter of carbon dioxide and nitrous oxide, and when including drained peat soils to the total amount of GHG emissions from the agricultural sector, it adds up to 2.4 millions tonnes of CO_2-eq in Scania (Hall et al., 2015). One way to decrease emissions from the agricultural sector is to make drained peat soil permanently wet which would be relevant for 5 % of Scania's farmland (Hall et al, 2015). This could lower the emissions of carbon dioxide and nitrous gas with 0.9 millions tonnes of CO_2-eq which would decrease the total emissions of GHGs from the agricultural sector in Scania with 37 % (Hall et al., 2015).

3.2.3.3 Conventional vs. Organic

3.2.3.3.1 Situation

Both organic- and conventional crop farms contributes to GHG emissions of nitrous oxide, carbon dioxide and methane but the amounts and sources differ in some aspects. According to Kirchmann et al. (2014), does organic nitrogen fertilizers used in organic farms emit more nitrous oxide in comparison to inorganic nitrogen fertilizers. This is due to the fact that the organic material is used as food for microorganisms and when using organic nitrogen fertilizers their activity increases resulting in more nitrous oxide emissions (Kirchmann et al., 2014). Inorganic nitrogen fertilizers used in conventional farming have a negative balance of net emissions of 1.7 kilo CO_2-eq due to that the production is based on fossil fuels, normally natural gas (Kirchmann et al., 2014). Nitrogen fixing crops on the other hand, used sometimes in organic production, have a positive balance of net emissions of 2.5 kilo CO_2-eq due to carbon sequestration (Kirchmann et al., 2014). But Kirchmann et al. (2014) mention that using nitrogen fixing crops instead of inorganic nitrogen fertilizers reduces the yield and it would require more land if the same amount of yield should be produced in organic production as in conventional production, and if including the land use changes the GHG emissions would likely increase. When using animal manure instead of nitrogen fixing crops, the yield in organic farming increases and it increases proportionally to the amount of nitrogen minerals the manure contains (Kirchmann et al., 2014). When animal manure is used in the production an increase of the amount of soil organic matter (SOM) in the farmland occurs hence more carbon will be bound to the soil which has positive effects in relation to the climate (Kirchmann et al., 2014). Kirchmann et al. (2014) mention though in some cases the amount of SOM increases in organic farming systems due to extra added organic fertilizers which have not been added to the conventional farming systems and hence the results are not comparable. Kirchmann et al. (2014) also mention that due to the fact that animal manure releases nitrous oxide when added to the soil and since livestock produces methane gases, manure will have higher emissions of GHGs than inorganic nitrogen fertilizers when calculating per unit product (Kirchmann et al., 2014). Venkat et al. (2012) also discuss that the production of pesticides and inorganic nitrogen fertilizers do not require large enough GHG emissions to offset the additional GHG emissions in organic farming. The general conclusion regarding GHG emission, which is stated by both Gomierio et al. (2008), Zikeli et al. (2014) and partly Kirchmann et al. (2014), is that conventional production is superior when it comes to GHG emissions per unit product but per unit area organic farming is superior with lower GHG emissions.

3.2.3.3.2 Measures

Both Zikeli et al. (2014) and Gomiero et al. (2008) states that important measures to reduce GHG emissions is to have proper soil management that enhances carbon sequestration. If acidification in soils were hindered by reducing nitrogen leaching and erosion, a lot less lime and urea would need to be added to neutralize the soil which would decrease the emissions of carbon dioxide. Other suggestions are to reduce pesticides, pumped irrigation and mechanical power using fossil fuels which have a great impact on the farmlands' total GHG emissions (Gomiero et al., 2008). Another suggestion by Gomiero et al. (2008), that also has been mentioned with different intentions by Toumisto et al. (2012) and Kirchmann et al. (2014), is the incorporation of biofuels on farms. Gomiero et al. (2008) discuss that organic farmers could produce methane as biogas for home and commercial use whilst Kirchmann et al. (2014), as mentioned, discuss it as an alternative for production of inorganic nitrogen fertilizers which now is based on fossil fuels. At the moment natural gas is used for fixating nitrogen from the air in the process of producing inorganic nitrogen fertilizers (Kirchmann et al, 2014). A life cycle analyzes (LCA) on biofuel showed that a 2.7 kilo straw or a 2.6 kilo energy forest could produce 1 kilo of inorganic nitrogen and the study showed that one hectare of straw or energy forest could produce 1.6 or 3.9 tonnes nitrogen (Kirchmann et al., 2014) which could be used instead of natural gas. As discussed before, Toumisto et al. (2012) also see biofuel as a solution but in regards to producing ammonium from anaerobic digestion technology which is easily absorbed by plants and would probably have lower GHG emissions than other organic nitrogen fertilizers. Other methods to decrease GHG emissions from the agricultural sector could be to restore drained peat soil and make it permanently wet again as suggested by Hall et al. (2015) which would reduce nitrous oxide and carbon dioxide emissions.

3.2.4 Biodiversity

Farming in general have always had affects on biodiversity and in Sweden and Scania have severe loss of biodiversity occurred due to the expansion of farmlands. In regards of different farming techniques is it generally known that organic crop farming have a greater deal of biodiversity in comparison to conventional crop farming.

3.2.4.1 Sweden

According to Jordbruksverket et al. (2012) agriculture has historically increased biodiversity in Sweden by keeping the landscapes open and varied but Naturvårdsverket (2010) also mention that the changes in land use have resulted in the worsening of ecosystem services and reduced habitats for organisms. In 2012 about half of Sweden's endangered species existed in the agricultural landscapes (Jordbruksverket et al., 2012). During 2010 the lowest value of agricultural birds were measured and almost half of all endangered species existed completely or almost completely in the agricultural landscapes (Naturvårdsverket, 2010). 132 species that have existed in the agricultural landscapes have completely disappeared (Naturvårdsverket, 2010). The greatest threats to biodiversity is changes to land use, intensified agriculture with monoculture crops and decreasing microhabitats (Naturvårdsverket, 2010). Jordbruksverket et al. (2012) have mentioned several measures that could increase biodiversity in farmlands such as having an open and varied landscape, wetlands and protective zones. Before the changes in CAP farmers could get environmental support for these measures but with the new CAP there are some uncertainties. Farmers can get support for restoring or landscaping wetlands and in certain cases farmers need to have 5 % of so called *ecological focus areas* (Jorbruksverket, 2015). The aim of ecological focus areas is to increase biodiversity and could be for example having non farmed edges around farmlands or letting the farmland be in lay-land (Jordbruksverket, 2015).

3.2.4.2 Scania

Scania is the region where most species are endangered or extinct (Skånes Länsstyrelse, 2004). According to Skånes Länsstyrelse (2004) 60 % of Scania's species exist in agricultural farmlands which is accounted for 70 % of all Sweden's endangered species. Some impacts that have affected biodiversity is the decrease of amount of wetlands in Scania from 350 000 to 27 000 (Hall et al., 2015). Another aspect is that microhabitats decreased greatly and between 1951 and 1996 the amount of fields that is larger than 50 hectare doubled and fields smaller than 5 hectare, were reduced by 85 % in Scania (Dänhardt et al., 2013). Since the 19^{h} century natural pastures have decreased by 80 % and a more specialized agriculture have as well affected the biodiversity negatively in the region (Dänhardt et al.,2013).

3.2.4.3 Conventional vs Organic

3.2.4.3.1 Situation

It is generally known that organic crop farming have a higher amount of biodiversity in comparison to conventional crop farming due to the lacking use of pesticides. But both in organic and conventional farming weed management is a part of the production which leads to a decrease in biodiversity since the weed otherwise could work as host plants for insects (Kirchmann et al., 2014). Since pesticides that are used in conventional farming are more effective than mechanical weed management, this results in higher biodiversity on organic farms (Kirchmann et al., 2014). Kirchmann et al. (2014) mention that in organic production biodiversity is about 30 % higher in comparison to conventional farms. In a meta-analyze by Zikeli et al. (2014) it was shown that out of 396 literature studies 83 % found higher biodiversity, 14 % were the same and 4 % had a lower amount of biodiversity in organic farms in comparison to conventional farms. The use of pesticides in conventional farming are discussed by Tscharntke et al. (2012) which states that the use of pesticides and fertilizers can create non-target effects on wildlife and other functional agrobiodiversity, for example the loss of bees and soil biota. In a study performed in Europe Geiger et al. (2010) state that the use of pesticides, especially insecticides and fungicides, had the most negative impacts on the diversity of plants, carabids and ground-nesting farmland birds. Kirchmann et al. (2014) states that there have already been a lot of restrictions regarding pesticides and the ones that are in use are less harmful than those used before and it is only small amounts that spreads outside the farmlands. But Kirchmann et al. (2014) still acknowledge the problem and says that measures needs to be taken to reduce the spread of pesticides. Another aspect Kirchmann et al. (2014) mention is the lower yields in organic farming which could mean that more organic productions would require more changes in land use if the objective is to reach the same production capacity as in a conventional farm which potentially could harm the biodiversity.

3.2.4.3.2 Measures

Biodiversity is greatest when farmland for example have permanent pastures, trees, hedges, edge zones, wetlands and transports paths close by and Kirchmann et al. (2014) state that this is more important than if the production is organic or conventional. Bengtsson et al. (2005) agree with Kirchmann et al. (2014) and state that factors such the heterogeneity and structure of the landscape had in some cases a greater importance for biodiversity than if the production is organic or conventional. Another aspect Kirchmann et al. (2014) discuss that pesticides have some advantages over mechanical weed management and argue that the greatest danger with pesticides is *when* it is sprayed on the fields. If it is done during a still day and if point leaching of pesticides is reduced or taken care of, leaching of pesticides will decrease and there will be less harm to the biodiversity (Kirchmann et al., 2014). Both Tschamkte et al. (2012) and Geiger et al. (2010) agree that pesticides on the farmlands need to be eliminated which Kirchmann et al. (2014) and Bengtsson et al. (2005) have not concluded. Geiger et al. (2010) state that to increase biodiversity there needs to be a change to a more biodiversity-based ecosystem services approach such as biological pest control which Kirchmann et al. (2014) state is not effective enough. Regarding biological control Gliessman (2007) mentions that niche organisms could be introduced to put negative pressure on pest or weed populations without using pesticides. Another suggestion is to implement intercropping methods where the interactions of the plants can create a natural system where it is more difficult for pests and weeds to populate (Gliessman, 2007). However, it takes enormous efforts for agroecologists to have full ecological knowledge of these processes and how it potentially could be implemented to commercial farmlands (Gliessman, 2007).

4. Discussion

4.1 Yield

At the moment organic farming is not meeting up to the yield that conventional farming produces which in that aspect makes conventional farming superior. It stretches from Kremen et al.'s (2014) suggestion of a 19.2 % lower yield to Kirchmann et al.'s (2014) suggestion of a 50 % lower yield in organic farming. In the analyze of crops in Sweden the yield was on average 35 % lower and in Scania it was 37 % lower on organic farms. In regards to Spring Barley that is produced in many of Sweden's regions the average yield is 33 % lower on organic farms. The amount of yield is very dependent on what kind of crop is grown, what geographic context and climate the production is set in and another aspect that affects the results is if it is in land-lay or when nitrogen fixing crops are grown on the farmland hence excluding any yield that year. Due to these aspects it is very difficult to give *general* solutions to what would increase yield and hence measures that need to be locally adapted and what types of crops that are going to be produced needs to be considered. With the low yields that organic farming is producing at the moment there needs to be an increase in farmland if the same amount of yields as in conventional farming should be reached. Changes in land use causes environmental issues such as possible loss of biodiversity and a potential increase in GHG emissions which Kirchmann et al. (2014) have discussed and is hence not a sustainable option. To produce crops with low environmental impacts an *integrated farming system* may be a solution to increase yield.

If inorganic nitrogen fertilizers could be produced with renewable energy as suggested by Kirchmann et al. (2014), that could minimize negative environmental impacts and at the same time very likely ensure a high yield. Other measures, such as Tuomisto et al. (2012) suggestion about using ammonium from anaerobic digestion technology may have an positive impact on the amount of yield since ammonium is easily absorbed by plants. These suggestions have not been tested greatly therefore more studies would be necessary to fully understand their potential. Since weeds compete with crops regarding space and nutrients it is of importance to implement measures that have little negative effect on the crop but more on other weeds. Gliessman's (2007) suggestion about introducing a niche organism which have negative impacts on weed but not on the crop may be a solution but there needs to be more studies on how this procedure affect the yield. Another method would be implementing intercropping methods which in some cases have been given a total amount of larger yields and could make it more difficult for weeds to spread in the farmland according to Gliessman (2007). These measures suggested by Gliessman (2007) need more examination for a broader understanding of how these practices could affect the yields in specific conditions that exists in Sweden. Pesticides have a positive effect on the amount of yield but are concerned with other issues, such as loss of biodiversity, and it may be more sustainable to use other practises to manage weed issues which will be further discussed in section 4.4.

If these measures are shown to have a positive impact on the environment and the amount of yield, all of these practises could be implemented on both a national level in Sweden and a regional level in Scania. This could enhance the potential to increase yields in a sustainable manner without relying on finite resources or pesticides that have negative impacts on biodiversity.

Organic crop farming produces lower yields than conventional crop farming.

4.2 Nitrogen leaching

In regards to nitrogen leaching is the consensus that nitrogen leaching in organic farms is greater per unit product but lower per unit area in comparison to conventional farms which is discussed by Zikeli et al. (2014) and Kirchmann et al. (2014). The main issue for this is due to the fact that organic nitrogen fertilizers is harder to control since the nitrogen is organically bound before it is decomposed and accessible for the plants. But to minimize nitrogen leaching an *integrated system* will likely have most environmental benefits.

Sweden and Scania have severe issues with nitrogen leaching and it needs to be addressed. The main practise would be to use inorganic nitrogen fertilizers that have been produced using renewable energy which is suggested by Kirchmann et al. (2014). This would help prevent nitrogen leaching and produce other environmental benefits such as securing higher yields. Toumisto et al.'s (2012) suggestion to use ammonium from biofuel technology, which is more easily absorbed by plants, might be easier to control than organic nitrogen fertilizers which may decrease nitrogen leaching. Kirchmann et al. (2014) also suggest that an implementation of protective zones, wetland and catch crops have lessening effects on nitrogen leaching and if these measures would be combined with inorganic nitrogen fertilizers produced using renewable energy the nitrogen leaching issues in Sweden and Scania would likely decrease to a great extent. Other system changes in Scania and Sweden would be to use perennial crops which reduces runoff during winter but more studies needs to be performed on the transition from annual to perennial crop systems. Cover crops are based on the same principles and might be a valid alternative in Sweden and Scania with the only negative effect that cover crops are not normally used as food hence lowering the total amount of yield. Another practise could be to make it mandatory for farmers to be a member of Greppa Näringen which would create more knowledge about nitrogen leaching in Sweden and Scania. A clarification of what kind of environmental support the CAP is funding would also help the farmers, and if environmental support is not only validated for wetlands but also catch crops and implementing of protective zones, these efforts would promote a reduction of nitrogen leaching.

Organic crop farming have lower amounts of nitrogen leaching per area but not per unit product in comparison *to conventional crop farming.*

4.3 GHG emissions

Organic farming has per unit product generally higher emissions of GHGs than conventional farming which is mainly due to lower yields and that organic nitrogen fertilizers emit more GHGs than inorganic nitrogen fertilizers. Though measuring and managing GHG emissions from farmlands is a very complex procedure, some measures give a result of both reduced and increased GHG emission simultaneously. For example an increase of the amount of SOM can both bind carbon to the soil but it can also potentially increase the activity of microorganisms resulting in an increase of nitrous oxide emissions. Though, proper soil managements suggested by several authors such as Zikeli et al. (2014) and Gomiero et al. (2008) state the importance of increasing the amount of SOM to reduce the amount of GHG emissions. This could be done by using for example organic fertilizers which have been suggested by Zikeli et al. (2014) and Gimero et al. (2008) but this relates to other problems such as the increasing risk of nitrogen leaching. Another problem regarding the use of organic nitrogen fertilizers is the loss in yield according to Kirchmann et al. (2014) and if an enhancement in production capacity is an aim more land needs to be converted to farmland. This conversion would likely increase GHG emissions and therefore would not be a very sustainable option. Using inorganic nitrogen fertilizers, which at the moment is based on fossil fuels, is neither a sustainable alternative even though it has positive affects on yield. As suggested before, an *integrated system* is likely to have the most possibilities to reduce GHG emissions.

To start producing inorganic nitrogen fertilizer with renewable resources would be a great step towards potentially increasing yield and reducing GHG emissions as suggested by Kirchmann et al. (2014). According to Hall et al. (2015) 44 000 tonnes of nitrogen is spread on Scania's farmland and if this nitrogen were produced on biofuels this would mean that about 27 500 hectares (straw) or 11 280 hectares (energy forest) would be needed to be grown to meet the needs of nitrogen. To produce 44 000 tonnes of nitrogen with biofuels (straw) it would take up about 5 % of Scania's farmland which is not too unrealistic and may also be an alternative on a national level. Another method that could be implemented on farms in Sweden and Scania could be Toumisto et al.'s (2012) suggestion of using ammonium produce by biofuel technology which could have a positive effect on both yield, nitrogen leaching and reduce GHG emissions. Gomiero et al. (2012) also mention that biogas could be used for farmers' homes, alternatively commercially, which would reduce GHG emissions and be an alternative for farmers in Sweden and Scania. Another method to decrease GHG emissions could be to drain peat soil until permanently wet as suggested by Hall et al. (2015) which is relevant for 5 % of Scania's farmland. This would reduce the GHG emissions by 37 % for the region (Hall et al., 2015) and this could as well be performed on a national level. As mentioned, proper soil management is important for reducing GHG emissions and if acidification can be prevented by reducing nitrogen leaching and erosion with proper soil management, there would be less need for urea and lime which emits carbon dioxide. Other aspects could be to minimize the use of transport that are dependent on fossil fuels at all stages in the production and a reduction of pesticides and pumped irrigation.

Organic crop farming have higher amounts of GHG emission per unit product in comparison to conventional crop farming.

4.4 Biodiversity

It is generally accepted that biodiversity is higher in organic farming than with conventional farming due to the high inputs of pesticides in conventional farming. Elimination of pesticides in conventional farming would have positive effects on the biodiversity since pesticides are very effective in eliminating organisms and can as well kill non-target wildlife. At the same time a lack of pesticides will likely increase the amount of weeds which will compete with the crop for space and nutrients, hence lowering the amount of yield. If the same amount of yield as in conventional crop farming is an objective, an increase of farmland might be necessary and this would likely have negative impacts on biodiversity and is therefore not an sustainable option. Due to the low yields in organic farming an *integrated system* may have most beneficial outcomes in regards of biodiversity.

Both Sweden and Scania have suffered from severe loss of biodiversity on the farmlands and Scania is the region in Sweden with most endangered species (Skånes Länsstyrelse, 2004). Therefore it is of great importance that measures to increase biodiversity are implemented and some suggestions by Kirchmann et al. (2014) is for example to have permanent pastures, trees, hedges, edge zones, wetlands and transports paths in and around the farmlands which work as microhabitats for organisms. Kirchmann et al. (2014) suggest that these measures are more cost effective hence environmental support should be given to these measures and not organic production which in regards to the low amount of yields in organic production may be reasonable. Kirchmann et al. (2014) is not for an elimination of pesticides so even if these microhabitats are landscaped the organisms would likely suffer if pesticides are still used. Because of this pesticides might not be a sustainable option if the aim is to secure biodiversity in and around the farmlands in Sweden and Scania. If pesticides would be used anyway is it of great importance to reduce point leaches and add pesticides when it is not windy to minimize spreading outside of the farmlands. But instead of pesticides a biological pest control could be used which Geiger et al. (2010) and Gliessman (2007) promotes but Kirchmann et al. (2014) argues is too ineffective. To reduce pests and weeds in a population Gliessman (2007) suggest that a niche organism could be introduce which would put negative pressure on weeds and pests but not on the crop. How this would adapt to conditions in Sweden and Scania, and what organisms could be added, need to be studied further but could be a viable option. Another method is to implement intercropping methods to a larger extent where the interactions between specifically chosen crops can make it difficult for weeds and pests to populate according to Gliessman (2007). This could be an alternative for Sweden and Scania which would probably have less negative effect on biodiversity than pesticides and may have positive effects on yields as well. Hence a farming system without pesticides, with a large extent of microhabitats and biological pest control would likely result in the most positive effects on the biodiversity in farmlands. The environmental support from CAP regarding *ecological focus areas,* with purpose to increase biodiversity, will likely also have a positive effect on the amount of biodiversity. Hopefully more environmental support can be granted for implementing measures that increases biodiversity such as landscaping microhabitats in the farmlands amongst others.

Organic crop farms have higher amount of biodiversity than conventional crop farms.

4.5 Method criticism

Due to only examining GHG emissions, biodiversity, yield and nitrogen leaching a complete overview of organic and conventional crop farming have not been made hence different conclusions could have been made if more parameters had been included. For example was phosphorus excluded which has a great impact on crops productivity and contributes to overfertilization. With more parameters analyzed the credibility of the result would increase.

Since a lot of measures that could potentially increase sustainability in the agricultural sector have not been tested in larger extent and/or in conditions that exists in Scandinavia suggested measures may not be as sustainable as they appear. Hence there is a great need for more research on how these measure would relate to larger productions in conditions that exist in Sweden and Scania.

Since the relation between crop farming and environmental issues regarding GHG emissions, yield, biodiversity and nitrogen leaching occur to a great extent can some certainty to the result be credited and with these four parameters analyzed it seems as conventional crop farming is superior to organic crop farming. But as discussed can more environmental benefits be sustained with an integrated system whereabout a suggestion is to invest in more research and efforts to examine the potentials of an integrated crop farming system.

5. Conclusion

In comparison to conventional crop farming organic crop farming produces a lower yield, has higher GHG emissions and nitrogen leaching per unit product but has a higher amount of biodiversity. In a comparison between these four parameters conventional farming is superior. With the aim to have a more sustainable crop farming with low negative impacts on the environment an *integrated system* can be beneficial to increase yields, lower GHG emissions and nitrogen leaching per unit product, and increase biodiversity.

Converting more farmland into organic production both nationally in Sweden and regionally in Scania would not increase sustainability in the agriculture sector. With an integrated system and a contextual perspective which focuses on geographic context, climate and crop type measures can be taken to increase sustainability nationally in Sweden and regionally in Scania.

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