

HFFA Research GmbH

## **Plant protection in Germany and biodiversity**

Impacts of conventional and organic land management practices on regional and global species richness

Corresponding author: Steffen Noleppa





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## List of abbreviations

BMEL	– Federal Ministry of Food and Agriculture (German: Bundesministerium für Ernährung und Landwirtschaft)
BÖLW	– Federation of the Organic Food Sector (German: Bund Ökologische Lebensmittelwirtschaft)
BLI	– Biodiversity Loss Intensity
BVL	– Federal Office of Consumer Protection and Food Safety (German: Bundesamt für Verbraucherschutz und Lebensmittelsicherheit)
CBD	– Convention on Biological Diversity
DEFRA	– Department for Environment, Food and Rural Affairs
DLG	– German Agricultural Society (German: Deutsche Landwirtschafts-Gesellschaft)
EASAC	– European Academies Scientific Advisory Council
EU	– European Union
FAO	– Food and Agriculture Organization
GEF-BIO	– Global Environment Facility’s Benefits Index for Biodiversity
GHG	– Greenhouse Gases
IUCN	– International Union for Conservation of Nature
IVA	– Industrial Association for Agriculture (German: Industrieverband Agrar)
LEL	– State Institute for the Development of Agriculture and Rural Areas (German: Landesanstalt für die Entwicklung der Landwirtschaft und des ländlichen Raums)
LfL	– Bavarian State Research Center for Agriculture (German: Bayerische Landesanstalt für Landwirtschaft)
MSA	– Mean Species Abundance
NBI	– National Biodiversity Index
PDF	– Potentially Disappeared Fraction
SITC	– Standard International Trade Classification
TI	– Thünen Institute (German: Thünen Institut)
UNEP	– United Nations Environmental Programme

## Summary

The aim of this study was to quantify current yield differences in Germany between organic farming and conventional farming and, correspondingly, derive the impact of these farming systems with their respective plant protection strategies on biodiversity at a national and global scale.

The area-weighted average of all major arable crops shows that organic farming in Germany results in 51 percent lower yields as compared to conventional farming. This difference has grown over time and is particularly high when taking specialized cash crop farms as a reference. The results on yields in conventional as well as organic farms in Germany compare well with other scientific analyses and have been confirmed by many researchers.

Calculating the resulting effects of these two different farming methods and their differences in yields on species richness is an exceptional challenge because there is still no scientific standard for quantifying complex biodiversity. Rather, the state of knowledge only allows stressing particular characteristics of biodiversity. Consequently, there are many indicators for measuring specific biological diversity. Eight such indicators suitable to calculate the biodiversity effects of organic farming and conventional farming in Germany could be identified.

The calculation results show that these indicators often assign a benefit to organic farming with respect to maintaining biodiversity on managed arable land. However, these indicators also show that already organic farming is a serious human intervention in natural ecosystems and results in a considerable loss of biodiversity. Conventional farming only adds very little additional loss. Biodiversity is calculated to decline on arable land in Germany on average by 67 percent in organic farming and 86 percent in conventional farming. Against this background, it can be concluded that organic farming often puts less pressure on biodiversity of farmed land compared to conventional farming.

However, this perspective changes when the sole objective of species protection is extended by a second objective - namely securing the supply of food and other agricultural products. The significant yield advantage of conventional farming in Germany results in less biodiversity losses per unit of yield in conventional farming compared to the organic alternative. Looking at the average of all major arable crops and the chosen eight biodiversity indicators, the loss of biodiversity in organic farming is about 55 percent higher than in case of using advanced, productivity-enhancing technologies in agriculture.

These results confirm that any biodiversity benefits which might exist in organic farming are no longer evident in light of an efficiency analysis. They can even com-

pletely disappear and turn into disadvantages, especially when extending the national to a global perspective. Shifting effects on international agricultural markets combined with domestic production losses – e.g. due to an increased conversion to organic farming in Germany – result in an expansion of the production and agricultural land use of our trading partners. However, most of these countries are located in world regions that do have higher biodiversity levels than Germany. This means small potential biodiversity gains from a conversion to organic farming in Germany are surely paid for by substantially higher biodiversity losses through cultivating new agricultural land elsewhere.

A yield decline in Germany - due to a partial (20 percent) or complete (100 percent) conversion from conventional farming to organic farming - would globally require about 815,000 hectares respectively 6.5 million hectares of currently unused arable land containing manifold biodiversity, i.e. species. Consequently, this global perspective must be considered when decisions on maintaining and improving the protection of specific species and biodiversity at large are pending in a national – e.g. German – context.

The results of this analysis are in line with the current state of scientific knowledge. They emphasize the special value of a “land sparing” approach to minimize the trade-off between agricultural supply and food security on the one hand and the conservation of species on the other hand for a highly productive agricultural region like Germany. Moreover, the state of knowledge does not justify an ideology-based overvaluation of particular land management options. It rather suggests to negotiate specific targets of various land use management options and generate win-win situations appropriately considering both objectives. In this regard a relatively intensive and resource-efficient arable farming in Germany can make a substantial contribution, both regionally and globally.

The analysis results in recommendations for economic, public and policy decision-makers. Polarizing the debate into “ecology” vs. “economy” is not target-oriented. Ideologically hardened fronts must be broken and converted into consensus-orientated discussions fully including existing scientific knowledge. In this regard science faces a particular challenge. Decision-makers need to understand and consider to what extent their decisions not only directly affect a specific target, but also influence other variables of complex systems such as the system of biodiversity and land use. Both systems, biodiversity as well as land use, are highly globalized. A sole focus on the national perspective is not appropriate in this context and further research is needed.

## 1 Introductory remarks: problem setting and objectives

A sequence of altogether four scientific studies implemented between 2011 and 2013 on behalf of Industrieverband Agrar (IVA) drew the fundamental conclusion that properly applied plant protection in Germany does have many positive effects for the society at large (Noleppa and von Witzke, 2013a):

- Such plant protection measures were shown to significantly increase agricultural yields per unit of area and thus, improve overall productivity in the agricultural sector.
- Hence, chemical plant protection considerably contributes to the versatile and needs-based supply of primary agricultural products in Germany and explicitly ensures global food supply.
- It is not only agricultural producers who gain from resulting economic benefits by higher income, but also consumers of agricultural products, e.g. through comparably low prices, as well as the economy as a whole by increasing the gross national product and maintaining livable and sustainable agricultural structures in rural areas.
- Also the environment profits in different ways from chemical plant protection in Germany, contrary to frequently opposing opinions: It was demonstrated that natural habitats and soil resources are globally spared, and thus, the emission of greenhouse gases (GHG) is reduced as well, in particular due to a positive energy balance of applying modern fungicides, insecticides and herbicides.

This assessment is based on the fact that conventional farming methods in Germany properly applying chemical plant protection measures result in significantly positive effects on area productivity compared to organic farming and corresponding plant protection measures. For the three marketing years of 2007/08 to 2009/2010 – used by Noleppa and von Witzke (2013a) as reference period and information base for argumentation and calculation – it has been shown that the weighted average of major crop yields in organic farming in Germany was about 48 percent lower than the area productivity in conventional farming.

Since the publication of the four studies in the years 2011 until 2013 (more particularly, see Noleppa and von Witzke, 2013b; Noleppa et al., 2012; von Witzke and Noleppa, 2012; 2011) the debate has developed and gained further facets. This mainly applies to the following two topics:

- First of all, the own as well as other authors' scientific core findings regarding the large yield differences of alternative production methods in Germany and also in the European Union (EU) (see, e.g., the meta analyses by de Ponti et

al., 2012; Noleppa et al., 2013; Seufert et al., 2012; Tuomisto et al., 2012) are opposed by the public opinion and other researchers denying large yield differences between conventional and organic farming or concluding that these are easy to overcome (see, e.g., BÖLW, 2015; DeLonge, 2014; Wittig, 2012).

- This dissimilar argumentation is especially supported and partly nurtured by a recently published comparative analysis of Ponisio et al. (2015) stating that yield gaps in organic farming are significantly lower than most studies suggest. Another key element of the study of Ponisio et al. (2015) – which by the way had strongly been criticized (Stein, 2014) even before its final release and is continuously criticized (Brazeau, 2015) – is that organic farming brings about major benefits for biodiversity. In fact, scientific, political and public debates in recent years have increasingly emphasized the possible biodiversity advantage of organic farming with Rahmann (2012) pointing out that in organic farming the trade-off between lost productivity and promoted biodiversity protection can be contained and Winqvist et al. (2011) as well as others emphasizing that organic farming increases biodiversity.

The effect of different land use intensities on biodiversity was not subject of the previous studies commissioned by the IVA. The present study shall catch up on this issue; in addition, it shall re-evaluate if the high yield differences of organic and conventional farming derived in previous studies were specified too high and need to be recalculated. Against this background, the following four questions emphasizing specific effects of different plant protection management strategies, specifically those of conventional and organic farming need to be answered:

1. What are the precise and up-to-date yield differences between organic and conventional farming in Germany?
2. What are the effects of conventional vs. organic farming on regional biodiversity, i.e. species richness, in Germany pursuing the two objectives of food security and environmental protection as being equally valued and simultaneously valid?
3. What impacts on biodiversity do arise from the two different land use concepts (organic vs. conventional) on a global scale?
4. What do these findings imply for minimizing the trade-off between food security and resource conservation?

Based on these questions this study fulfills several tasks. First of all, the findings of earlier studies on yield differences between organic and conventional farming in Germany need to be updated and re-elaborated. Secondly, biodiversity effects of these different farming systems and their yields must be scientifically determined and if possible quantitatively estimated and backed up with qualitative assessments.

This relatively complex analysis requires a systematic approach, which is reflected in the structure of this report. The following chapter 2 examines the yield differences (organic vs. conventional farming) in Germany and re-evaluates findings of previous studies. Chapter 3 then analyses and assesses resulting biodiversity effects in Germany distinguishing a calculation of affected biodiversity by unit of area and unit of production. Chapter 4 extends this quantitative analysis of biodiversity effects of the two different farming concepts to the global scale. Chapter 5 moreover discusses the results obtained in light of the existing scientific knowledge. Chapter 6 finally draws conclusions including recommendations for decision making.

## **2 Yields of organic and conventional farming in Germany: current differences in area productivity**

As stated initially, von Witzke and Noleppa (2011) as well as Noleppa and von Witzke (2013a) determined significant yield differences between organic and conventional farming in Germany applying respective plant protection measures during the marketing years of 2007/08 to 2009/10. At that time the yields of organic farming were on average 48 percent lower than those of conventional farming.

These yield differences of organic and conventional farming derived with a scientific analysis were based on comparative data from farms belonging to the German farm accountancy data network. These are statistically determined operating farms of both farming systems comparable in terms of their natural site conditions as well as their factor use and other structures. Systemic errors, e.g. in terms of farm sizes (organic farms are often smaller than neighboring conventional farms) or site characteristics (compared to conventional farms organic farms work more often on marginal and thus less profitable land), are therefore explicitly avoided (see Offermann et al., 2014).

With respect to the increased public awareness supporting the belief that the actual yield difference between organic and conventional farming is not as high (anymore) as previously thought (see again chapter 1), this study analyzes whether current yield gaps actually deviate from previous results. Again, information from the German farm accountancy data network for most recent marketing years and representing comparable organic and conventional farms could be retrieved and analyzed for the necessary update. Differences to previous studies commissioned by the IVA only arise with regard to the grouping of some cereals in the statistics. Hence, no information loss occurs.

Figure 2.1 compares the average yield levels of organic farming vs. conventional farming in Germany for major arable crops cultivated during most recent marketing years for which data is now available (2011/12 to 2013/14) and marketing years covered in previous studies (2007/08 to 2009/10). Using the average over three marketing years thereby minimizes temporary outliers and other sporadic, falsifying effects, e.g. weather phenomena.

**Figure 2.1: Yield level of organic farming compared to conventional farming in Germany (in percent, conventional farming = 100)**

Arable Crop	MY 07/08 to MY 09/10	MY 11/12 to MY 13/14
Wheat	45.2	43.0
Barley	52.4	50.1
Other Cereals	49.4	46.7
Oilseed Rape	64.1	55.2
Potatoes	55.2	54.5
Sugar Beets	82.9	82.8

Source: Own calculations and figure based on TI (various years); MY – marketing year.

In light of this new analysis two basic statements can immediately be drawn:

1. The level of organic yield shortfalls in Germany has changed over time requiring indeed a reassessment of the findings from Noleppa and von Witzke (2013a).
2. However, this re-evaluation leads to the conclusion that the organic yield shortfall in Germany has not decreased but rather increased!

In fact, this yield difference has increased for all arable crops considered here and covering at least 8.5 million hectares of agricultural land respectively more than 70 percent of all arable land in Germany (BMEL, 2015):

- For example, wheat yields in organic farming are not anymore 55 percent lower than those of conventional farming, but nowadays even 57 percent.
- To mention a second example, organic yield losses in oilseed rape of about 36 percent a few marketing years ago now amount to 45 percent.

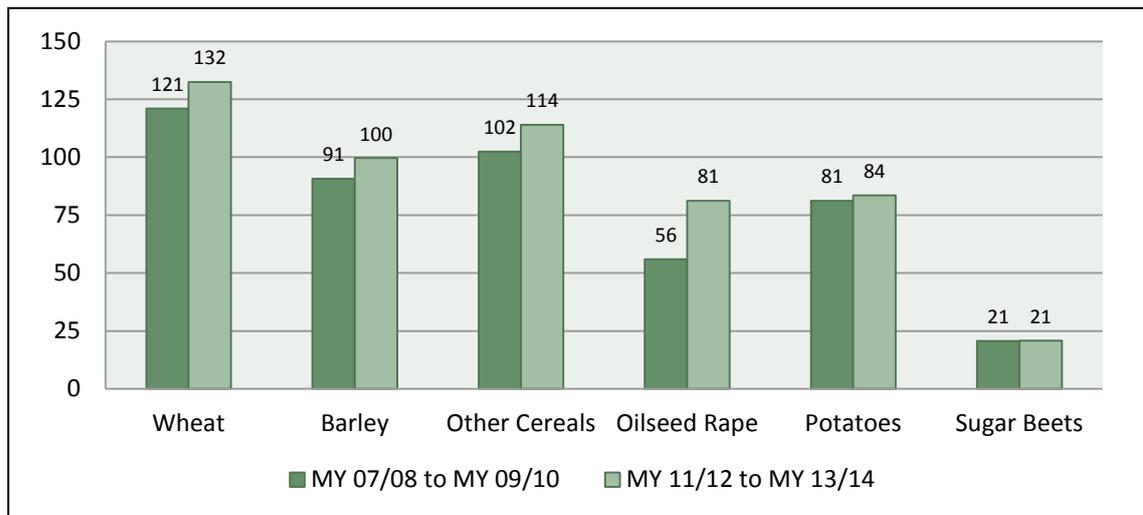
The average of all considered arable crops weighted by the actual crop acreage according to the BMEL (2015) shows an overall organic yield loss of 51 percent compared to a previous loss of 48 percent. Referring to the German-wide differences in area productivity, this adds almost one percentage point of yield losses per marketing year to the already weak comparative result of organic farming. Consequently,

organic farming does not even achieve half the yield level of productivity-orientated farming.

This result would even look more dramatic if not all representatively selected organic farms were compared to corresponding conventional farms, but only highly specialized arable crop farms. In this case, the yield ratio of specialized organic vs. conventional farms would be e.g. in wheat only 41 percent instead of 43 percent; for potatoes this ratio would decrease from almost 55 percent to less than 52 percent (see again figure 2.1).

This noteworthy development, which is contrary to public perception, is also illustrated in figure 2.2. It shows the increasing additional yield of conventional farming applying, among others, chemical plant protection products compared to organic agriculture in Germany. Accordingly, it can be concluded that the weighted additional yield of conventional farming has grown from about 96 percent (in the marketing years of 2007/08 to 2009/10) to now about 103 percent.

**Figure 2.2: Additional yield of conventional agriculture compared to organic agriculture in Germany (in percent)**



Source: Own calculations and figure based on TI (various years); MY – marketing year.

These new results on yield levels in conventional vs. organic farming do resist a stress test as they are confirmed by other sources:

- The Committee for Education, Research and Technology Assessment of the German Parliament reaffirms that organic wheat yields are less than half of corresponding conventional yields and 54 percent in case of potatoes (Deutscher Bundestag, 2013).

- According to LEL and LfL (2014), yield differences are even bigger: In southern Germany organic wheat and potato yields are 61 respectively 51 percent lower than conventional yields.
- Schaak et al. (2014) also calculate partly significantly higher yield differences for Germany.
- So does Krall (2014) who emphasizes the higher productivity of conventional management in modern and high-quality agricultural systems, what is equivalent to roughly 50 percent less yield of organic farming compared to conventional farming.
- Forster et al (2015) as well as Schmid and Hülshagen (2015a, b) also report similarly high and partially even higher yield differences of both farming types in Germany.

It can be stated that the use of official statistics depicting comparable conventional and organic farms allows deriving existing yield differences in a reasonable way. These calculations as well as the results of previous studies commissioned by IVA and now used as reference systems in other studies (see, e.g., Möckel et al., 2015) therefore also allow to conclude that yield differences in favor of conventional farming are serious, at least in Germany. These differences have increased over time. Since these results are principally confirmed by other authors, they represent a factually correct basis for further analysis and can be used accordingly.

### **3 Regional biodiversity effects of conventional and organic farming**

Prior to scientifically analyzing biodiversity effects of different farming systems in Germany – first from a regional, i.e. national, perspective and later also from a global perspective – the term biodiversity and its consequences for the forthcoming review need to be discussed.

Officially, the term biodiversity or synonymously biological diversity is defined as follows (see, e.g., CBD, 2015; Hood, 2010; Rahmann, 2011): It is the variability among living organisms from all sources; this includes diversity within species, between species and of ecosystems. Accordingly, biodiversity is manifested in various and partially hierarchical forms:

- First, there is genetic diversity meaning genetic variety or rather variability of all genes within one species and/or within an ecosystem.
- Then there is species richness meaning a great number or variety of species in one ecosystem.

- Furthermore, there is a diversity of ecosystems which describes the variety of habitats and ecosystems.
- Finally, functional biodiversity is of interest meaning the variety of realized ecological functions and processes within one ecological system.

The comprehensive description and analysis of biodiversity and the effects on species richness as required by the European Union (EU) regulation concerning the placing of plant protection products (Europäisches Parlament und der Rat, 2009) need an approach suitable to investigate all these four forms or levels of biodiversity. However, the scientific community is far from reaching a consensus on how to achieve this. A standard of biodiversity measurement is rather far away, and several hurdles remain to be overcome (Souza et al., 2015). Terpl (2013) even argues that an objective measurement of biodiversity is quite an impossible undertaking.

Not least due to these issues, the scientific and even more the public discourse on biodiversity aspects are often constrained to a more or less clearly defined interpretation of the biodiversity concept (see, e.g., DLG, 2015; Rahmann, 2011; Settele et al., 2010). This might also trigger the frequently synonymous use of the terms biodiversity and species richness in the political and public debate as well as in science.

Accordingly, there are numerous indicators for measuring biodiversity (or rather: species richness), what makes the analysis even more difficult. However, looking at the available indicators and their respective definitions as a whole detached from the more or less complex inclusion of species within these indicators (see, e.g., EA-SAC, 2005; IUCN, 2014; Weiskopf and Nemecek, 2013), it can be noticed that the quantitative allocation of biodiversity usually matches with a predefined unit of area. This unit can be a hectare, the area of a particular habitat or even a region or a country. In fact, biodiversity patterns and their changes are almost exclusively considered at a specific spatial level (Bernhardt, 2015). This also applies to many published studies which analyze the advantages of organic farming over conventional farming in terms of biodiversity or more precisely species richness.

### **3.1 Effects on biodiversity in Germany from an area perspective**

In their entirety these studies conclude that from an area-focused perspective the management of arable land (and/or grassland) with organic farming methods has clearly positive biodiversity benefits compared to conventional farming. At least the majority of authors involved in the discussion – albeit not all of them – support this argument:

- For example, Rahmann (2011) examined nearly 400 study results and found that five sixths of these, or more concretely 84 percent worldwide and 80 percent in the EU, assign a biodiversity benefit to organic farming. However, in 16 percent of the investigated cases this advantage was not given or even negative.
- Some years earlier, exactly the same percentage was assessed by Bengtsson et al. (2005): 16 percent of the analyzed studies concluded that conventional farming had advantages in terms of biodiversity/species richness compared to organic farming. The authors stated that organic farming was only better in half of the examined cases. The remaining studies represented ambivalent findings.
- In this context – with about 50 to 80 percent of all study results stressing area-related biodiversity benefits of organic farming when compared with conventional farming – further findings of other more or less extensive (meta-) analyses have to be mentioned: Hole et al. (2005) as well as Bavec and Bavec (2015) show that about two thirds of the analyzed observations indicate a corresponding advantage of organic farming over comparable conventional agricultural methods.
- Pfiffner (1996), to mention an additional author, provides similar findings: At that time 68 percent of all cases analyzed proved greater biodiversity benefits of organic farming, even though only fauna was investigated.

The results of above listed meta-analyses already suggest that the often simplified assumption of conventional farming generally being less biodiversity-friendly when considering species richness per area unit is not always suitable (see, e.g., Feber et al., 2015). Not only in individual cases productivity-oriented farming methods might rather bring about benefits depending on the location and specific agricultural use. Still, there seems to be consensus in the scientific and even more in the public perception that organic farming protects species and increases biodiversity (see, e.g., Grid Arenal, 2014; Henckel et al., 2015; Winqvist et al., 2011). It needs to be underlined that this perception holds true especially for Germany (see, e.g., Gottwald and Stein-Bachinger, 2015; Möckel et al., 2015; Rahmann, 2011).

It is repeatedly overlooked that organic farming – just as conventional farming and countless other human activities – represents a distinct intervention in the ecosystem and quite often extensively uses natural resources (see, e.g., Taube et al., 2006). The cultivation of each arable crop, regardless of the specific farming system, exerts pressure to flora, fauna and microorganisms to a much higher extent than determined by nature (see Krall, 2014). Biodiversity on the German territory for example would look totally different (and perhaps even poorer) without the influence of human use: Detached from anthropogenic influences deciduous and mixed deciduous forests (mostly with beech) would most likely dominate. Only in

middle and higher altitudes as well as in very dry or very wet locations coniferous forests (mainly pine) would replace this landscape (Huth and Werntze, 2010). The whole complex of today's open landscapes and associated agricultural biodiversity would be completely absent in such a fixed reference system of flora and fauna.

Indeed, also organic farming uses inputs that not only selectively but massively displace species. Even on organically farmed land other fauna competing planted crops is considered unfavorable and controlled: Various biotechnological measures, fatty acids and salts as well as natural insecticides are used to combat natural fauna; mechanical weed control measures (e.g. hoeing) or heat measures reduce unwanted flora (Krall, 2014; Rahmann, 2011). In addition, sulfur and copper (compounds) are used to control fungi (BVL, 2015). All this and respective soil tillage undoubtedly reduce species such as ground-dwelling birds and amphibians. However, the extent of biodiversity destruction often remains unclear and the special protective value of organic farming compared to conventional farming is not even close to be comprehensively quantified (see Kühn, 2013).

However, a comparative analysis of the biodiversity effects of different land use types – as done in this study – requires that such effects of different farming systems on species richness are measurable. Thus, the particular challenge of this analysis becomes clear: Science still is in the infant stage of exploring and evaluating biodiversity effects of different land management concepts in a comparative manner. This should be kept in mind with the following deduction and subsequent discussion of an own specially designed and approximate evaluation approach in light of lacking evaluation standards.

In fact, each scientific quantification of biodiversity or species richness can currently only be described as “approximate” depending on the taxonomic and area-specific features of the investigated object as well as the used definitions, conventions, etc. (Saling et al., 2014). In other words: There is not “the” biodiversity as such and its measurement is always more or less subjective. This means that a specific choice or design of a biodiversity indicator can be used to achieve explicitly desired results (de Baan et al., 2013). The authors show for example that the (targeted) selection of appropriate indicators alone may have a larger influence on statements about biodiversity (changes) than different land use intensities may have because the design of indicators already pre-defines the desired research scope in advance. Terpl (2013) even puts it into concrete terms: Today, biodiversity indicators can be applied in a way that the spectrum of species can formally be extended where it is actually declining and vice versa.

However, it is possible to reduce this scientifically undesirable subjectivity of existing (but still very rudimentary) evaluation approaches if the individual concepts to

be further developed were considered as a whole. In other words: If the scientific state of the art is generally trusted and it is furthermore assumed that any (subjective) indicator or evaluation approach reflects a partial reality of biodiversity/species richness and their changes due to land use, then the entirety of derived (subjective) indicators describes reality more accurately than a single indicator; the picture of e.g. the effects of different farming intensities would consequently get wider, more comprehensive and thus more objective without being complete and holistic at the end. This is the basic credo for the own following analysis.

Against this background eight different indicators (see below) could be identified by comprehensively analyzing recent scientific literature on farming practices and biodiversity or species protection allowing for a synergetic quantitative analysis. All these determined useful indicators do have the following in common: They represent index systems or can easily be converted into such systems with changes in biodiversity allocated to agriculturally used land. This is important because such index values provide better comparability of the various definitions of spectrums of species and changes of these spectrums and thus, do allow for an aggregation (Croezen et al., 2014).

A first step of such indexing must be to define or postulate a reference value for biodiversity per area unit in a natural or at least near-natural reference system. This reference value is fixed to 100 percent (or 1.0). In a second step actually “measured” or calculated or otherwise determined biodiversity (here more precisely: species richness) can be aligned to this reference value at different intensities of land use on a corresponding area. A calculated (measured) value of e.g. 70 percent (or 0.7) then indicates that 30 per cent (or 0.3 units) of the natural biodiversity or species richness of the specific area are lost due to agricultural land use. Scientific debate describes this loss as “Potentially Disappeared Fraction” (PDF) of species in an observation area (see e.g. Croezen et al., 2014; Slay, 2011).

When selecting appropriate indicators in this context it is crucial to relate the quantitative characteristics of these indicators to the economic activities of agriculture, or more concretely to the different levels of intensification of arable land. This is even more important for the intended comparison with a reference situation largely detached from anthropogenic influences (here: near-natural habitat) (Croezen et al., 2014). Against this background and with reference to the preparatory work of Croezen et al. (2014; 2011) and the investigated land use systems of organic and conventional farming (in the sources listed below synonymously described as “low-input” and “intensive” agriculture) already the following four measurable values for biodiversity (or more precisely: richness of species) could be identified:

- The so-called “Mean Species Abundance” (MSA) indicator traces back to the work of Alkemade et al. (2009) and is described by Croezen et al. (2014; 2011). Its index quantifies the number of different species and populations of these species still found on a certain agricultural area in comparison to the “natural” population of this area (see also Smeets et al., 2013). Low-input agriculture assumes an MSA-based decline of biodiversity on the utilized area of about 70 percent (PDF = 0.70) on average, while intensive agricultural use shows a decrease of about 90 percent per unit area (PDF = 0.90).
- According to the so-called ReCiPe approach the biodiversity losses of the two investigated farming techniques are less different. The approach goes back to Goedkopp and Spiensma (2000) and its acronym reflects the institutions involved in the development. According to Croezen et al. (2011) the ReCiPe indicator calculates an average of 85 percent of biodiversity loss (PDF = 0.85) for extensively and around 89 percent (PDF = 0.89) for intensively managed areas.
- A slightly deviating measure of biodiversity effects is the so-called “Eco Indicator”, which is also based on Goedkopp and Spiensma (2000) but was newly determined and specified by Goedkopp et al. (2012). It forms the basis on which Croezen et al. (2014) measure the effects of organic vs. conventional agriculture with a PDF of 0.82 (organic) and 0.91 (conventional).
- However, the so-called TNO approach reveals much bigger differences in terms of biodiversity losses or losses of species richness. The indicator’s name itself is meaningless and goes back again to the developing institution. The approach is described by Weidema and Lindeijer (2001) as well as Lindeijer et al. (2002) and states a PDF in organic farming of 0.40 and in conventional agriculture of 0.70. However, as Croezen et al. (2011) make clear: The basis of calculation and assessment for this significant discrepancy remains rather unclear.

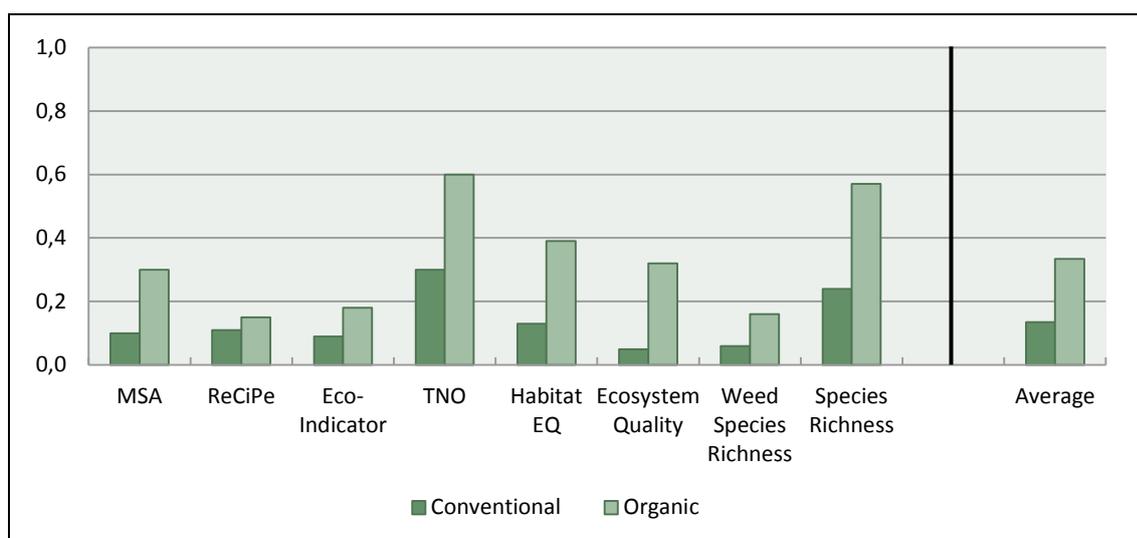
Beside these four measured values with comparable characteristics in terms of biodiversity or species losses in organic vs. conventional farming as summarized in Croezen et al. (2014; 2011) another four additional indicators were identified. Their specifications with regard to the two different farming intensities under investigation should also be considered in the own analysis:

- A modified MSA approach is pursued by Keeling and Lillywhite (2012) (see also Lillywhite et al., 2012). With their research they establish an equivalence factor – the so-called “Habitat EQ” –, which determines the average density of remaining species richness of various farming methods applied in a given area as measured by natural habitats. Accordingly, the decline in organic farming can be expected at about 61 percent (PDF = 0.61) and that of comparable conventionally managed fields at 87 percent (PDF = 0.87).

- Next, the so-called “Ecosystem Quality” indicator should be mentioned, which was used by Reidsma et al. (2006) for an analysis of biodiversity effects in case of an expansion of the organically farmed area in the EU. The indicator is defined by a subjective assignment of biodiversity per farm type. Extrapolating the rates of conversion from conventional to organic farming reported in this study, the losses with regard to ecosystem quality are about 68 percent (PDF = 0.68) in case of 100 percent conversion to organic farming and around 95 percent (PDF = 0.95) in case of 100 percent conventional agriculture.
- Another indicator to be considered in the analysis was introduced by Armengot et al. (2011) and is referred to as “weed species richness”. Thus, the indicator depicts a very specific part of biodiversity which the authors allocate a decline of around 84 percent (PDF = 0.84) on organically farmed land and around 94 percent (PDF = 0.94) in comparable conventional farming.
- Finally, the scientific approach of van Zeijts et al. (2011) is remarkable. The authors define a so-called relative “species richness” indicator, which defines the ratio of the remaining number of species in extensively as well as intensively managed agricultural systems and the total of existing species in a given region. Based on this index, extensive farming (in the context of this study organic farming) reaches a PDF value of 0.43, while intensive farming (here conventional arable farming) achieves a PDF value of 0.76.

Figure 3.1 displays the results of this meta-analysis and shows what biodiversity measured against natural habitats does still exist on organic or conventional farmland.

**Figure 3.1: Remaining biodiversity of organically and conventionally managed arable land (1.0 = 100 percent)**



Source: Own calculations and figure.

The description mathematically resulting from deducting the relevant PDF value from the reference value (1.0) is done for each of the previously outlined eight indicators individually, but also for the average of all included indicators. The particular result of the analysis, thereby, might overestimate the importance of organic farming for preserving biodiversity and all the assumptions made above should rather be seen to favor the biodiversity benefit of organic farming. Indeed, Tuck et al. (2014) indicate an information bias which should not be neglected: Most of the information used to evaluate biodiversity effects of organic farming vs. conventional farming and set biodiversity indicators as shown above is born by studies, which clearly highlight the specific benefits of organic farming while searching from the very beginning only in academic papers of ecological and environmental sciences (as in Rahmann, 2011). This leads to results in favor of conventional agriculture being less represented, ignored at all or “corrected” (see, again, Tuck et al., 2014).

The authors mentioned tried to exclude this bias via statistical methods. Based on a re-calculation of the meta-analysis by Bengtsson et al. (2005) they conclude that the area-based biodiversity advantage of organic farming decreases by about 40 percent when excluding the information bias. Accordingly, smaller differences of both farming types are found by e.g. Jonason (2012), Schader et al. (2011) as well as Weisskopf and Nemecek (2013). In this context it is repeatedly emphasized that organic farming shows “on average” a biodiversity that is only 30 percent higher than the one of conventional farming (Batary et al., 2005; Fuller et al., 2005; Garratt et al., 2011; Hole et al., 2005; Tuck et al., 2014).

Jonason (2012) even argues – in a Swedish context – that biodiversity benefits may get lost over time after the first years of converting to organic farming practices. It seems that the persistent specialization of organic farms and their long-term participation in a competing market go along with an at least partial loss of initial benefits in terms of biodiversity. In this context Jonason (2012) underlines the complexity of relationships between the different variables, which yet have to be understood before allowing for targeted policy decisions.

Nevertheless, it should be mentioned at this point that organic farming practices often exert less pressure on the biodiversity of a cultivated area than conventional farming practices as not each and every weed and pest can be controlled by appropriate means. However, also organic farming significantly reduces biodiversity. Consequently, the particular results of the study confirm two things:

- First, an issue long known is confirmed: Organic farming can facilitate a higher level of biodiversity on a concrete area; however, differences to conventional farming are often relatively small (DEFRA, 2004).

- Second, as other authors stress: Possible advantages organic farming may have with regard to some environmental parameters if the perspective is area-focused are not that obvious if the amount of primary produce is additionally used as a target criterion (see, e.g., Meier et al., 2015; Krall, 2014; Tuomisto et al., 2012).

### **3.2 Effects on biodiversity in Germany from a product perspective considering a fundamental trade-off**

The growing world population and the associated growth in demand for food, feed, fuel and fiber as well as water, land and other scarce resources such as energy undeniably increase the already strong pressure on regional and global ecosystems. In this context the conservation of biodiversity is certainly the biggest challenge alongside climate protection. The continuing loss of the species richness induced by land use and land use changes has been recognized as a significant problem (Souza et al., 2015). Consequently, the particular challenge for German, European and global agriculture is to simultaneously (a) meet the growing demand for food and other agricultural raw material and (b) conserve biodiversity and species richness to the largest extent possible.

It is principally unavoidable that modern agricultural cultivation practices, both organic and conventional, negatively influence biodiversity or rather species richness – in terms of natural occurrence – in various ways. Obviously, it is a matter of minimizing a classic conflict of objectives, as both goals – increasing primary agricultural production and the protection of biodiversity or species richness – are societal consensus. Therefore, the real challenge is to search for systemic approaches which mitigate this conflict or trade-off.

The question is: How can this trade-off be operationalized and dissolved or at least minimized? Analytically this is quite easy to handle: With respect to the described conflict of stopping or at least slowing down the loss of biodiversity on the one hand and increasing agricultural production to meet demand requirements on the other hand either the highest possible agricultural production per unit of biodiversity loss or the least possible loss of biodiversity per unit of agricultural production have to be inquired. Those measures with the best ratio should be implemented or internalized.

Benton et al. (2011), Gabriel et al. (2013), Sayer and Cassman (2013), Taube et al. (2006), Tschardt et al. (2012), Vergez (2012) and others do claim this rationale or even aim at it. Degrees of goal accomplishment principally need to be analyzed by

means of an equivalence considering biodiversity loss in relation to the production of an agricultural good (Vergez, 2012).

This idea is applied in the following. Equation (1) defines the so-called *Biodiversity Loss Intensity (BLI)* in German arable farming:

$$(1) \quad \text{BLI} = \text{PDF (in percent)} / \text{yield (in percent, organic farming} = 100)$$

[with PDF – Potentially Disappeared Fraction]

Due to scaling BLI does have no unit simplifying the comparability across regions and crops and thus facilitating later aggregation or adjustment for different previously described indicators of biodiversity or species richness. First, however, the development of average yields and biodiversity losses in organic vs. conventional farming based on above discussed data shall be assessed deriving step by step the following results of equation (1):

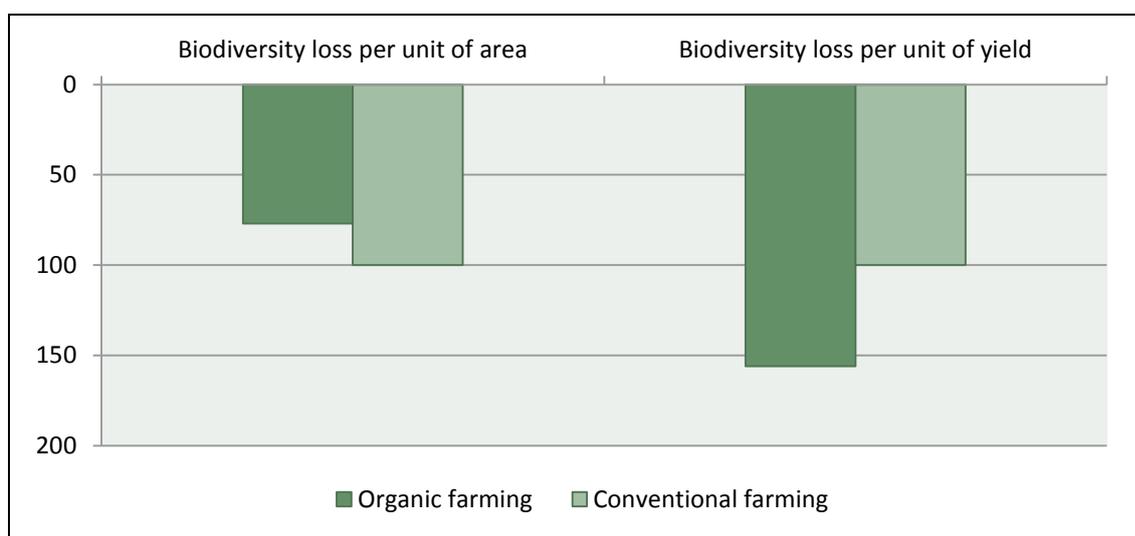
- Defining the yield per hectare in organic farming in Germany 100 percent, conventional farming currently produces 203 percent of that yield (see argumentation following figures 2.1 and 2.2).
- With regard to arable land and according to above identified indicators organic farming faces an average loss of 66.6 percent of the original biodiversity, whereas conventional farming loses about 86.5 percent of species richness in the affected areas (see figure 3.1).
- Consequently, 0.67 percent of biodiversity are lost per percentage point of yield unit in organic farming (BLI = 0.67), but only 0.43 percent (BLI = 0.43) in conventional farming.
- Thus, the BLI is about 55 percent higher in organic farming than in modern technology and productivity-oriented farming systems in Germany meaning that a certain amount of agricultural produce achieved with organic methods in Germany costs substantially more and not less biodiversity than under conventional farming conditions.

The alleged biodiversity benefit of organic farming from the sole perspective of cultivated area, i.e. in the context of a one-dimensional objective, dissolves when the objective's range is extended by the production of agricultural goods as fundamental objective of agricultural activity (for an overview of these objectives in Germany see, e.g., §1 of the Agriculture Act; for the EU see, e.g., Bureau et al., 2012). This conclusion was already drawn by Gabriel et al. (2013). More precisely, the alleged area-related biodiversity benefit of organic farming turns into a disadvantage in a highly productive country like Germany if the objective of resource protection is realistically extended to food security and the availability of raw material.

Figure 3.2 visualizes this reversed consideration by comparing biodiversity loss per unit of area and per unit of yield:

- Defining the contribution of conventional farming in Germany to biodiversity losses 100, the corresponding bias of conventional farming considering a one-dimensional objective (relating to the area) is about 23 percent as in organic farming “only” 77 percent of species richness is lost compared to conventional agriculture (see left pair of columns in figure 3.2).
- The opposite holds true when taking into account a multidimensional, yield-unit focused definition of objectives: Then the biodiversity loss in organic farming is 55 percent higher (see right pair of columns in figure 3.2).

**Figure 3.2: Biodiversity loss per unit of area and unit of yield in organic and conventional farming in Germany (index, conventional farming = 100)**



Source: Own calculations and figure.

Additional and more detailed findings can be obtained when the BLI analysis described above is broken down to individual indicators and arable crops. Using the PDF values of figure 3.1 and relative yields of organic farming compared to conventional farming according to figure 2.1 and based on equation (1), the following BLI values as shown in figure 3.3 for conventional and organic farming in Germany can be derived. It displays a total of 48 “case studies” comparing organic and conventional farming. In 43 (or 90 percent) of these cases, the corresponding matrix values disclose a higher BLI for organic farming.

**Figure 3.3: Biodiversity Loss Intensity in organic and conventional farming in Germany (index values)**

Arable Crop	Management System	M S A	Re-Ci-Pe	Eco-Indicator	T N O	Habitat EQ	Eco-system Quality	Weed Species Richness	Species Richness
Wheat	conventional	0.39	0.38	0.39	0.30	0.37	0.41	0.40	0.33
	organic	0.70	0.85	0.82	0.40	0.61	0.68	0.84	0.43
Barley	conventional	0.45	0.45	0.46	0.35	0.44	0.48	0.47	0.38
	organic	0.70	0.85	0.82	0.40	0.61	0.68	0.84	0.43
Other Cereals	conventional	0.42	0.42	0.43	0.33	0.41	0.44	0.44	0.36
	organic	0.70	0.85	0.82	0.40	0.61	0.68	0.84	0.43
Oilseed Rape	conventional	0.50	0.49	0.50	0.39	0.48	0.52	0.52	0.42
	organic	0.70	0.85	0.82	0.40	0.61	0.68	0.84	0.43
Potatoes	conventional	0.49	0.48	0.50	0.38	0.47	0.52	0.51	0.41
	organic	0.70	0.85	0.82	0.40	0.61	0.68	0.84	0.43
Sugar Beets	conventional	0.74	0.74	0.75	0.58	0.72	0.79	0.78	0.63
	organic	0.70	0.85	0.82	0.40	0.61	0.68	0.84	0.43

Source: Own calculations and figure.

This means, not only the average of all eight scientific indicators across all arable crops used here assigns a biodiversity benefit to conventional farming when including a supply target (yield argument) beside the resource protection goal (area argument) but also each individual one of the identified indicators and almost all crops principally do. Only for sugar beets some drawbacks can be found in a very few cases, possibly owed to the fact that they represent a niche product in organic farming (Drangmeister, 2011) which might benefit from an “island position” as concerns phytosanitary measures applied by surrounding conventional agricultural enterprises.

The results thus confirm findings on other sustainability indicators such as GHG emissions etc.: Initially apparent advantages of organic farming while only considering the cultivated area and abstracting from the ultimate objective of agriculture – the production of food and agricultural commodities – are no longer obvious when additionally considering the unit of generated produce or yield (see, e.g., Halberg, 2012). This finding is also supported by Bavec and Bavec (2015) who conclude from assessing currently existing meta-analyses on environmental effects of organic vs. conventional farming that benefits of organic farming with respect to the area approach diminish when considering the produced unit or the achieved yield.

## 4 Global biodiversity effects of conventional and organic farming

The loss of biodiversity and species richness is undoubtedly one of the most important current environmental problems. This does not only hold true from a national perspective, but in particular from a global perspective (see, e.g., Croezen et al., 2014). In this context it needs to be stressed that yield losses due to organic farming in Germany cannot simply be compensated by a higher use of necessary agricultural land, as such a massive reallocation of natural habitats is impossible from a legislative point of view and, furthermore, would not be accepted by society.

It would be foremost outside Germany that biodiversity effects materialize as the loss in domestic production volumes due to organic farming needs to be re-imported via international trade to meet the still existing demand for food as well as agricultural raw materials for feeding and other purposes in Germany.

Against this background the following two scenarios are examined in the following:

1. Global biodiversity effects of a politically endorsed and assisted expansion of organic farming in Germany of currently about 6.3 percent (Statista, 2015a) to 20.0 percent (Bundesregierung, 2012; see also Möckel et al., 2015) shall foremost be assessed.
2. Resulting consequences of a theoretically possible complete conversion to organic farming with substituting consequent losses of agricultural products by international trade shall additionally be evaluated.

Figure 4.1 shows how many tons of locally producible amounts of arable crops examined in this study would have to be replaced while enlarging organic farming by decreasing exports and increasing imports to further meet the existing demand. The assessment, thereby, is based on latest statistical data from BMEL (2015; 2014) and uses a three-year average to abstract from erratic quantitative effects, for example changing weather conditions:

- Consequently, it turns out that expanding organic farming in Germany to 20 percent would already cause a loss of domestic production equal to over 2.0 million tons alone in wheat – what, by the way, would be enough to feed more than 30 million people worldwide with an average annual wheat ration (see FAO, 2015a).
- In case of a complete conversion it would be even more than 14 million tons of wheat.
- The associated change in export/import volumes of other crops can be calculated accordingly.

**Figure 4.1: Production losses to be replaced through international trade in case of a partial or complete conversion to organic farming in Germany (million tons)**

Arable Crop	“20 Percent“ Scenario	“100 Percent“ Scenario
Wheat	2.038	14.115
Barley	0.755	5.231
Other Cereals	0.846	5.858
Oilseed Rape	0.343	2.376
Potatoes	0.624	4.320
Sugar Beets	0.586	4.060

Source: Own calculations and figure.

Importing these quantities requires *ceteris paribus*, i.e. in case of unchanged crop yields in other parts of the world, additional global area for agricultural production to be obtained either from natural habitats or extensively used grasslands. Where to find how many of these needed areas and what global biodiversity effects to be derived can be determined by a meanwhile often applied and repeatedly published method.

*Excursus: Determining global land use and biodiversity effects in case of changing domestic conditions for agricultural supply and demand*

*The hereby applied analysis is based on the reasonable assumption that converting to organic farming in Germany also triggers production effects in other regions of the world. This mainly applies when the decline in domestic supply can neither be compensated by expanding the own area nor by immediate productivity gains. Increased transactions in international trade then transfer incentives for an increased production elsewhere.*

*Worldwide land use effects caused by expanding production as a result of changes in supply (or demand) in certain regions (here Germany) can be analyzed with the concept of virtual land trade. The methodology of this approach was first developed in von Witzke and Noleppa (2010). Since then the concept has been revised several times and successfully applied, for example in Noleppa and Carlsburg (2014) and most recently in WWF Germany (2015). Meanwhile, the approach has also been published within two comprehensively peer-reviewed articles (Kern et al., 2013; Lotze-Campen et al., 2015) and is scientifically accepted as a reference system in research (see e.g. Meier et al., 2014; UNEP, 2015). Main features of this methodology have also been established in statistical publications (Destatis, 2013a; b).*

*This tool makes it possible to include land resources used outside the territory of a given region to satisfy local demand. Necessary essential data concerning international agricultural trade flows and regional yields needed to make appropriate calculations are thereby taken from mainly Eurostat (2015) and FAO (2015b).*

*As international trade data is based on so-called Standard International Trade Classification (SITC) categories which all can be assigned to primary agricultural products it is possible – with the use of technical coefficients (especially according to FAO, 2012) – to determine what amount of a raw product (e.g. wheat) is included in a concrete internationally traded good (e.g. wheat flour). Hereby, potential coupling effects, especially with regard to oilseeds, have to be taken into account as well. If the regional crop yield of the raw product (here taken from FAO, 2015b) is additionally known and under the assumption of unchanging trade preferences, it is possible to derive the area needed in each region with which a country (here: Germany) has foreign trade relations to compensate for, e.g., domestic production losses.*

*This concept also creates the basis for global biodiversity considerations. In the past, various scientific approaches were tested and a number of different global biodiversity indicators have been developed, which can now be used for analyzing worldwide biodiversity losses caused by land use changes. All these concepts have got diverse advantages and disadvantages and most of them are still under development (see, e.g., Wright, 2011). In light of this uncertainty, the present study will apply not only one, but two different indicators to measure changes in global biodiversity.*

*The first indicator used here is the Global Environment Facility Benefits Index of Biodiversity (GEF-BIO). This index was developed by Dev Pandey et al. (2006) and already applied in scientific studies (see, e.g., Wright, 2011; UNEP, 2009). Besides, it can be combined with the virtual land trade analysis used here. In particular, the following characteristics of the GEF-BIO indicator make its application reasonable:*

- *The GEF-BIO represents both the status quo as well as changes in biodiversity over time.*
- *The indicator provides the mapping and national distribution of species and their threatening across the globe. Biodiversity can thus be calculated on a country as well as global level.*
- *The indicator has frequently been used and is just on its way to be well established. Moreover, it is consistent with the objectives of the Convention on Biological Diversity (CBD) and used by various international research groups and organizations (see World Bank, 2015).*

*The GEF-BIO basically measures the relative biodiversity of a country based on the species of this country, their threatening and the diversity of their habitats and ecosystems. Brazil is defined as the country with the highest biodiversity rated by the*

*index value 100. It is composed of a wide variety of different ecosystems, the Amazon, Cerrado, Mata Atlantica, the Atlantic rainforest, etc. and thus considered the country with the greatest diversity of flora and fauna worldwide. In contrast Nauru is evaluated with the index value 0. Nauru is a small island nation in the Pacific Ocean with very low biodiversity, only a few birds and insects as well as coconut palms, which grow on a narrow fertile coastal strip. All other countries are classified between these two extremes and obtain index values bigger than 0 and lower than 100.*

*Following the rationale of the GEF-BIO-indicator, this study assigns to one hectare of land in Brazil still not used for agricultural purposes or any other way by people 100 points of biodiversity. In Nauru one hectare of such land is assigned 0 points. In all other countries this rating is done according to their individual index figures. Regional area losses then can be translated into region-specific biodiversity losses by multiplying the number of lost natural or near-natural habitats per region (measured in hectare) by the national index values. Aggregating these region-specific results finally leads to total global biodiversity losses (based on the GEF-BIO).*

*The second biodiversity indicator to be used here is known as the National Biodiversity Index (NBI). This index was developed by the CBD itself and the main contents are documented in CBD (2001). The NBI is based on estimates of the occurrence and abundance of four groups of different terrestrial vertebrates and vascular plants in a country. Vertebrates and vascular plants are equally weighted in the index. The NBI assigns the country with the highest biodiversity 1.00 and defines Indonesia as the country with the highest biodiversity. The country with the lowest biodiversity according to NBI is Greenland, and it is assigned 0.00. Again, all other countries rank somewhere in between. Countries with an area of less than 5,000 square kilometers are, however, not considered. The basic principle is very similar to the one of GEF-BIO. Hence, NBI is also used here by multiplying regional area effects with national biodiversity index values and then aggregating the resulting multipliers. In order to compare the NBI and the GEF-BIO, the results of the NBI still need to be multiplied by 100.*

*Nevertheless, there are obviously differences between the two concepts calculating global biodiversity effects due to altered human behavior (here: supply changes due to a conversion to organic farming in Germany):*

- *Aggregating all biodiversity index points of the GEF-BIO indicator leads to a currently given global biodiversity of about 289 billion index points. This means that the current global biodiversity is equal to the biodiversity that can be found on (theoretical) 2.89 billion hectares of Brazilian ecosystems. This is*

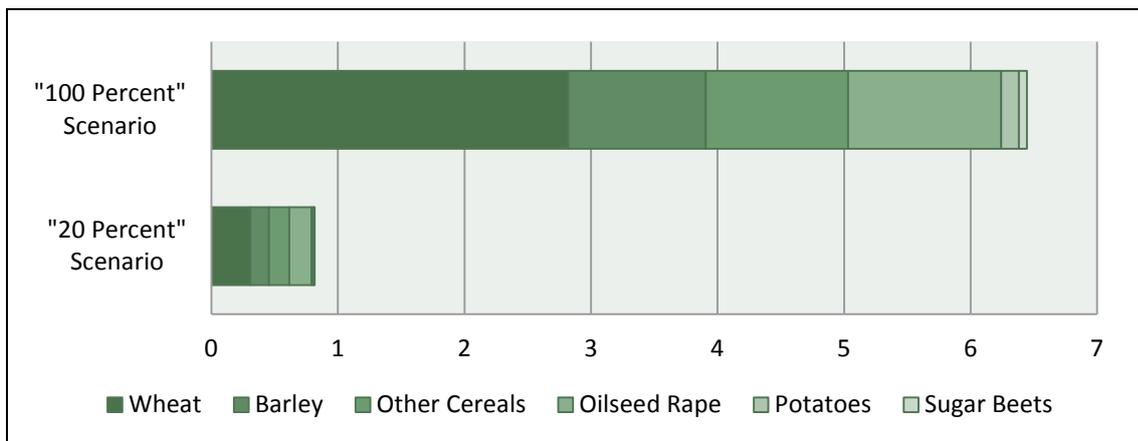
more than twice the global arable land and eight to nine times as much as the area of the Brazilian Amazon region (FAO, 2014).

- The NBI indicator even reveals 475 billion index points. This corresponds to 4.75 billion hectares of species-rich ecosystems as (theoretically) found in Indonesia and almost the total global agricultural area (FAO, 2014).

This shows: Analyzing and quantifying global biodiversity and its losses are a complex process and research in this field is still in its infancy. Nevertheless, the use of the two presented indicators grants valuable insights into potential changes of global biodiversity caused by a changing domestic supply such as due to an increase of organic farming in Germany.

Figure 4.2 illustrates in this context what share of additionally needed global area specific arable crops require if Germany partially or completely converts to organic farming. The most recently published data by Noleppa and Carlsburg (2015) on Germany's current land demand abroad serves here as a reference system.

**Figure 4.2: Additional virtual land use abroad with partial or complete conversion to organic farming in Germany (million hectares)**



Source: Own calculations and figure.

A partial (20 percent) conversion to organic farming requires about 815,000 hectares of additional global land. A complete conversion would even require 6.5 million hectares. For comparison: A partial conversion corresponds to the total arable land of Haiti or Namibia or almost the territory of Berlin. In case of a complete conversion the additionally required land is roughly as large as half the arable land of countries like Sudan or Niger (NationMaster, 2015), the 6.5 million hectares, to take another example, also almost cover the territory of Bavaria (see Statista, 2015b).

The land additionally required worldwide is thus significantly larger than the areas affected by the change in Germany, which would account – for the given arable crops – for nearly 600,000 hectares (in case of a 20 percent conversion) or more than 4.0 million hectares (in case of a 100 percent conversion). This result can be explained by the rather high yields in Germany compared to the rest of the world and once again underlines the enormous area productivity advantage of German agriculture that would consequently be given up.

The amount of this additionally needed land in the different world regions after partially or completely converting to organic farming in Germany is visualized in figure 4.3.

**Figure 4.3: Additional land use abroad with a partial or complete conversion to organic farming in Germany, by region (million hectares)**

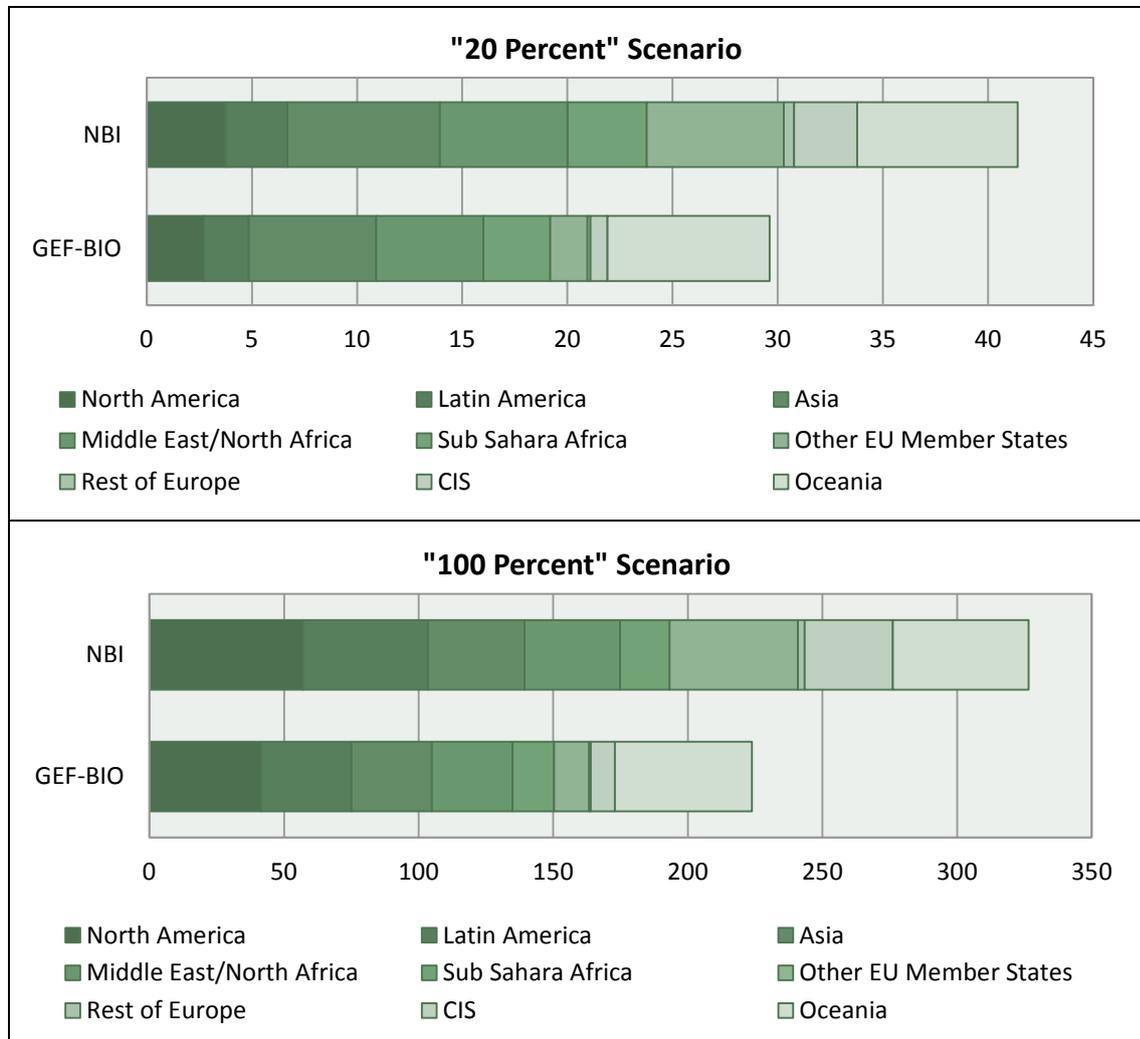
World Region	"20 Percent"-Scenario	"100 Percent"-Scenario
North America	0.075	1.114
South America	0.061	0.911
Asia	0.092	0.456
North Africa/Middle East	0.170	0.993
Sub-Saharan Africa	0.105	0.512
Other EU Member States	0.141	1.051
Rest of Europe (without CIS)	0.011	0.057
CIS	0.068	0.746
Oceania	0.092	0.605
<b>Total</b>	<b>0.815</b>	<b>6.445</b>

Source: Own calculations and figure.

All regions of the world would be affected by an additional virtual land trade of Germany and would have to till additional grassland or even cultivate natural habitats. Biodiversity and specific species richness currently still existing and living in the respective areas of these regions would surely suffer and – at least partly – get lost. The corresponding biodiversity effect can be determined in accordance with the methodological explanations made in the above excursus.

The results are presented in Figure 4.4 for the “20 percent” scenario as well as the “100 percent” scenario.

**Figure 4.4: Global biodiversity loss in case of a partial or complete conversion to organic farming in Germany (million index points)**



Source: Own calculations and figure.

A politically endorsed conversion to organic farming in Germany on “only” 20 percent of the agricultural land would have serious consequences. Based on the GEF-BIO nearly 30 million index points of biodiversity would get lost corresponding to the current richness of species of almost 300,000 hectares of Brazilian ecosystems or the biodiversity on about 5.8 million hectares of Kazakh prairie. Hence, the emanating threat potential of a partial conversion to organic farming in Germany is as large as that of about eight months of deforestation in the Amazon (see Butler, 2014) or an expansion of farmed area in Kazakhstan of about 25 percent (Nation-Master, 2015).

Applying the NBI, consequences would be similarly severe. A partial conversion would cause a loss of more than 41 million index points of biodiversity (what equals the species richness of 415,000 hectares of Indonesian rain forest or of almost 1.0 million hectares of natural land in Ukraine). With a complete conversion the NBI-based loss of biodiversity would be equivalent to nearly 3.3 million hectares of natural habitats in Indonesia or almost 8.0 million hectares in Ukraine. The following comparison is to underline the potential threat: It corresponds in case of a partial conversion with the current annual increase of land for palm oil production in Indonesia and in case of a complete conversion with about its total increase between 2005 and 2013 (FAO, 2015b); in relation to Ukraine, the associated biodiversity loss would be similar to that of newly cultivated farmland in the country in the size of about one quarter of the already existing arable land (NationMasters, 2015).

It becomes apparent: Beside the regional perspective this global perspective should strictly be kept in mind or even from the focus of the analysis because it makes a difference if human actions and decisions do cause an impact only where these people live or also elsewhere. The global perspective gets even more important in the context of biodiversity as it is not precisely Germany but large parts of South America, sub-Saharan Africa, South Asia and Southeast Asia that are considered hotspots of global species richness as biodiversity increases worldwide towards the equator. Moreover, these world regions are currently most affected by biodiversity losses due to additional agricultural land use and related land use changes (Hood, 2010).

## **5 Linking the study results with the current scientific debate**

This study uses updated statistical data, latest scientific findings and other information from public debate to elicit yield differences between organic and conventional farming in Germany and resulting effects on biodiversity or more precisely on regional and global species richness. The applied perspective is new – as it is two-dimensional – i.e. it includes societally equally accepted environmental as well as production goals, and the knowledge gained from this perspective is surprising in the sense that on the basis of science-based indicators the loss of biodiversity in Germany (and globally) per unit of yield (i.e. per unit of agricultural produce) is bigger in organic farming with its specific phytosanitary measures than in conventional farming with adequate plant protection management strategies.

This key finding can be positioned and backed up in the current scientific discussion. Researchers and practitioners frequently and comprehensively discuss which

land management and land use options contribute most to environmental objectives in general and biodiversity considerations in particular. The discussion is known as the “land sharing” vs. “land sparing” debate. It mainly focuses the following question: How can the dual challenge of supply (or food) security for a globally growing population on the one hand and the protection of local and global biodiversity on the other hand be best addressed?

Proponents of the “land sharing” approach foremost argue that a more extensive land use increases biodiversity on the cultivated area without immediately decreasing yields or deteriorating the supply situation (see, e.g., Chapell and LaValle, 2009; Fischer et al., 2011; Geiger et al., 2010). Apart from the fact that this argument needs to be re-discussed and reconsidered given the results of this study – at least with regard to Germany and the organic and conventional farming practiced there – proponents of the “land sharing” reiterate that either means to secure a more effective resource protection (e.g. renaturation of land) are not available or that many soils are not suitable for intensive farming (Fischer et al., 2011). In addition, they argue that the “land sharing” approach could be used to change other external factors such as disease dynamics (Mendenhall et al., 2013) and socio-political conditions (Perfecto and Vandermeer, 2010; Phelps et al., 2013).

Looking into the details of such arguments, it becomes obvious that this discussion usually takes up issues of particular relevance in the context of developing countries or respectively emphasizes aspects like unsuitable soils or the lack of financial incentives that are not at all or less relevant for a relatively prosperous country with a highly productive agricultural sector such as Germany.

In fact, the results obtained in this analysis rather support the “land sparing” idea, which argues that especially intensive farming systems allow to increase the yield per area unit and thus protect uncultivated area elsewhere containing more biodiversity than comparably extensively managed farmland. In line with this study, advocates of this approach explicitly agree that the necessarily increased input of yield-enhancing and yield-ensuring resources in the farming sector may cause a reduction of biodiversity on the cultivated land; however, the net effect on biodiversity is positive because of the more or less complete protection of other areas from agricultural (and other anthropogenic) use (see, e.g., Egan and Mortensen, 2012; Matson and Vitousek, 2006; Phalan et al., 2011).

These assumptions especially apply from an international perspective and in light of the latest forecasts published by Newbold et al. (2015). According to the authors, global species richness or biodiversity will particularly decrease in the future, if reducing the expansion of agricultural land fails where global biodiversity hotspots are located, e.g. in regions located on the territory of many German agricultural

trading partners. The authors see options for compensation in (a) further expanding agricultural land in areas where natural biodiversity per se is relatively low and (b) where from a historical point of view the conversion of land towards agricultural use has already taken place. In this context it is especially Europe including Germany that is addressed by Newbold et al. (2015).

In line with that and against the background of the results obtained in this analysis a “green paradox” is proven (for definition of the term “green paradox”, see Sinn, 2012). This is expressed by the fact that an extremely strong focus on organic farming (here in Germany) might bring about some positive impacts on local biodiversity on these less-intensively cultivated areas but would have to be paid for with significantly more negative biodiversity effects on land elsewhere consequently leading to a negative net effect.

It is precisely this increasingly discussed (see, e.g., Grau et al., 2013; Meyfroidt et al., 2013; Weinzettel et al., 2013) and just analyzed shifting effect that indicates the highly complex analysis of trade-offs between the various objectives in the context of biodiversity and land management and an adequate decision-making. This complexity is insufficiently recognized and strongly requires more research (Blackmore, 2015; Fischer et al., 2014).

This study has contributed special knowledge to reduce this complexity by arguing on the basis of reliable data and sound scientific methods and by questioning too quickly raised beliefs on apparent biodiversity effects of farming systems of different intensity levels in a country like Germany. By incorporating new expertise in the societal debate, by bringing together allegedly diametrically opposed goals in a methodically reasonable way, and by expanding the horizon for future policy decisions, the study in particular provides a consensus-orientated contribution to demystify the debate on dissolving trade-offs in the context of nature and environmental protection as recently demanded by Küster (2015).

In fact, over the past years and decades an increasing politicization of environmental and nature protection has been observed what consequently leads to a polarization of economy and ecology and thus hampers consensus-based policy decisions. Against this background and also in the light of this study it is a future responsibility of society to renegotiate and balance the different interests (environmental, economic, and certainly social ones) (Reichholf, 2015). A real cost-benefit analysis is needed to finally create “win-win”-situations (see Smith, 2014).

The study has shown that such science-based cost-benefit analyses are possible and multi-dimensional solutions can be identified as discussed in the context of highly productive agricultural systems. In fact, conventional, i.e. intensive land management based on a reasonable and efficient use of resources, at least in Germany but

probably also elsewhere, can play an important part in order to significantly contribute to simultaneously meet different global sustainability goals, such as food and energy production on the one hand and biodiversity conservation on the other hand.

The described outcome interestingly does not change when the discussion of further aspects is considered by private, public and/or political decision-makers. Resources – financial or natural ones – should always be used in an efficient way, even if less discarded food, an overall healthier dietary habit, decreasing land sealing for urban and infrastructural measures, etc. reduced the pressure on agricultural land in Germany, the EU and the world and thus, on associated biodiversity.

Next steps of the scientific debate could be disclosing these relationships and thereby not only investigating how much biodiversity is affected by different land use systems and trade-offs, but also exploring what quality and composition of species are affected. This study can only be a first step towards a better understanding of regional and global biodiversity effects of modern and productivity-oriented, i.e. economically efficient as well as resource-saving land management practices including appropriate pest management strategies.

## 6 Conclusions and recommendation

The aim of this study was to quantify current yield differences in Germany between organic farming on the one hand and conventional farming on the other hand and derive the impact of these farming systems (always based on certain plant protection strategies) on biodiversity in Germany as well as at a global scale. The findings gained in the study can be summarized in the following twelve theses and recommendations for action:

1. On a weighted average across all major arable crops organic farming in Germany achieves 51 percent lower yields than conventional farming. In opposite to contrary public debates and political opinions the difference has even grown over time and is particularly high in specialized cash crop farms.
2. These results on yields in conventional vs. organic farms in Germany are confirmed by other scientific analyses and backed up by numerous researchers in terms of trends as well as the specific level of yield differences.
3. Measuring the impact of these two different farming methods and their differences in yield on species richness forms a particular challenge as there is still no scientific standard of quantifying complex biodiversity. The current

- state of knowledge rather allows stressing particular characteristics of biodiversity: For measuring species richness a number of indicators are available.
4. Eight such indicators allowing for a comparison of organic vs. conventional farming in Germany could be identified and applied. The results show that all indicators confirm advantages of organic farming with respect to the remaining biodiversity on managed arable land.
  5. However, the indicators also show that already organic farming has to be considered a serious human intervention in natural ecosystems leading to a significant loss of biodiversity. Conventional farming only adds very little additional losses. In fact, the average decline of biodiversity on arable land in Germany can be estimated 67 percent for organic farming and 86 percent for conventional farming.
  6. Against this background it can be concluded that organic farming often puts less pressure on biodiversity of an already cultivated piece of arable land than conventional farming as not each and every weed and pest can be controlled by appropriate means. However, this perspective changes when the sole objective of species protection is extended by a second equally societally relevant objective, namely ensuring the sufficient supply of primary agricultural products.
  7. The significant yield advantage of conventional farming in Germany means that notably less biodiversity is lost per unit of yield and thus per unit of primary agricultural produce if conventional rather than organic management is applied. On average of all major arable crops and scientific indicators used in the analysis, the corresponding biodiversity loss per unit of yield in organic farming is about 55 percent higher than with the use of advanced, productivity-enhancing technologies in agriculture. This also applies to 90 percent of all individual arable crops and indicators.
  8. These results confirm what has already been stated on a number of other environmental and sustainability indicators in the scientific debate: Any existing benefits of organic farming on the cultivated area are no longer evident when conducting an efficiency analysis, i.e. if related to a unit of produce or yield. Such area-based benefits might disappear completely or even turn into disadvantages, especially in highly productive countries such as Germany.
  9. This research finding also holds true when the analysis is extended from a national perspective to a global perspective. In case of a loss of domestic production, e.g. due to an increased conversion from conventional farming to organic farming in Germany, shifting effects on international agricultural markets result in an expansion of production in other countries and world regions. International agricultural trade activities compensate production losses in Germany leading to an increase of arable land use of trading partners. However, most of these countries are located in world regions that do have a

higher biodiversity level than Germany. That means small potential gains of biodiversity from a conversion to organic farming in Germany are surely paid for by substantially higher losses of biodiversity through cultivating new agricultural land elsewhere.

10. Such shifting effects can be quantified. About 815,000 hectares or 6.5 million hectares of yet unexploited area still being a treasure of biodiversity or species richness would be globally required to compensate production losses in Germany due to a partial (20 percent) or complete (100 percent) conversion from conventional farming to organic farming. Consequently, it is important to be aware of this global perspective whenever decisions for preserving and enhancing species richness and biodiversity in a national, for example German, context have to be taken.
11. The results of the analysis are in line with the current state of scientific knowledge and emphasize the particular importance of a “land sparing” approach in a highly productive agricultural region like Germany for minimizing the trade-off between agricultural supply or food security and biodiversity protection. The actual state of knowledge does not justify an ideology-based overvaluation of particular land management options. Instead, target contributions of the various land use management options have to be negotiated and win-win situations have to be generated that adequately consider both objectives, namely global biodiversity protection on the one hand and worldwide sufficient production of primary agricultural products on the other hand. In this regard a relatively intensive and resource-efficient arable farming in Germany can make a substantial contribution, both regionally and globally. This statement does not change when additional aspects targeting the reduction of pressure on agricultural land such as a healthier diet or reducing food waste enter the decision-making process.
12. All this results in recommendations for economic, public and policy decision-makers. Polarizing the debate into “ecology” vs. “economy” is not target-oriented. Ideologically hardened fronts must be broken up and converted into consensus-based discussions. Existing scientific expertise should be fully incorporated into the debate. Science faces particular challenges and must mainly elucidate the complexity of change processes and quantify direct as well as indirect effects resulting from changes. Decision-makers need to understand this complexity and should be aware that their decisions not only directly affect a specific target, but also other multi-dimensional variables within the complex system of biodiversity and (agricultural or other anthropogenic) land use. Both systems – biodiversity and land use – are highly globalized. A sole focus on the national perspective seems to be inappropriate in this context and further research is needed.

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## **Imprint**

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