Sustainably securing the future of agriculture

Impulses and scenarios for ecological, economic and social sustainability – using agriculture in Germany as an example

Sustainably securing the future of agriculture

Impulses and scenarios for ecological, economic and social sustainability – using agriculture in Germany as an example

DR. TORSTEN KURTH

DR. HOLGER RUBEL

ALEXANDER MEYER ZUM FELDE

JÖRG-ANDREAS KRÜGER

SOPHIE ZIELCKE

DR. MICHAEL GÜNTHER

PROF. DR. BIRTE KEMMERLING

NOVEMBER 2019 | BOSTON CONSULTING GROUP

NOTE FOREWORD

This study was prepared by Boston Consulting Group (BCG).
Our special thanks goes to the members of the WWF Germany team for their constructive input and evaluation of analyses.

CONTENTS

For the sake of readability, the generic masculine will be used. However, all sexes are always addressed in the interests of equality. The abbreviated form of language is used for editorial reasons only and does not imply any value judgment.

ABSTRACT

ACROSS THE WORLD, AGRICULTURE plays a crucial role not only in supplying food, but in shaping rural areas, preserving landscapes and cultural practices and heritage. In the EU, agriculture plays a central role for the European economy and provides the key source of food, income and employment to their rural populations. Farmers deserve our appreciation and recognition for this.

But the industry is facing enormous pressure: Society has grown accustomed to low food prices. At the same time, it expects the agriculture's environmental footprint to be as small as possible – with reduced greenhouse gas emissions and protection of biodiversity.

This study is intended to contribute to the current debate on sustainable agriculture. We aim to provide new impetus without casting the blame. And we want to raise the question of what kind of agriculture we want to achieve – and can achieve in the EU and especially in Germany.

The EU's agricultural sector contributes around 1.2 percent to the EU's GDP [107] and employs around 10 million people. However, by contrast, EU's agricultural sector accounts for around 10% of the EU's total greenhouse gas emissions [109]. Additional negative externalities, for example from air pollutant emissions as well as pollutant emissions from water and soil, cause external costs. These external costs are costs caused by agriculture that are not included in farmers' economic decisions, but are borne by society. External costs are often difficult to measure and quantify. Looking at Germany as the second largest agricultural producer in Europe, this study creates holistic transparency on external costs for the first time using methodologies that can easily be replicated in other countries. Using Germany as a specific country example with a large, representative agricultural sector within Europe, we also showcase the types of impact agricultural production has, as well as the potential of sustainable agricultural practices within a European agricultural context. The potential societal and political instruments and paths to strengthen agricultural practices and reduce external costs are equally relevant for discussion in other European countries and beyond. We therefore hope to provide impulses that are relevant beyond just our focus country Germany.

EXTERNAL COSTS

External impacts in the form of external costs (or negative externalities) of agriculture are negative impacts of agriculture that are not reflected in food prices and are therefore not included in the economic decisions of the polluters, i.e. farmers. They are therefore not borne by consumers or farmers, but by society instead. These external costs do not necessarily incur at the time of production. They may also incur at a later stage as a consequence of the use of certain agricultural practices or the intensive use of ecosystem services. The external costs of agriculture are borne by society either implicitly (e.g. through loss of biodiversity in local recreation areas) or explicitly (e.g. through increased tax revenue expenditure for water treatment).

This study shows that negative externalities from agriculture, for example from greenhouse gas emissions, are very high - in Germany these external costs come to at least 40 billon euros per year. Taking into account the loss of biodiversity as well, in particular the diversity of species, genes and habitats and the associated loss of ecosystem services, the external costs of agriculture increase by a further 50 billion euros according to conservative estimates. Furthermore, the government spends roughly an additional 10 billion euros each year to support the agricultural sector, e.g. administrative support for farmers. Whilst assessing the external costs remains complex, particularly regarding biodiversity, there is no doubt that we need to find solutions in reducing external effects of agricultural practices today. The exact impacts might vary around the world, but external effects occur everywhere and better ways to reduce those are required globally. In the case of Germany, these costs face a gross value added of the German agriculture of around 21 billion euros.

If these external costs including the government's expenditure were allocated to various food products to determine an approximation to the true cost of food, animal food products in particular would in some cases have to become significantly more expensive given their comparatively high external costs. For example, the producer price at farm gate for one kilogram of beef would have to increase by a factor of five to six.

The external costs were calculated based on the best available findings from other studies. They do not claim to be exhaustive, but they do form a solid, conservative basis for the necessary discussion about the actual costs of agriculture and the potential of sustainable agriculture.

The debate surrounding the negative external effects of agriculture is an emotionally charged one, with farmers in particular often being blamed. The use of pesticides and intensive animal husbandry, for example, are strongly criticized. But farmers do not bear sole responsibility for this. The agricultural system in the EU is also significantly impacted by society, politics, food trade and industry, consumer decisions, legislation, pricing policies and lobbying. These actors also bear some pivotal responsibility for the negative external effects of agriculture.

In light of this, they must also be involved in finding solutions to reduce the external costs of agriculture, above all in further developing the current agricultural system toward greater sustainability. A clear and shared understanding of sustainable agriculture by all actors involved is required in order to be able to conduct a factual and target-oriented debate. For us and for many farmers as well, sustainable agriculture means environmentally friendly, economical and social management with future generations in mind.

Our analyses show that the external costs from German agriculture can be reduced by one third through selected, and in some cases relatively low-threshold measures and methods. A reduction in agricultural intensity in this way in favor of greater environmental protection would entail a loss of agricultural yields estimated at around 18 percent for plant products and seven percent for animal products.

To further reduce external costs in Germany, it would be necessary for society as a whole to change its consumption behavior in line with natural conditions and limits. It is against this backdrop that we have modelled four different scenarios as thought experiments, which are equally applicable to other European countries:

- Assuming that meat consumption in Germany would be based on the EAT-Lancet recommendations, i.e. 45 grams per person per day, and production is adjusted accordingly, external costs would be reduced by around 25 percent.

- If we managed to reduce waste from food consumed in Germany from around 30 percent at present to zero, there would be a potential reduction in external costs of around 15 percent.

- If, purely hypothetically, German agriculture were to no longer produce for export purposes but only for domestic consumption instead, the external costs incurred in Germany could be reduced by up to 40 percent.

- If we were to combine all three of the above scenarios, i.e. if sustainable methods and measures were used, food was produced only for domestic consumption, no more food was wasted in Germany and domestic meat consumption was based on EAT-Lancet, the external costs would be reduced by up to 75 percent. Conversely, this also means that agriculture will not be possible without external costs in the near future.

The results of our analyses are in line with the latest IPCC Climate and Land Report and the EAT-Lancet study, specifically that agriculture with reduced greenhouse gas emissions can only succeed if we challenge and change our current food system.

This study is intended to encourage discussion between stakeholders from agriculture, politics, science, society and nature conservation. We want to foster a broader societal discussion on how we can secure affordable, healthy and safe food in the future – yet creating awareness of the actual costs of production. As the common agricultural policy (CAP) will be decided again in 2020, it is more important than ever to foster a constructive discussion.

Section 1 addresses the current role of agriculture in the EU and in Germany and its continuous change, as well as the increased demands on agriculture. Section 2 looks at the current challenges facing agriculture and Section 3 identifies the associated external costs. In this context, we will also analyze how an allocation of external costs would affect the prices of selected food products. Sections 4 and 5 focus on sustainable agriculture. To this end, we will provide a definition of sustainable agriculture on the one hand and analyze the potential of sustainable methods to reduce external costs on the other. Section 6 identifies instruments that can be used by the actors involved in the agricultural system to promote sustainable agriculture. Further, Section 7 presents possible future scenarios in the form of thought experiments to make an important contribution to further discussion. Even though we use the German agriculture as an example for this study, the approach of calculating external costs and reduction potential as well as of identifying instruments to promote sustainable agriculture can be transferred to any other country in the world.

1. GERMANY NEEDS ITS AGRICULTURE

1.1 Agriculture's Social Responsibility

The EU's agricultural sector contributes around 1.2 percent to the EU's GDP [107] and employs around 10 million people[108]. It supplies us with food on a daily basis, shapes and cultivates rural areas and is increasingly contributing to the local supply of energy and raw materials.[1]

Nearly half of the surface area of the Federal Republic of Germany – some 16.7 million hectares – is used for agriculture. The majority of this area – around 14 million hectares – is used for the production of food products, with around two million hectares used for energy crops.[2] Around one million people work in agriculture today, 617,000 of them full-time. In 2017, 275,000 farms generated gross value added[3] of 21 billion euros, corresponding to approximately 0.7 percent of Germany's total gross value added (see Figure 1).

1 Our focus here is only on the supply of raw materials and the agricultural land used for that purpose. Contributions to the energy supply (for example via wind energy or photovoltaic systems installed on agricultural land) are not taken into account.

2 The remaining area is currently set aside and plants for industrial use (e.g. Christmas tree farms, medicinal plants and the like).

3 Agriculture's gross value added can fluctuate widely. The estimate for 2018 (second estimate, last updated in January 2019) is around 17 billion euros.

FIGURE 1 | Key economic data for German agriculture

Current status	Historical development
940,000 workers, of which around 50% are family workers, around 30% seasonal workers and around 20% salaried employees (as of 2016)	~2% decrease in employment per year over the last 20 years
~€21 billion gross value added, or ~0.7% of total German value added in 2017	Strong fluctuations in recent years, 2013: ~€21 billion, 2015: ~€15 billion
~50% (16.7 million ha) of the area of Germany is farmed, the majority as arable land (11.8 million ha) (as of 2018)	Agricultural land in Germany has remained more or less constant since 1991
The average price for one hectare of land in Germany is 25,485 € (as of 2016)	More than 170% price increase for agricultural areas in Germany between 2005 and 2018
In 2018, ~37.9 million metric tons of cereals, ~4.9 million metric tons of pork, ~1 .8 million metric tons of poultry, ~33 million metric tons of milk, 13.6 million eggs, ~8.9 million metric tons of potatoes and ~4.8 million metric tons of fruits/vegetables were produced	Meat production has increased by ~12% in the last ten years - Harvest quantities of fruits/vegetables fluctuate due to weather conditions, etc.
Germany is a net importer of agricultural products: foreign trade deficit in 2018 around ~€14 billion	Exports of agricultural products have increased 2.5-fold since 2000
31,700 farms (~12% of all farms) engaged in organic farming spread over 9.1% of the surface area (as of 2019)	Since 2009, around a 60% increase in the number of organic farms and organically farmed land

Note: The figures given represent the data most recently published by the respective institutions at the time of the study
Source: [1]; [2]; [3]; [4]; [5]; [6]; [7]; [9]; BCG

These farms include enterprises of very different sizes, different degrees of specialization and diversification, and different regional structures. Germany is one of the largest agricultural producers in the European Union after France, Spain and Italy [8]. *(The numbers in the squared brackets refer to the sources as listed in the bibliography at the end of this document)*.

Continuous Change

German agriculture is undergoing continuous changes toward larger, more specialized farms – the same trend is also happening in other industrial nations. These changes are rooted in increasing administrative demands on farmers, higher investment pressure, low producer prices, increasing requirements and volatile globalized markets, not to mention a growing risk of loss of earnings due to climate change. This structural change in agriculture has been ongoing for decades and we believe it will continue to have an impact in future. At the same time, however, societal views of agriculture have also changed. Some developments in agricultural practices are controversial, particularly with regard to growing farm and herd sizes, the increasing specialization and intensification of farms, as well as increasing geographical concentration, particularly in livestock farming. Society is increasingly demanding higher standards and blaming farmers for species loss, greenhouse gas emissions, water pollution and soil degradation. Overall, agriculture – and farmers in particular – are under increasing pressure.

Farmers under Pressure

Farmers often feel that they are getting all the blame and held solely responsible for the problems wrought by the system as a whole. It is true that farmers are crucial actors; what ultimately happens on their land lies within their control. However, their scope for action is constrained by the underlying conditions set in place by all actors in the system – policymaking, associations, trade, the food industry and society.

> "People always think they can't do anything about the situation anyway. But every single one of us shapes policy every day with our shopping carts."
>
> Organic farmer, ~200 ha arable farming and grassland

The public discourse is crying out for sustainable agriculture, but generally with a lack of any overall consideration of all the essential elements of the environmental, economic and social aspects involved. The debate usually focuses on either the environment or economy, with the social aspect and other aspects almost always neglected. Yet farmers in particular often face major economic and social challenges. For example, low producer prices and high rental costs are forcing more and more farmers to give up their farms. At the same time, farms are finding it increasingly difficult to find successors to take over running the business.

Focus on Sustainability

Politicians and society, farmers, scientists and industrial actors all have different ideas about what sustainable agriculture should look like in practice. And in the face of structural change, too, there is broad and controversial discussion about what sizes of farm and what forms of agriculture and food production can be considered sustainable. The debate often tends toward a simplistic comparison of small-structured, organic, rural agriculture on the one hand and industrially organized, conventional agriculture with large farms on the other. However, this simple polarization does not reflect the actual diversity of the different regional and farm conditions and challenges facing agriculture in Germany. In many respects, every farm in this country is unique, for example in terms of its soil, expertise or social and natural environment. There is therefore no standard solution for all farms to deal with the many different requirements and conflicting goals. This means that existing conflicts surrounding goals and solutions must always be considered on a farm-by-farm basis.

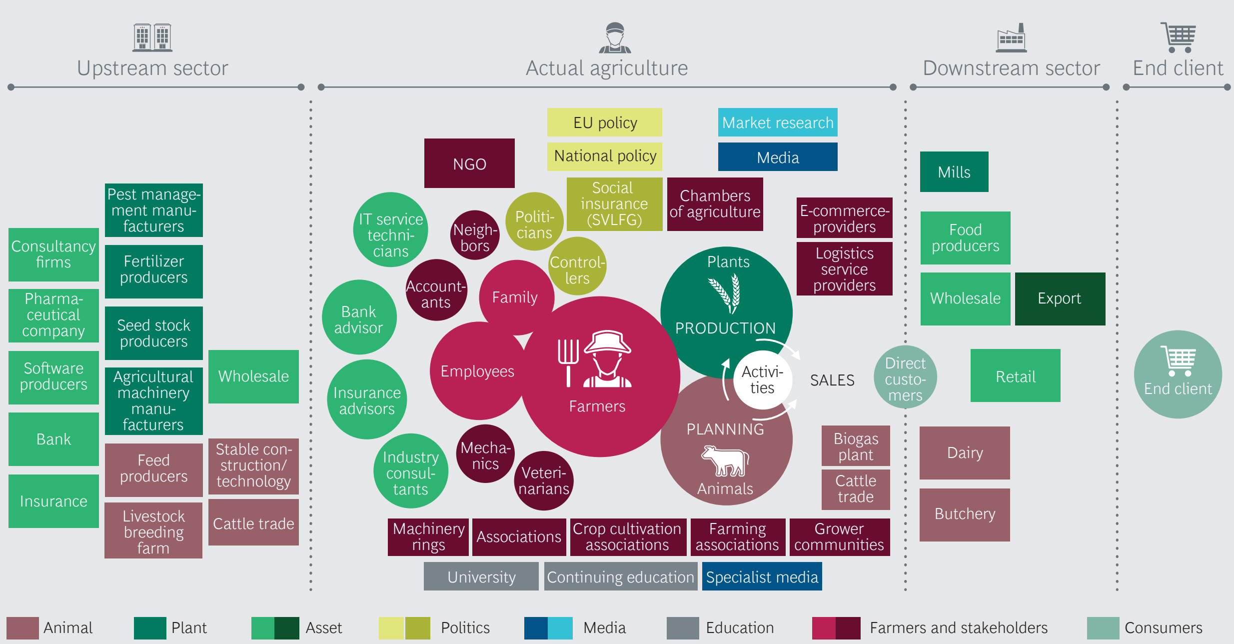
Basis for Holistic Debate

Our study aims to provide new insights beyond those arguments that are generally known and practiced. In doing so, we aim to contribute to defining and further developing the topic of sustainability in agriculture in Germany, in Europe and beyond. Our analytical findings are intended to serve as a neutral basis of data to launch a valued, qualified dialog in which the various stakeholders in politics and society, agriculture and industry are equally involved. In addition, we hope to do away with prejudices and provide facts to accompany frequently used buzzwords in the debate.

We will analyze the current challenges in agriculture and the associated external costs (Sections 2 and 3), provide a definition of sustainable agriculture (Section 4) and consider the potential of sustainable methods (Section 5). We are aware that there will be no agriculture without negative externalities. Sustainable agriculture would also generate costs for the environment and society. However, it is important to clarify how these factors can initially be minimized and how remaining external costs in the system can be distributed in such a way that, unlike today, they can also be borne in the long term. We have shown the effects of internalization via producer prices for selected foodstuffs in Section 3.

Section 6 identifies instruments that can be used by the actors involved in the agricultural system to promote sustainable agriculture. Section 7 then presents possible future scenarios in the form of thought experiments to make an important contribution to further discussion. Because farmers are at the heart of the agricultural system, they are also at the heart of our analysis (see Figure 2).

FIGURE 2 | Farmers at the heart of the agricultural system



Source: BCG

As part of our study, we have therefore conducted a series of interviews with both conventional and organic farmers (details in "Farmers' Perspectives"). It became clear that farmers have a major self-interest in sustainable agriculture. For them, too, it is important not to engage in the debate on sustainability in a one-sided manner, focusing solely on nature conservation, but to keep an eye on economic and social aspects in equal measure. In addition to interviews with farmers, we also held a series of talks with representatives from agricultural research institutes, agricultural associations and agricultural policymaking to include perspectives from the other relevant stakeholders.

FARMERS' PERSPECTIVES

Farmers are at the heart of our analysis. In light of this, we conducted 11 interviews for this study: eight with conventional farmers and three with organic farmers. Their farms range in size between 100 and 4,000 hectares, keeping between 200 and 2,000 pigs, 200 and 1,000 cattle and a total of 350 chickens and 400 goats. Eight farms are mixed farms. It was clear in the interviews that the farmers' statements – whether conventional or organic farmers – largely coincided.

Farmers think about sustainable agriculture across four aspects

Sustainable agriculture...

	...means managing farming with future generations in mind	...requires more conscientious consumption	...requires long-term policy measures	...requires a collective understanding
Challenges	Maintaining profitability Sustainable operational management Enhanced understanding of roles as an ecosystem service provider	Immoral food prices Food in bulk "Stingy is sexy" society	Inconsistent policy measures Lack of political special interest groups Lack of political action to raise prices	Failure to take nature/ agriculture into account Negative public image of farmers Low consumer awareness

Farmers are aware of their role in implementing sustainable agriculture. From their point of view, the other success factors primarily include:

- Changes in consumer behavior toward conscientious consumption and a willingness to pay more for sustainable food.
- Long-term political measures that enable farmers, as ecosystem service providers, to earn money with nature conservation measures – i.e. an incentive model instead of the usual compensation for disadvantages in nature conservation.
- A genuine appreciation of farmers' performance in food production and nature conservation by society.

Farmers consider professional exchange among one other, for example by sharing best practices in working groups, revising teaching materials and curricula for agricultural professions, qualified agricultural payments and subsidies as well as bolstering consumer awareness through active cooperation with societal actors and stakeholders, to be effective tools for promoting sustainable methods and measures.

Source: Interviews with farmers, BCG

1.2 The Role of Agriculture

This study is based on an integrated view of agriculture and nature conservation, i.e. that nature conservation[4] also takes place in the fields and is not a contradiction to agriculture. This contrasts with a segregated approach, in which nature conservation is carried out in separate areas and the focus of agricultural land is primarily on short-term yields – not on environmental aspects.

One of the primary objectives of local agriculture should be to meet the demand for food in Germany as much as possible. We are therefore of the opinion that agriculture must be maintained as a production sector in Germany, including in the long term. We consider largely or exclusively relying on food imports and shifting the environmental, economic and social challenges of agricultural production abroad neither realistic nor desirable.

Furthermore, agriculture must be economically viable for farmers in the long term. German agriculture is part of the European internal market, which is also largely shaped by global markets. Solutions for greater sustainability must therefore work within this global system, and the framework it provides cannot be discounted.

Agriculture fulfills an important task for society as a whole in Germany – and not merely for food production. In many places, agricultural structures stabilize and maintain rural areas. Farmers and their employees deserve the appreciation, recognition and adequate remuneration of society as a whole for carrying out this important task.

4 According to the Federal Nature Conservation Act (BNatSchG) of 2009 nature conservation includes the protection of species, habitats and ecosystem services.

2. MULTIFACETED CHALLENGES FOR AGRICULTURE

THIS SECTION WILL OUTLINE selected core environmental, social and economic challenges the agricultural sector in Germany faces today. Since the connections and interactions involved in agriculture are extremely complex, we can only present a small part of the problem here – but that alone demonstrates the sheer scope of the challenges being faced. Many of the following aspects are relevant not only in Germany, but also in other regions, depending on geography and the production system.

2.1 The Environment: Pressure from All Sides

There are a multitude of environmental challenges in agriculture. Primary issues at present include biodiversity, soil, water, climate and air as well as the effects of livestock farming.

Decreasing Biodiversity

With regard to species diversity, the effects of different forms of agriculture on the agroecosystem and its environment are clearly visible. Fewer cultivars and a decline in the diversity of flora and fauna in fields result not only in a reduction in species, but also in insect biomass, which in turn reduces the food supply for many bird species. The decline in flora and fauna along the food chain is reflected in the "Biodiversity and landscape quality of agricultural land" indicator used by the German Federal Agency for Nature Conservation. The index value has been stagnating at a very low level for years. At present it stands at 59 points, with the target value for 2030 set at 100 points; historical comparative values from the 1970s are around 120 points [10].

Reduced soil fertility

Intensive agricultural use also negatively impacts the soil. The primary challenges include soil erosion, loss or reduction of the humus layer, soil compaction, silting and the reduction of soil functions and soil organisms. Soil erosion has increased significantly over the past 50 years. Reasons for this include narrowing crop rotations, drops in manure yield and intensified soil cultivation. On average, 10 metric tons of fertile soil per hectare per year are lost to erosion and humus degradation on arable land in Germany [11].

Water pollution

The high nitrate load in groundwater and the eutrophication[5] of surface waters, the leackage of pesticides, antimicrobial substances and hormones into surface and groundwater represent particularly relevant challenges in terms of water. The excessive use of nitrogen leads to the pollution of aquatic ecosystems, with inputs from agriculture comprising a significant source. At present, approximately 190 kilograms of nitrogen per hectare are added annually to agricultural land. The nitrogen surplus in Germany is therefore around 95 kg per hectare per year [12].

---

5 Eutrophication generally refers to the natural or artificial process of nutrient enrichment in a body of water. Eutrophication has numerous environmental and economic impacts, including large-scale algal blooms, loss of biodiversity and fundamental deterioration of water quality [48].

Nitrogen inputs have been an environmental problem for decades. Measurements from 2012 to 2014 document that 22.7 percent of the aquifers below agricultural land are significantly to heavily contaminated with nitrate [13]. 28 percent of measuring points exceeded the maximum permissible value of 50 milligrams of nitrogen per liter [14].

Climate-damaging Greenhouse Gases and Air Pollution

With emissions of around 66 million tonnes of CO_2 equivalents[6] (CO_2e), agriculture is responsible for seven percent of total greenhouse gas (GHG) emissions in Germany. If GHG emissions from land use changes are also taken into account, agriculture emits a total of around 104 million tonnes of CO_2e per year [15]. This total amount is accounted for in roughly equal measure by emissions from agricultural soils, for example from soil cultivation and nitrogen fertilization, from livestock farming, where methane and nitrous oxide emissions are the main sources, and from land use changes (see Figure 3).

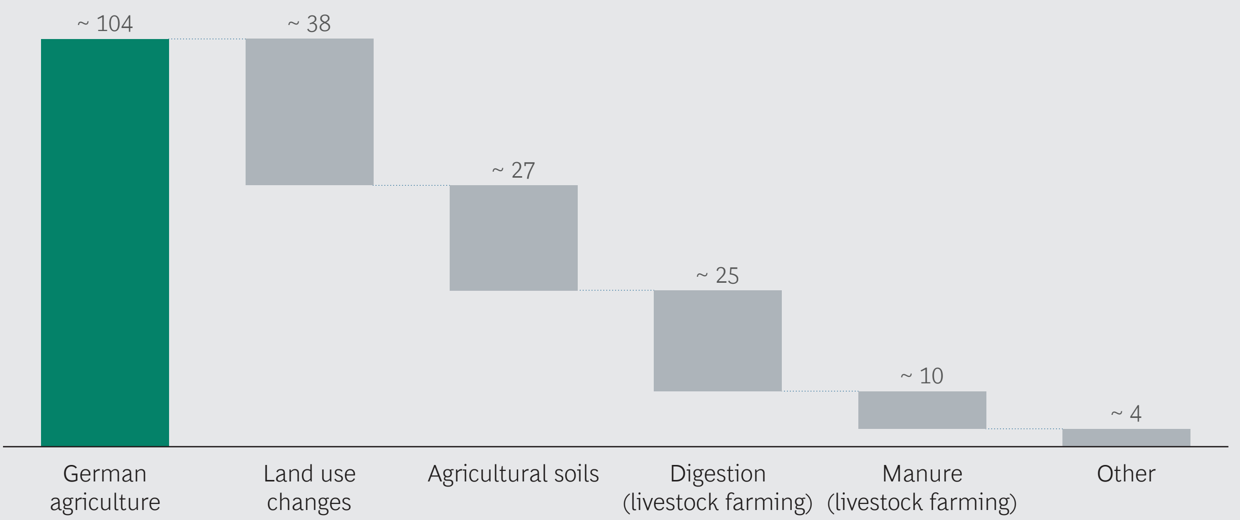
In return, the current climate changes are already posing problems for German agriculture. As a result, strategies for climate resilience in agriculture are gaining traction; among other things, biodiversity and synergistic approaches are the focus here [16].

Additional pollution comes from air pollution. This includes both primary fine dust emissions (PM10 and PM2.5), for example from soil cultivation, and what are known as aerosol precursors, which, in agriculture, include ammonia in particular. For example, ammonia is released when liquid manure is used and significantly contributes to the formation of fine dust through chemical reactions. This affects both human health and biodiversity.

6 CO_2e, or CO_2 equivalent, is a measure of the comparability of contributions to the greenhouse effect of different greenhouse gas emissions. For example, the effect of one kg of methane (CH_4) emissions corresponds to the impact of 25 kg CO_2 equivalents (over a period of 100 years) [49].

Figure 3 | German agriculture responsible for ~104 Mt CO_2e GHG emissions — of which ~1/3 each from land use changes, soils and livestock farming

Greenhouse gases in millions of metric tons of CO_2 equivalent (Mt CO_2e), values for 2017



Source: [15]; BCG

Problems Involved in Livestock Farming

Sick animals, epidemics and animal suffering as well as the heavy use of antibiotics are major farming issues with a high public impact. The discussion surrounding increased animal welfare in agriculture is in full swing. In response, the German federal government launched its Animal Welfare Label (Tierwohllabel) in early 2019, with private animal welfare labels having been in place for some time. Although the use of antibiotics in agricultural livestock farming is declining, a total of 733 metric tons were still used in 2016 [17]. By using manure[7] of animal origin, some of the antibiotics get into the soil and the active substances are already being detected in the groundwater.

2.2 Economy: Major Economic Pressure

Recent decades have seen rapid mechanical and technological progress in agriculture, leading to the development of newer, larger machines and equipment and, as a result, to significantly higher work and area productivity. However, increased production combined with low population growth and more or less saturated food markets have ensured that real agricultural prices declined in long-term trends. To maintain their farming income, farms have been and continue to be forced to further specialize their farms or increase production by increasing the size of their farms or livestock numbers.

In addition, German consumers do not spend much on food. For example, the Federal Republic of Germany, where food expenditure per capita as a share of gross domestic product (GDP) is equivalent to ten percent, ranks at the bottom of the European rankings. By comparison, in France this figure is 13 percent [18]. In particular, the willingness to pay for sustainably produced agricultural products is comparatively low in Germany.

The high degree of concentration in food retail places additional strain on farmers' incomes. It promotes intensive competition at the upstream stages of the value chain and builds up strong pressure on prices and margins in agriculture.

> "The discounters are constantly undercutting each other with their cheap food prices and that's then passed on to the producers."
>
> Conventional farmer, ~120 ha and ~1000 pigs

On the cost side, the strong increase in prices of farmland through the activities of supra-regional investors and thus the continued rise in rental prices is having an increasingly negative impact on agricultural farms, especially given that 60 percent of German agricultural land is leased. In 2016, the annual rent per hectare of agricultural land averaged 288 euros, almost 20 percent above the 2013 level [1].

7 Farm fertilizer, or fertilizer produced by the farm itself, refers to organic substances that are produced in agriculture as animal excrement or plant substances and are used for fertilization. Animal excretions may come in the form of solid manure, semiliquid manure and liquid manure, and plant substances also include fermentation residues from biogas plants (Section 2 Number 2 of the German Fertilizer Act and [50]).

A further factor in the increasing competitive pressure on German farmers in the European and global context is poor network availability in rural areas. In times of increasing digitalization, all farmers are suffering as a result; cost savings and increases in efficiency that could be achieved using digital methods are not feasible for German farmers everywhere.

2.3 Social: The Problem of Succession

It used to be that taking over the farm was a special social feature of peasant families. Today there is a clear decrease in willingness to take over the parental business. Long working hours and high levels of physical strain, very low wages and little leisure time reduce farming's attractiveness as a profession. This is particularly true for smaller farms, where family are often called on to work. For nearly 70 percent of farms – primarily smaller ones – farm succession is not certain [19].

In addition, nearly every farm is suffering from the exodus of labor from rural areas due to good employment opportunities and better income opportunities outside the agricultural sector, particularly in urban areas.

Between 2007 and 2016 alone, 46,200 farms were abandoned, equivalent to almost every sixth farm in Germany. In addition, the average size of farms has doubled over the past 25 years, from 28 hectares in 1992 to around 60.5 hectares in 2016 [20]. These changes also impact the landscape. Agricultural enterprises and their fields have a crucial impact on the landscape and help shape life in rural areas.

3. EXTERNAL COSTS BURDEN SOCIETY

THE ECONOMIC, ENVIRONMENTAL AND social challenges in agriculture affect not only farmers themselves, but all stakeholders in the agricultural system. The costs incurred through these challenges are borne by farmers, for example through lower yields due to soil erosion – something that is particularly noticeable in dry years – or crop failures due to soil compaction, which are particularly evident in wet periods due to flooding in fields [21]. Measures to improve soil structure and tackle erosion and compaction also benefit yields, which means farmers can take cost-benefit effects into account in their decision making. However, many costs directly or indirectly caused by agriculture are not included in farmers' economic decisions, but are borne by society as external costs, which are often difficult to measure and quantify. The external effects of agriculture quantified in this study primarily concern costs for the challenges being faced in the field of ecology that can be attributed to climate and air, soil, water and livestock farming. In addition, we have included the external costs for the loss of ecosystem services (see Box 2) in our analysis. Furthermore, there are some effects in the areas of ecology (e.g. inputs of hormones into water), economy (e.g. effects of intensive competition in agriculture on product quality) and society (e.g. consequences of farming activities on the structure of rural areas) which we could not quantify in this study. These effects must of course also be taken into consideration when finding a solution.

The resulting external environmental costs of agriculture today amount to around 90 billion euros per year, of which around 50 billion euros are attributable to the loss of ecosystem services. For comparison this means that external costs are more than four times higher than the total gross value added of the agricultural sector (~21 billion euros) and correspond to about three percent of German gross value added in 2017 (~3,000 billion euros). Agriculture accounted for only 0.7 percent of gross value added.

ECOSYSTEM SERVICES

Ecosystem services are those services that people receive from ecosystems. These include supply services such as food and water, regulatory services such as flood protection and protection against drought, soil degradation and disease, basic services such as soil formation and nutrient cycles, and cultural services such as recreation, spiritual, religious and other non-material services (cf [32]). Ecosystem services provide the basis for staple foods and for the production of various industrial products. Such services therefore make a significant contribution to economic value creation.

"The prerequisites for all ecosystem services are the basic services that make the functioning of ecosystems possible in the first place. Habitats or species communities form the direct or indirect basis for individual ecosystem services. However, these conditions are increasingly coming under threat from intensive land use." [33]

Additional costs of around ten billion euros a year are incurred through EU direct payments, agricultural social policy, subsidies and administrative services related to agriculture.

External costs were calculated on an evidence basis. All calculations are based on the best available findings from other studies and have been applied by us to German agriculture where necessary, providing us with a holistic overview for the first time. In general, we have always calculated conservatively, which means that the actual external costs are likely higher. We have also eliminated any double counting from the study findings used. Specifically, some environmental topics are closely related and can be allocated to different categories. For example, flood protection plays a role in both climate and water. We have taken this into account in the overall analysis. Similarly, indirect effects, such as emissions from the use of agricultural machinery, are not taken into account.

The calculated external costs are therefore not exhaustive. Whilst assessing the external costs remains complex, particularly regarding biodiversity, there is no doubt that we need to find solutions in reducing external effects of agricultural practices today. The exact impacts might vary around the world, but external effects occur everywhere and better ways to reduce those are required globally. In our estimation, the actual external costs of agriculture are higher, especially if externalities for the social and economic sectors could be quantitatively taken into account.

Calculation of External Costs for Each Category[8]

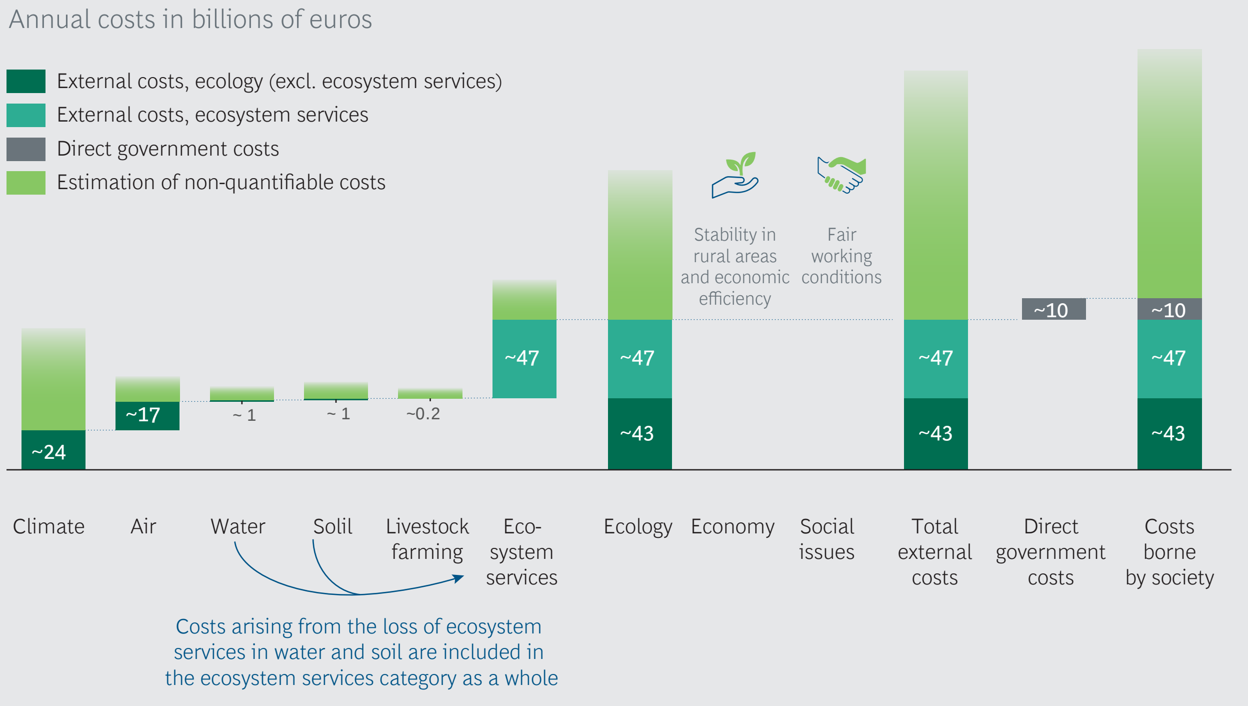
- **Climate:** Climate costs include greenhouse gas emissions from agriculture and land use changes attributable to agriculture of around 104 million CO_2e (see Figure 4). Emissions from the production of mineral fertilizers and pesticides as well as the imports of mineral fertilizers and animal feed such as soy and rapeseed were taken into account. Greenhouse gas emissions from imported soy also include[9] emissions from land use changes. In total, they cause around 130 million metric tons of CO_2e of per year. To calculate the external costs, we use the cost rate of 180 euros per metric ton proposed by the German Federal Environment Agency in Methodological Convention 3.0. The current market prices for CO_2 certificates are significantly lower – the market price in the EU in 2018 was between ~10 and ~25 euros per metric ton – and the prices of ten to 60 euros per metric ton envisaged in the new German 2030 climate protection program are also significantly lower [22]. Nevertheless, this is a rather conservative approach. In order to weight the damage of future generations equally with the problems already occurring today, the German Federal Environment Agency recommends a cost rate of as much as 640 euros per metric ton of CO_2e for a sensitivity analysis.

- **Air:** With respect to the external costs of air pollution caused by agriculture, the cost rates for damage to health caused by air pollutant emissions, such as particulate matter, nitrogen oxides and, above all, ammonia, are taken into account in accordance with the German Federal Environment Agency's Methodological Convention 3.0. We have not taken into further account the biodiversity loss cost rates listed therein in order to avoid double counting with the external costs for the loss of ecosystem services (see below).

8 For the sake of legibility, we have opted not to include a dedicated list of references in this section. A detailed list of the sources used can be found in the appendix.

9 All told, the 3.4 million metric tons of soy feed imports account for around 2.5 billion euros in external costs.

FIGURE 4 | German agriculture with costs borne by society



Source: BCG

- **Water:** In terms of water, the costs for securing the supply of potable water, i.e. for potable water treatment and monitoring, as well as for the eutrophication of inland waters are included.[10] Not included are already existing water supplier costs, the costs for the fourth purification stage in sewage treatment plants and possible health costs for consumers. We have also refrained from including costs that are difficult to quantify, such as the pollution and eutrophication of the Baltic Sea. The impairment of ecosystem structures and processes (e.g. uptake and degradation of pollutants by organisms living in water) and the resulting losses in ecosystem services are not taken into account here, but in the external costs of the loss of ecosystem services (see box "External Costs from the Loss of Ecosystem Services"). Our calculation is therefore also very conservative here and the true costs are presumably significantly higher.

- **Soil:** External costs incurred as a result of the loss of organic matter, soil contamination or compaction cannot currently be reliably quantified. The decline in soil organisms or biodiversity is considered part of soil function. All ecosystem services affecting the soil and potential external costs of their loss are not taken into account here, but, as is the case for water, are included in the external costs of the loss of ecosystem services (see below). The calculation of external costs for the soil category is therefore limited to the direct costs of erosion damage removal. This is based on an EU-wide study by the European Commission, the findings of which have been broken down for Germany. In light of the Intergovernmental Panel on Climate Change (IPCC) report from August 2019 [23] and the associated discussion on the degradation of agricultural soils, the costs in Germany are surprisingly low.

10 Potential effects of the new German Fertilization Ordinance (Düngeverordnung) have not yet been taken into account here.

By way of comparison, in Africa and Asia soil degradation is already reaching existentially threatening proportions and the resulting loss of earnings is already impacting the availability of food for people in the region [24].

- **Livestock Farming:** Quantifiable costs in this category include the costs of epizootic funds and the costs that can be attributed to the use of antibiotics in livestock farming for hospital treatment and research on resistance. External costs for animal welfare are difficult to measure in monetary terms and are not taken into account here.

In total, the five environmental categories lead to external costs of at least 43 billion euros caused by German agriculture. Other external costs (such as costs for the loss of ecosystem services in soil and water), which theoretically could also be assigned to the categories already described, are taken into account overall in the ecosystem services considered below due to difficulties in quantifying the proportions for individual categories.

Calculation of Costs for the Loss of Ecosystem Services

It is particularly important to take into account the external costs of the loss of ecosystem services because this category includes the loss of biodiversity. For example, there is no dispute that biodiversity losses account for a significant proportion of the external costs of agriculture. However, quantifying these costs is far more difficult than quantifying the external environmental costs mentioned above. Given the current state of research, these costs can best be estimated from the loss of ecosystem services and their impact on a country's value creation. Because of this, the estimation of external costs is based on an EU assumption for its 2020 Biodiversity Strategy.

In its 2020 Biodiversity Strategy, which was adopted in 2012, the European Parliament assumes that biodiversity losses worldwide account for three percent of gross domestic product (GDP). This statement is followed by the assumption that the use and consumption of natural resources is associated with a loss of ecosystem services, which subsequently leads to losses in value added and reduced GDP (see Box "External Costs from the Loss of Ecosystem Services"). If the European Parliament's assumptions were applied to Germany's GDP for 2018, the three percent external cost to Germany of the loss of ecosystem services would be around 100 billion euros.

These 100 billion euros are caused by all institutions and facilities that use land in Germany. The amount of agricultural land in Germany is 16.7 million hectares – around 47 percent of the total German surface area. In line with this use of land, we are allocating 47 billion euros in external costs to agriculture. Even though this assumption by the EU Parliament and the land allocation represents a highly simplified view of the facts, we consider it to be the best source currently available and an approximation for assessing this important category in monetary terms. In "External Costs from the Loss of Ecosystem Services" we have undertaken a critical examination of this assumption.

The collated findings demonstrate that one of the main drivers of external costs is land use in agriculture. This applies not only to greenhouse gas emissions from land use changes, but in particular to the loss of ecosystem services through agricultural use. This leads us to a clear conclusion, namely that the use of existing land is a key factor in developing sustainable agriculture. Less intensive management can lead to a significant reduction in the impact on the environment, but may also lead to a loss of yield. If more land were used for this purpose, the overall effect on external costs would not necessarily be positive. It would be premature to conclude that less intensive farming on more land would have a positive effect on external costs.

The collated findings demonstrate that one of the main drivers of external costs is land use in agriculture.

EXTERNAL COSTS FROM THE LOSS OF ECOSYSTEM SERVICES

While some of the external environmental costs of agriculture (such as climate impacts) are comparatively well documented and deduced, quantifying the external costs of biodiversity loss and ecosystem services is a much more difficult task. However, it remains undisputed that habitat loss or the loss of species communities impair the functionality of ecosystem services and that intensive agricultural land use plays a significant role in this (cf [33], [34]). This is responsible for a considerable proportion of the external costs of agriculture.

In order to take into account the loss of ecosystem services in our study and to lend appropriate weight, we have taken the 2012 EU Resolution on the 2020 Biodiversity Strategy as a basis, along with its assumptions on the global costs of biodiversity loss [35]. According to the resolution, the global loss of biodiversity leads to a three percent loss of gross domestic product (GDP). With reference to the 2010 TEEB study [36] and the 2008 COPI study [32], the EU assumes that the use and consumption of ecosystem services, as well as the impairment of their functionality, leads to a loss of value in the form of lost GDP. This includes losses from ecosystem services, which include the following categories:

- Regulatory services (e.g. water and climate regulation, air and soil quality)
- Utilities (e.g. food, fiber, fuels)
- Cultural services (e.g. recreation and tourism)

The values determined in the COPI study are to be considered conservative estimates since various impacts were not or were only partially taken into account, non-linear impacts were not taken into account and potential feedback effects between GDP growth and the development of ecosystem services are also not included. For example, the losses of ecosystem services specified in the COPI study do not include losses due to the reduction of pollination services and costs incurred as a result of invasive species in native ecosystems. The COPI study nevertheless assumes that the socioeconomic costs resulting from the loss of ecosystem services could more than double in the coming years (to seven percent [32]).

Based on the assumption of three percent GDP losses in Germany due to the loss of ecosystem services, we have allocated the external costs to German agriculture over its land share of about 47 percent. This implicit equal distribution of external effects between all land users is a very conservative assumption since agriculture is one of the main users of ecosystem services and is therefore more involved than other economic sectors in their reduction. Agricultural land use is a major driver of biodiversity loss [34], and land-based conversion of the associated external costs – in this case ecosystem services – will therefore most likely relieve the burden on agriculture as the polluter.

However, significant losses of ecosystem services (and costs) tend to occur in tropical countries. Land use change is still the main driver of these losses there. With a comparatively high GDP and conversion with a global factor of 0.03, we may be placing an excessive burden on Germany here given that significant land use change in Germany took place centuries ago.

On the other side, essential ecosystem services such as pollination are not included in the current estimation. In Germany, pollination services are responsible for approximately 13% of the value added from agricultural plant production [37]. The welfare losses from the reduction in pollination services are estimated at up to 550 billion euros worldwide [38]. In addition, the external costs of invasive species are not included. In the EU, these costs amount to up to 12.5 billion euros annually [39]. Determining a proportionate calculation for German agriculture for these two cost items is not the focus of this study. However, the examples listed demonstrate the magnitude of the external costs from the loss of ecosystem services. To give an example for a specific country, a 2006 study [40] found that US welfare losses from insect decline alone (not only including pollination but also other ecosystem services) were estimated to be at least $57 billion annually.

Impacts on ecosystem services related to water and soil, however, are included here. The external costs from the loss of ecosystem services from these categories are therefore included in the 47 billion euros for our consideration and are not separated. If clear allocation to each of these respective categories were possible, the external costs for the categories of water and soil would be correspondingly higher. In our view, they are relatively low at around one billion euros each. Taking all these facts together, we assume that the 47 billion euros is a good estimate of the external costs incurred by German agriculture for the loss of ecosystem services.

The detailed calculation of external costs is provided in the appendix. Figure 4 also indicates the non-quantifiable costs of the economic and social challenges described in this study. Given our conservative assessments, disregard of interdependencies, and the qualitative assessment of the experts we interviewed, we therefore assume that the actual external costs of German agriculture are significantly higher than calculated in this study.

FOOD COSTS

When it comes to who should bear the external costs, the public debate often calls for higher food prices to reflect the real costs to society – the "true" costs of food.[1] In light of this, we have undertaken an analysis to illustrate the extent to which price increases would be necessary if all relevant external costs of agriculture were internalized in producer prices (see Figure 6). We are applying the total external costs of 90 billion euros, including the 50 billion euros attributable to the loss of ecosystem services, we have determined. The price increases would be correspondingly lower without taking ecosystem services into account.

In this analysis, we considered both animal and plant-based food products. To simplify matters, we have limited ourselves to beef, pork and poultry meat, milk and eggs as well as wheat, apples, carrots and potatoes.

The main driver for the external costs of food products is the land consumption in each case. For animal-based food products, this is the land used to cultivate animal feed. Added to this are the costs of greenhouse gas emissions from livestock farming, a major reason for the different price premiums between animal and plant-based food products

For example, producer prices would have to be five to six times higher for one kilogram of beef, and the other animal-based food products considered would likewise have to be two to four times more expensive in order to internalize the external costs currently incurred. The price premiums for fruit and vegetables are significantly lower since the area used is very small by comparison.[2] In 2018, only 64 thousand hectares was used for tree and soft fruit cultivation in Germany, accounting for less than 0.5 percent of the area used for agriculture in Germany [41]. One kilogram of potatoes would have to be twice as expensive to cover all external costs.

The producer prices we calculate tend to be similar but significantly higher overall than the calculations from other studies, which often only take into account the costs of greenhouse gas emissions. However, our calculation has taken into account all external costs mentioned before.

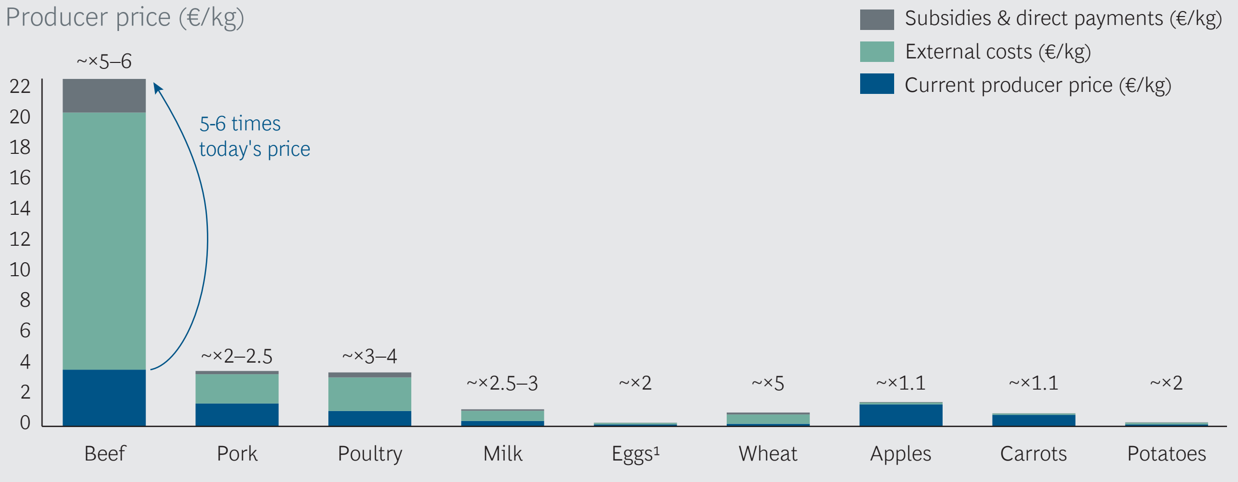
Internalizing external costs is obviously not the same as eliminating the negative externalities of current agricultural practices. In principle, however, internalization would remedy the market failure and the actual costs incurred could be included in the economic decisions of the players involved.

Whether allocating negative externalities to food prices is a viable or desirable path to internalization remains a political decision. At this point, we do not wish to make a specific recommendation for action, but to enrich the debate by providing greater transparency in terms of costs.

[1] Cf. The True Cost of Food initiative by the World Business Council for Sustainable Development (WBCSD).

[2] To simplify matters, we assume that fruit and vegetable areas generate the same external costs as other agricultural land. Although there are some significant differences in practice with regard to the use of pesticides and fertilizers, this is not taken into account in our model.

Internalized external costs make beef 5-6 times more expensive — land requirements as main driver of external costs



[1]Producer price and external costs per unit
Source: BCG

4. SUSTAINABLE AGRICULTURE MEANS MANAGING FARMING WITH FUTURE GENERATIONS IN MIND

BASED ON THE EXTERNAL costs of agriculture described above, the question arises how an alternative, sustainable approach could look like and what role sustainable agriculture should play. Sustainability is also a much-used term and therefore a clear, shared understanding of the concept of sustainable agriculture is essential to be able to conduct an objective and purposeful debate.

> "This land has been in my family for 14 generations. So, to me, it's clear: I need to preserve the fertility of the land for the next X generations."
>
> Organic farmer, ~100 ha of arable land and ~600 animals

The various actors within the agricultural system interpret sustainable agriculture differently: While the public and consumers focus primarily on the environmental aspects, farmers often focus on economic and social aspects because they ultimately have to make a living from agriculture. It is important for the debate to take these different perspectives into account. Only together is any progress on the matter itself possible.

> "Sustainability means working with future generations in mind. Above all, that means maintaining the soil's ability to yield."
>
> Farmer of a mixed farm, ~120 ha of conventional arable farming and grassland, biogas plant and ~900 pigs reared under Neuland husbandry principles

---

For us, sustainable agriculture means managing farms with the environment, economy and society in mind. But what does that mean specifically? We define sustainable agriculture as follows:

FIGURE 5 | Sustainable agriculture means environmentally friendly, economical and social management with future generations in mind

Environ-mentally friendly

Meet the demand for food while preserving the climate, air, soil and water as well as supporting and fostering ecosystem services and habitats for species within the agricultural landscape in the long term

Economic

Provide for economically viable enterprises while preserving natural capital and pursuing local knowledge

Social

Guarantee appropriate working conditions, safeguard the attractive-ness of the professional field and gain social recognition

Source: BCG

Sustainable agriculture is not the same as organic farming or organic certifications, although many methods of sustainable agriculture are used in organic farming. So far, organic farming has been the only land use system with legally defined guidelines as well as a consistent review of its activities based on its respective certification for all plant production, livestock farming and further processing of products. Nevertheless, organic farms can still improve their sustainability, especially since the yield figures between conventional and organic farm-ing methods can vary greatly depending on the product, and organic farming often involves higher land use with the same yield target. Additionally, conventional farms can also apply sustainable methods and significantly reduce external costs. This study therefore deliberately addresses both types of farming: conventional and organic.

CONFLICTING GOALS

Sustainable agriculture does not exist without conflicts. Organic farmers, conventional farmers, politicians, consumers, the food industry and other actors sometimes have very different priorities, which inevitably leads to conflicting objectives. Higher standards versus steady prices is one example of this. Consumers want better food quality at similar prices, while farmers demand appropriate pay for higher standards in food production. The food industry's primary objective is to maximize profits while at the same time trying to serve the "stingy is sexy" mentality. The political sphere considers low food prices as part of its social policy.

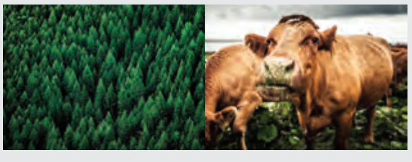
The conflict between structural change and the image of agriculture with colorful meadows and small fields is similarly controversial. In recent years, it has become clear that merging farms has also led to an increase in field sizes. However, many consumers and the tourism industry picture agriculture as a landscape replete with beautiful natural scenes and colorful meadows.

The conflict between climate goals and animal welfare is also often discussed. The fact is that around one third of greenhouse gas emissions from German agriculture are caused by livestock farming[1]. Air filtration is possible in modern farming facilities with exhaust air filters. But more grazing space for cattle and outdoor access for pigs is required for greater animal welfare.

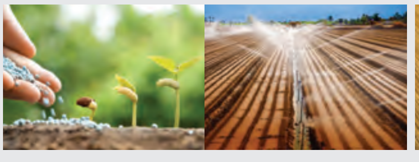
When switching to sustainable agriculture, the different interests and expectations associated with the conflicting objectives must always be taken into account. The decisions regarding this change must be taken by policymakers and the consequences of these changes must be socially accepted. Under no circumstances should farmers be left alone with these conflicting objectives.

POTENTIAL CONFLICTING OBJECTIVES OF SUSTAINABLE AGRICULTURE

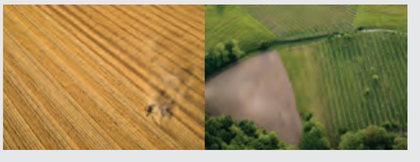
Climate targets versus animal welfare



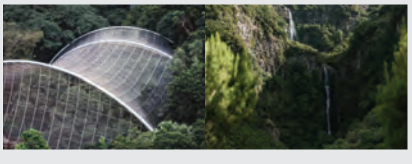
No-plow land management versus the use of chemical pesticides



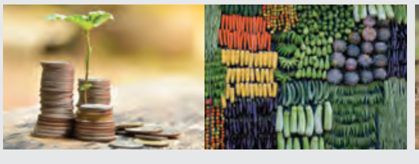
Structural change versus image of agriculture with colorful meadows and small fields



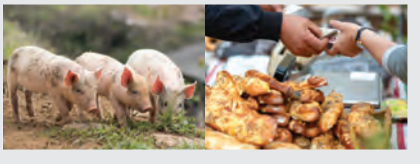
Organic farming versus nature conservation areas in surface comparison



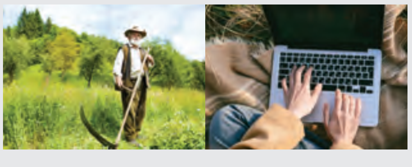
Bio-economy versus food production



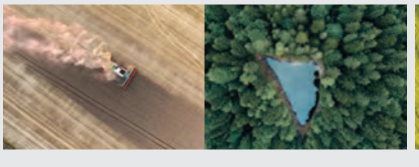
Higher standards versus unvaried pricing



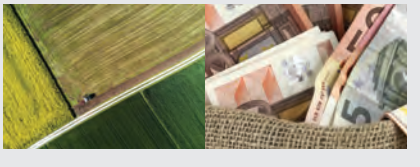
Local knowledge preservation versus centralized data analysis



Efficiency versus nature conservation



Differentiated crop rotations versus short-term economic profit

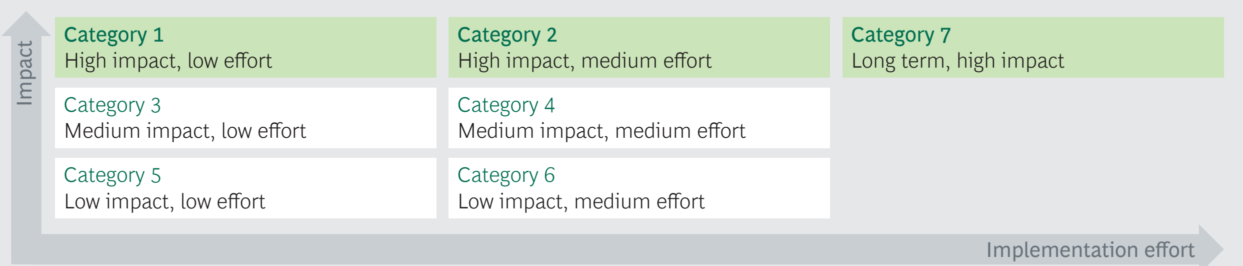


[1]If emissions from land use changes are taken into account.

5. REDUCTION OF EXTERNAL COSTS POSSIBLE

Our aim below is to show measures and methods of sustainable agriculture and, in doing so, discuss options for farmers to take action (see Figure 6). This study initially concentrates on the environmental aspects. Not all of the methods and measures considered are equally effective or easy to implement. However, they are already possible today and, in some cases, are already in practice today. To better understand the exact individual impacts on external costs and determine the overall effects, including interdependencies and taking into account downstream effects such as process emissions, we believe that further long-term

FIGURE 6 | Measures and methods of sustainable agriculture



Category 1

1. Wide crop rotations
2. Cultivation of undersown crops and catch crops
3. Reduction in pesticide use
4. Reduction in fertilizer use
5. Cultivation of fodder grass and legumes

Category 2

6. Land-based livestock farming
7. Creation of fallow land
8. Creation of extensive grassland

Category 7

32. Agroforestry systems
33. Precision agriculture and livestock farming
34. Smart farming

Category 3

9. Cultivation of mixed crops
10. Use of organic fertilizers
11. Construction of erosion protection strips
12. Creation of field margins and wildflower strips
13. Creation of hedges, field shrubs, field margins
14. Creation of drill gaps and light fields
15. Adjustment of mowing times at breeding times
16. Creation of nesting aids
17. Creation of clearance cairns

Category 4

18. No-plow land management
19. Use of mechanical crop protection
20. Use of natural enemies for pest control
21. Creation of wider riverbank strips
22. Processing of liquid manure (liquid manure recycling)

Category 5

23. Cultivation of extensive varietals and species
24. Adjustment of planting and sowing times
25. Rainwater storage
26. Late stubble cultivation

Category 6

27. Cultivation of nitrogen-efficient plant varieties
28. Covering slurry tanks
29. Reduction in machinery and support weight
30. Use of drip irrigation
31. Creation of small-scale cultivation structures

Note: This list is not exhaustive
Source: BCG

research is needed. This research especially needs to consider location-specific factors before a qualified recommendation for specific measures and methods can be made.

Measures and Methods at a Glance

Figure 7 offers an overview of the methods and measures considered as well as their categorization with regard to impact and implementation effort based on a qualitative assessment. An explanation of all measures with a comparatively high impact – i.e. those in Categories 1, 2 and 7 – can be found in the appendix.

The measures and methods listed are relevant not only to Germany, but also to other regions and agricultural production systems, taking local conditions into account.

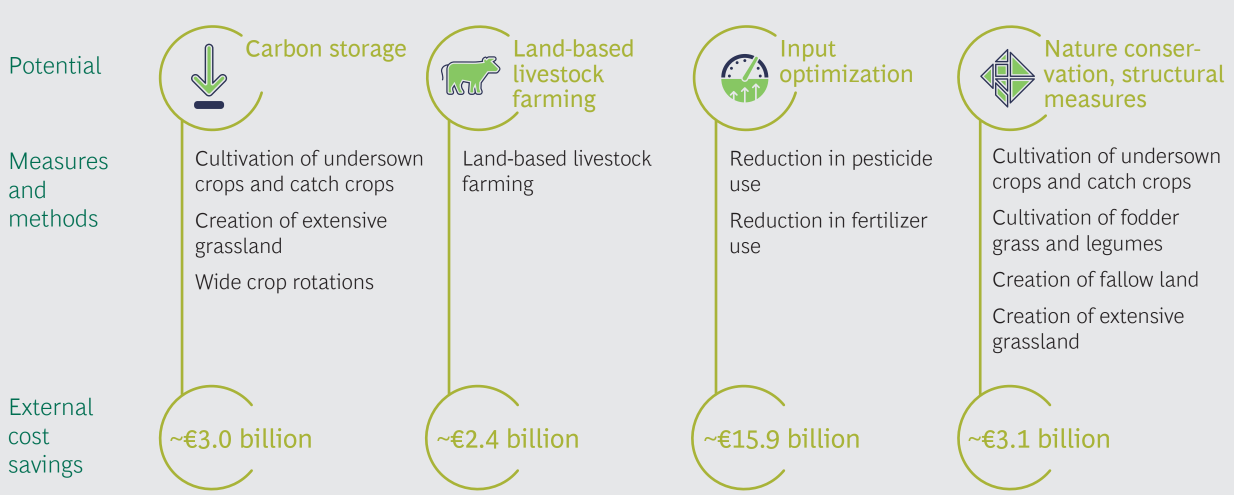
For the purposes of our analysis, we have focused on four potentials which are considered to have a high reduction potential and which are frequently discussed and demanded in the current debate. Due to the complexity of their implementation and the possible ambivalence of their effects, we did not consider methods and measures from Category 7.

Our subsequent potential analysis shows which methods and measures we attribute a high impact to and which measures – some of which are being called for prominently – may actually achieve a rather low impact according to our calculations. Potentials could only be quantified for the environmental aspects (see Figure 7). Nevertheless, the public discourse should not forget that many crucial economic, social and even cultural aspects must also be taken into account for sustainable agriculture in order to achieve the objectives of sustainable agriculture.

These potentials are enhanced using underlying methods and measures with a high impact, for wide broad crop rotation, cultivation of undersown seeds and catch crops or reducing the use of pesticides. We will discuss the consequences for earnings following an individual analysis of the potential.

The following analysis is based on the external costs determined by us in Section 3. The distribution of potential for reduction among the different environmental categories is shown in Figure 7.

Figure 7 | Four potential external cost reductions through the use of measures and methods



Source: BCG

1. Carbon Storage

The additional storage of around 13 million metric tons of carbon in agricultural soil in Germany can save around three billion euros annually in external costs for agriculture.

- The primary driver behind this is changes in land use, including both the rewetting of agricultural marshland and the conversion of arable land into grassland.

- The buildup of humus through wide crop rotations, undersown crops and catch crops, for example, represents a further positive effect. When calculating the potential, a recent 2019 study by the Öko-Institut [25] shows that the potential for additional carbon sequestration in mineral soils is realistic for only a quarter of the areas theoretically eligible for carbon sequestration.

- The largest share of the reduction in external costs through carbon storage is in the climate category, measured at about 2.4 billion euros. Thereof 0.5 billions are in the ecosystem services category, since intercropping and extensive crop rotation support soil life as well as above-ground biodiversity, therefore promoting ecosystem services. In the water and soil categories, smaller amounts are possible. However, the higher humus content in the soil leads to an increase in water absorption, transport and storage, thereby reducing the risk of erosion, among other things.

- In light of current debates (i. e. the IPCC report focusing on land management [23]), it may come as a surprise that we see a relatively low financial savings potential for Germany in carbon storage. This is primarily due to the nature of agricultural soils and regional characteristics in Germany, which significantly impact the potential for carbon storage. In other countries and regions, the potential can sometimes be significantly higher, depending on the approach. Box "Carbon sinks and storage" provides a detailed overview of the topic of carbon storage.

CARBON SINKS AND STORAGE

In the current discussion on preventing climate change, the potential of carbon storage in soil has come to the fore. Prominent examples are the 4 per 1000 initiative launched at the Paris Climate Conference in 2015 and the Terraton Challenge launched in 2019 by US agricultural company Indigo. Even the 2019 IPCC Special Report [23] addresses this. The potential of agricultural soil as significant carbon sinks plays an important role in this debate, which is sometimes very controversial.

On the one hand, global agricultural land stores more than 500 metric gigatons[1] of carbon [42]. On the other, it is also the source of almost 50 percent of agricultural greenhouse gas emissions (~2.5 metric gigatons of CO_2e) worldwide. In Germany, at least 2.5 metric gigatons of carbon is currently stored in agricultural soils [43]. Without taking land use changes into account, soils in Germany are responsible for around 40 percent of agricultural greenhouse gas emissions [15].

Given this, the focus here is on agricultural practices that can reduce emissions from agricultural soil and/or sequester additional carbon in soil. The practices discussed range from more incremental changes, such as improvements in crop rotation, to major changes in management, such as no-plow land management, to systematic and innovative changes, such as agroforestry systems or newly developed deep-rooted arable crops. However, the actual potential of such practices in the global context is sometimes subject to considerable uncertainty and disagreement.

While some practices may have an immediate impact on reducing emissions, it is often difficult to capture additional organic carbon buildup over a long period of time. The realistic potential is, in turn, highly dependent on location-specific factors such as soil texture, existing carbon and nutrient stocks, the amount of organic matter available to be brought into the soil and climatic conditions.

To illustrate this, due to changes in agricultural practices, not including land use changes, the values for global potential currently under discussion range from around 0.1 to 3.5 metric gigatons of additional carbon storage per year [44], [45]. This corresponds to a greenhouse gas savings potential of around one to 13 metric gigatons of CO_2e and therefore between one and 25 percent of the annual greenhouse gas emissions caused by humans.

In an international comparison, the potential for Germany and Europe is seen as rather low due to the given location-based factors; larger potentials are seen in other regions, for example in the tropics. Agroforestry systems in particular are considered to have great potential here. However, further studies are necessary for an accurate estimation to be made.

It is undisputed, however, that the practices discussed have other positive impacts on agricultural soil. These include the restored ecological functionality of the soil, improved soil structure and the boosting of soil organisms, which, for example, positive impacts water storage capacity and soil resistance. Although these effects should be taken into account in the overall assessment, they should not be intermingled with the potential calculation of carbon storage.

[1]Gt = metric gigaton, equivalent to one billion metric tons

2. Land-based Livestock Farming

The introduction of a land-based livestock system with 1.5 livestock units[11] per hectare could save around 2.4 billion euros annually in external costs for agriculture.

- Land-based livestock farming means that only as many animals are kept on a certain area as that area is able to produce fodder for and absorb the manure without damaging the environment. For farms with more animals than the upper limit assumed in each case, stock numbers must be reduced accordingly or areas outside the farm in the surrounding region must be included. To calculate the potential of land-based livestock farming, we have based our figures on rural regions and have assumed a maximum animal population of 1.5 livestock units and an input of 170 kilograms of nitrogen per hectare. The results of our analyses does not necessarily reflect the hopes associated with this approach in the

11 The livestock unit (LU) serves as a reference unit to facilitate the comparability and aggregation of livestock of different species. One livestock unit is equivalent to 500 kilograms of live weight (the same weight as a full-grown cow).

public debate. Land-based livestock farming only has a significant impact in certain regions, primarily in the northwest of Germany. Most regions already fall below the 1.5 livestock unit threshold, which is why the potential is comparatively low overall. The savings potential of land-based livestock farming is around 2.4 billion euros per year in external costs. These calculations are also based on the Öko-Institut's 2019 study [25].

- Overall, the number of livestock would have to be reduced by seven per cent if 1.5 livestock units per hectare were to be used throughout Germany. According to the Öko-Institut, this would reduce greenhouse gas emissions by around 2.5 million tonnes of CO_2e, which would reduce climate costs by around 0.4 billion euros. Added to this are the reduced imports of animal feed, which amount to around 0.2 billion euros.[12] Further potential can be realized by the categories of air at 1.4 billion euros and ecosystem services at 0.4 billion euros. This is based on the assumption of seven percent less ammonia emissions, commensurate with the reduction in the number of animals. The ammonium produced after ammonia is converted is partly responsible for the formation of fine dust and, through its input into water bodies and soils, for species loss and therefore the loss of ecosystem services. Less ammonia therefore has positive effects on air and ecosystem services.

- We have not been able to quantify reductions in external costs resulting from reduced nitrogen inputs due to low manure inputs in the relevant rural regions. However, these reductions may lead to significant improvements in ecosystems in regions such as large parts of Lower Saxony or Lower Bavaria.

3. Input Optimization

Input optimization could reduce the external costs of agriculture by around 15.9 billion euros annually.

- Here, we consider measures such as the reduction of nitrogen surpluses, for example through savings in nitrogen fertilizers, slurry treatment and processing as well as improved application techniques, the optimized use of pesticides and the use of farm fertilizers in biogas plants.

- At around 14.6 billion euros, ecosystem services account for the largest share of the reduction potential. The reduction of the nitrogen surplus to 50 kilograms per hectare corresponds to a reduction of almost 50 percent compared with current values. Based on various studies, we consider a mid-to long-term reduction potential of up to 70 percent realistic in terms of the use of pesticides (under conventional agricultural practices). A report by the EU Parliament's Research Service concludes that there is a correspondingly high reduction potential, especially with the current intensive use of pesticides, where Germany falls above the EU average [26]. According to the study, it is possible to achieve a reduction of up to 50 percent without affecting yields. For this precision technologies and digital solutions play a crucial role [27]. According to our assumptions, a trade-off between positive effects resulting from reduced pesticide use and negative effects due to loss of yield begins at 70%. This trade-off results from the fact that the loss of yield would have to be offset.

12 We are assuming that, despite land-based livestock farming, animal feed imports would still be necessary as a first step, especially protein-rich animal feed. Converting feed cultivation to full self-sufficiency as provided for in the case of land-based livestock farming would then be the second step, which would involve further implications with regard to land use, the precise impacts of which have yet to be investigated.

- The climate also benefits. According to the Öko-Institut, reducing nitrogen surpluses through liquid manure treatment and processing as well as exhaust air filtration in farm facilities will save around 5.4 million metric tons of CO_2e. The use of farm manure in biogas production leads to further savings of around 0.9 million metric tons of CO_2e. Additional reduction potentials lie in the production of pesticides, the climate costs of which are reduced proportionately by around 55 million euros. A reduced nitrogen surplus also means less nitrate-nitrogen input into the groundwater. Given the agricultural costs of providing potable water estimated by German Federal Environment Agency, the absolute reduction potential for external costs in the water category is only marginal.

4. Structural Measures in Nature Conservation

The use of structural measures in nature conservation as part of the greening process could generate an annual savings potential of around 3.1 billion euros in external agricultural costs.

- The cost reduction potential is strongly dependent on the structural measures actually implemented on the repurposed land. Intercropping and fallow land have clearly different impacts on species diversity and emissions, for example. Some six percent of arable land in Germany is currently designated as prioritized nature conservation areas, but the effects achieved as a result have so far been negligible. The EU Court of Auditors [28] comes to the same conclusion.

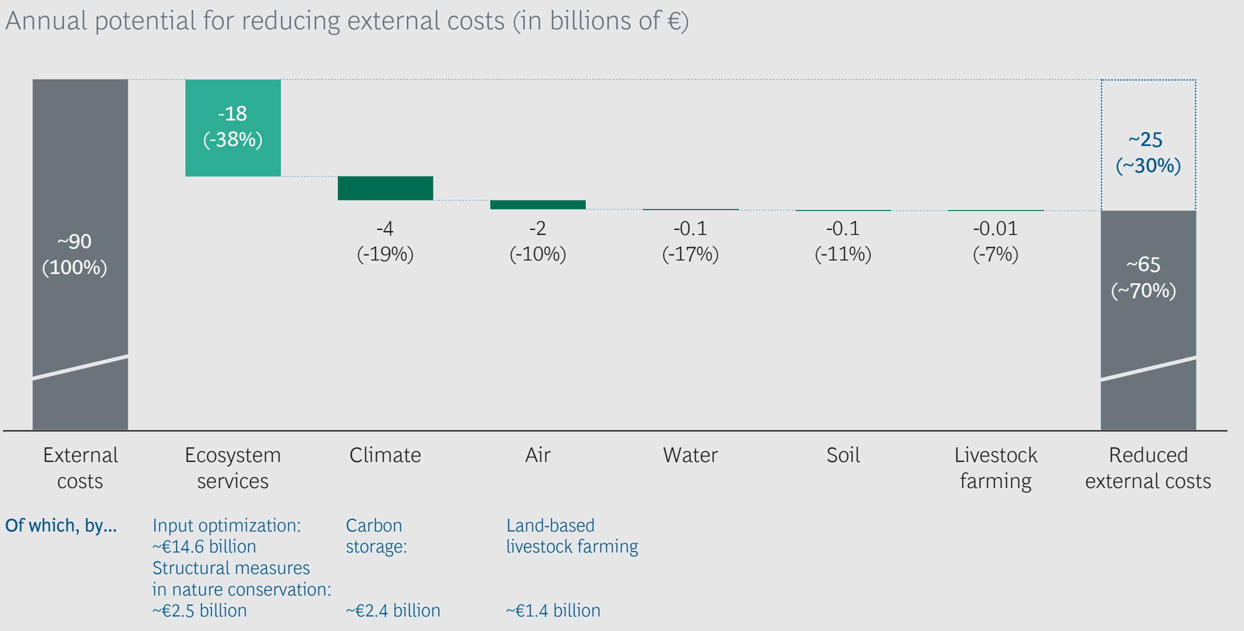
- To design the best possible impact for the conservation of ecosystem services, we focus on fallow land when calculating the savings potential, because it is the element with the demonstrably highest contribution to the conservation of biodiversity as well as to water, climate and soil protection.

- Our calculations are based on the 2017 recommendations of the German Federal Agency for Nature Conservation. Accordingly, every farm of at least 15 hectares in size should convert ten percent of its area into prioritized nature conservation areas and initiate appropriate structural measures. This covers a total area of around one million hectares.

- Converting one million hectares into fallow land would result in a reduction in external costs of around 3 billion euros. At 2.5 billion euros, the greatest reduction potential would lie in the category of ecosystem services.

- Since (intensive) land use is the main driver of external costs, allowing land to grow fallow would result in further marginal reductions for climate, air and soil. We have not considered potential effects on water, since the retention and filtering function against the input of pollutants into water bodies is strongly dependent on the location and width of the riverbank strips and fallow areas. Impacts on adjacent parts of land, in particular on ecosystem services and species diversity, have also not been taken into account.

FIGURE 8 | Four potentials can reduce external costs by ~30%



Source: BCG

Positive Net Effect

The four potentials listed above could reduce the environmental external costs of agriculture by around 30 percent to approximately 65 billion euros per year[13] (see Figure 8). Achieving this potential, however, involves a trade-off. If the measures described were implemented, agricultural yields would be reduced by around 18 percent for food products of plant origin and around seven percent for products of animal origin. If we compare this with a cost reduction potential of around 30 percent for negative externalities, we can nevertheless assume a clearly positive net effect.

The positive net effects of the potentials described demonstrate that farmers can make an important contribution to reducing external costs through sustainable methods. Most options considered in our calculation are already applicable and comparatively easy to implement. One exception is rewetting drained marshland areas, which would then be taken out of agricultural use. Ideas are already being tested to preserve rewetted areas for agricultural production.[14]

However, it is by no means the sole responsibility of farmers to implement these measures. Some of the options identified are so costly and burdensome that farmers would not be able to cover them through higher producer prices. The entire agricultural system is responsible and farmers are dependent on the support of the various stakeholders – in particular policymakers and society.

---

13 To simplify matters, we work on the assumption that the reduction potentials of the methods and measures considered are additive and that any interdependencies and overlaps do not significantly alter the results.

14 One example is what is known as paludiculture, which provides for the cultivation of reeds or grazing by water buffalo [51].

As such, a public discussion on how to realize this potential together with farmers is required, taking into account economic and social challenges and guaranteeing the right conditions in the long term. Our initial thoughts are provided in the next section of the study.

The results of our potential analysis indicate that agriculture in Germany is already well positioned in some areas and that, for example, humus buildup or land-based livestock farming do not allow for a significant reduction in external costs. However, in other areas, there is definitely relevant potential for savings; we see great potential for reducing external costs, particularly by reducing pesticide use and nitrogen pollution. We assume that a major further portion of the external costs can be avoided, but this requires changes in society as a whole. At the conclusion of the study in Section 7, we offer insight into what this might look like with possible future scenarios presented as thought experiments.

6. COOPERATION AS THE KEY TO SUCCESS

FARMERS WANT TO CONTRIBUTE to environmental protection, run their businesses sustainably to preserve their farms for future generations and secure jobs in rural areas in the long term. And some farmers are already succeeding at this today. However, many cannot easily adapt their farm structures and processes to engage in sustainable agriculture. They lack the financial leeway as well as the necessary expertise and support. It is therefore not enough to hang our hopes on farmers' intrinsic motivation, but rather to consider the entire agricultural system and the underlying conditions to which it is subject. It would also be wrong to simply burden farmers with the entirety of the necessary changes. All actors have a duty here, and a debate across society is necessary to come together to define what sustainable agriculture could look like for Germany and how we can jointly realize the potential of sustainable methods and measures.

"90% of the population is so far removed from agriculture. People need to visit farms more, and we need to capture awareness early on."

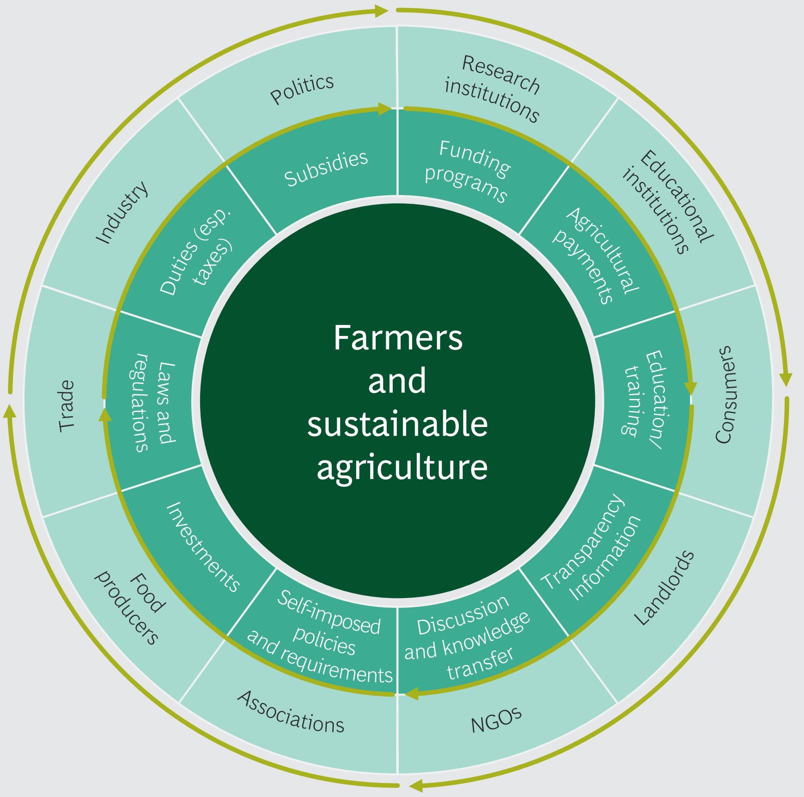
Conventional farmer converting to organic, arable farming, >300 hectares

---

Figure 9 shows the relevant actors and their options for taking action. Not everyone can take advantage of every option for taking action: Some options, such as levies (especially taxes), laws and regulations, are reserved for politicians who are in a position to define the framework conditions. Trade and industry have a significant influence on pricing in particular, and they can also set standards through self-imposed purchasing guidelines, for example. Society places an even greater role as it exerts a key influence on all other actors through electoral decisions, consumer behavior, communication and specific demands.

Below, we would like to point out various options for action. These are not meant as demands or recommendations, but, from our point of view, demonstrate the most important options.

FIGURE 9 | Overview of the actors involved and their options



Source: BCG

Policy Options

There are three key ways for policymakers to promote sustainable agriculture:

1. They can do this by internalizing external costs according to the polluter pays principle, for example through levies for farmers. In these cases, farmers would bear[15] the external costs as polluters. This could be done, for example, through a CO_2 tax. However, this would increase farmers' production costs and, in the absence of relief in other areas, would probably result in many farmers no longer being able to run their farms in an economically viable way. At the same time, however, this kind of internalization creates incentives for farmers to reduce additional production costs as much as possible and therefore to reduce external costs as well. To illustrate how the theoretical allocation of external costs would affect producer prices for selected foods, we have provided an explanation in Box "Food Costs". The result would be higher food prices that would approach the true costs of food. The current prices, however, are neither environmentally, economically nor socially sustainable. They do not take into account the external costs of agriculture and, in many cases, farmers are unable to make a living from the producer prices paid. Farmers in particular would like to see sustainable and therefore higher food prices.

15 The external costs for feed imports and the production of fertilizers are not attributable to German farmers.

> “Animal feed prices are absurdly cheap. You can’t make a living off of that in Germany. That’s why we’ve specialized in market fruits.”
>
> Farm manager of an agricultural estate, ~4000 ha focusing on food crops and forestry

However, since this redistribution would have far-reaching consequences for the entire agricultural system and presupposes that the more expensive production in Germany is not replaced by cheaper imports from abroad without special conditions. This requires a comprehensive analysis of the necessary conditions and the social and economic consequences.

2. They can also reduce the external costs through (a) **laws and regulations** or (b) **agricultural payments** that incentivize farmers to implement sustainable methods and measures.

a. **Laws and regulations** to reduce external costs can take effect at different points. For example, stricter rules on the use of pesticides and fertilizers would directly affect farmers.

Switching public procurement, for example for ministry, schools and university cafeterias, to sustainable agricultural products – as is already being done in large parts of Denmark – would also promote sustainable agriculture. Overall, policymakers have far-reaching options for reducing external costs.

b. With respect to **agricultural payments** to encourage farmers to use sustainable measures and methods, it makes sense to consider livestock, arable and mixed farms separately. In the case of livestock farms, the State can accomplish improved livestock farming through agricultural payments in the form of a livestock farming premium, for example. Farmers would then receive financial co-payments if they adapted their facilities to a certain type of farming, for example by meeting a certain level for animal welfare labels.

For arable farms, the primary issue is that of the financial reward for ecosystem services, which should be better managed under the Common Agricultural Policy (CAP)[16].

At present, some environmental measures are already being rewarded, but a clear expansion and increased focus on such measures would be crucial. For mixed farms, both approaches to agricultural payments – i.e. those for livestock and arable farms – would play a role.

In principle, the aim should be to enable livestock, arable and mixed farms to adopt better environmental practices through agricultural payments instead of tightening up technical legislation. Nevertheless, in the long term, support for farmers to implement sustainable methods and measures can be reinforced by restricting or even banning unsustainable

16 The second pillar of the CAP includes voluntary agri-environmental and climate protection measures in agriculture, with the primary objective of promoting rural development and designing an attractive future for people living in rural areas.

practices. The German Fertilization Ordinance in particular is an important instrument here.

3. **Policymakers can also use indirect incentives** for promoting the necessary social change toward a more sustainable lifestyle. As Section 5 makes clear, we need society as a whole to change in order to significantly reduce external costs. A consumer levy on certain products could steer demand toward greater sustainability and use the revenues generated to further promote sustainable methods and measures.

   Another approach may be to reduce food waste. France, for example, is trying to combat food waste by requiring supermarkets to donate rejected food items. Violations are punishable by fines. These kinds of incentives to reduce food waste would not only include farmers but all downstream economic sectors and consumers as well. These are just two examples of how incentives could bolster change.

   However, as with all other options for action described above, social and economic effects must be carefully analyzed and taken into account.

> "As soon as a banana goes a little brown, you throw it away. It didn't cost anything, after all... But nobody thinks about the effort behind its production."
>
> Farmer of a mixed farm, >120 ha of conventional arable farming and grassland incl. wildflower strips, wild herbs, etc.

Options for Action by Other Stakeholders

In addition to these policy options, other instruments are available to promote sustainable agriculture, of which the following, in our view, play a special role:

- **Transparency:** Besides the political sphere, food producers and trade are the central actors here. Transparency would mean consumers could be encouraged to consume more consciously and sustainably in the long term, partly through voluntary sustainability standards and labels, sustainable purchasing, a fairer pricing policy and greater supply chain transparency. NGOs can also provide support with information and transparency.

- **Exchange, Knowledge Transfer and Research:** In our interviews, farmers have repeatedly told us how important it is for them to exchange experiences with each other. Interest groups as well as research and educational institutions can support networks by providing them with accessible databases. Further research is needed, for example on plant species and varieties with greater adaptability to drought and other climatic changes.

- **Investment in Innovation:** Investments in better production processes, environmentally friendly water-saving technologies, application techniques, smaller machinery and, in particular, the development of newer, more environmentally friendly products such as nitrogen-efficient plant varieties can make a key contribution to sustainable agriculture. Investments in digitalization and systematic technological innovations like smart farming open up new ways of making agriculture more resource-efficient and sustainable.

- **Training and Consulting:** From our point of view, methods and measures of sustainable agriculture belong in the curricula of agricultural education. We believe that policymakers and educational institutions have a duty not only to train farmers, but to include these issues the curricula of all schools. The challenges of sustainable agriculture should also be addressed at an early stage in general schooling to equip (future) consumers with the necessary tools for conscientious consumption. Another central key is independent consulting on agricultural and nature conservation issues. Farmers' financial situations should not be a barrier to accessing these kinds of services. Instead, this kind of consultancy should be provided by independent, predominantly State-trained personnel.

"Farmers should not only be trained in technical production factors, but also in the conservation of nature and biodiversity."

Farmer of a mixed farm, ~120 ha of conventional arable farming and grassland, biogas plant and ~900 pigs reared under Neuland husbandry principles

---

7. THE FUTURE OF GERMAN AGRICULTURE – FOUR SCENARIOS

As explained in the previous sections, the methods and measures described are already available to farmers to reduce the external costs of agriculture by around 30 percent. We have drafted four future scenarios and thought experiments to identify possible additional options for taking action to reduce external costs outside of farmers' direct sphere of influence.

These hypothesis-based scenarios (see Figure 10) are intended to help open up more scope for options in the discussion on sustainable agriculture and present the impacts of even more radical ideas. As explained in Section 5 as part of the potential analysis, changes in society as a whole are needed in order to reduce external costs by more than 30 percent. It is important to note that the scenarios under consideration here are not recommendations for action, but are intended to show other available options. When assessing these options, it is important not to disregard the social and economic impacts, for example on jobs, in addition to the environmental implications considered here. However, these impacts are not taken into account in our scenarios.

FIGURE 10 | Four scenarios for reducing external costs

Scenario	Assumptions	Outstanding external costs of the scenario (reduction vs. ACTUAL in %)		
		ACTUAL	Scenario	Reduction
1 No production for the export of food products	German agriculture produces only for domestic consumption, i.e. no more production for export; Import of food products remains unchanged	~90	~55	-40%
2 No food waste in Germany	Food waste (currently ~30% in Germany) is reduced to 0%; Food waste in other countries remains unchanged	~90	~80	-15%
3 Reduced meat consumption in Germany	Daily meat consumption in Germany (currently ~164g) is adjusted to the EAT-Lancet recommendation of 45g per capita; Consumption in other countries remains unchanged	~90	~65	-25%
4 Agriculture optimized for domestic consumption	German agriculture now produces only for domestic consumption; Domestic food waste is reduced to 0%; Domestic meat consumption adjusted to 45g per capita; Sustainable methods and measures used	~90	~20	-75%

Source: BCG

The following analysis is based on the external costs determined by us in Section 3. In scenarios 1, 2 and 3 we consider the possible implications of systemic changes in agricultural production or social consumption under the assumption that agricultural methods and measures correspond to current practices. This means that, in these scenarios, we do not take into account the impact of sustainable methods and measures, the potential of which we have calculated in Section 5. Sustainable methods and measures are only taken into account in scenario 4, in which we consider the systemic changes from scenarios 1 to 3 and the potentials from Section 5 together.

Scenario 1
No Production for the Export of Food Products

We assume that German agriculture produces exclusively for consumption in Germany and that no more goods are exported. The import of food products, however, remains unchanged. In Germany, around 6.9 million hectares is currently used for the export of agricultural products, which corresponds to almost 50 percent of the land used for food production in Germany (around 14 million hectares) [4]. The negative externalities from land use could therefore be significantly reduced. With respect to animal food products, in addition to land use for animal feed there are also negative externalities from livestock farming, in particular emissions. With an export share of around 40 percent of total production – for eggs the share is around 20 percent, for poultry meat up to 50 percent [2]– there is also a significant reduction potential here. Overall, this scenario would lead to a reduction in external costs of around 40 percent.

If we take a closer look at the exports, there are even more exciting findings. For example, the export of pork and pork products alone currently results in external costs of around 4 billion euros attributable to agriculture. This is in contrast with agricultural exports of pork worth around 3.8 billion euros [2]. German farmers' gross value added would be only a small part of this. It therefore becomes clear that, under the current conditions, the export of pork results in higher external costs for society as a whole than the economic output gained. In other words, German society subsidizes the export of pork abroad by paying for the environmental consequences within our own country. However, this also applies to the overall view from a global perspective. If the food products currently exported by Germany were substituted by those producers whose agricultural production methods are less sustainable than those of German agriculture, the problem would not simply be shifted, but possibly also aggravated from a global perspective.

Scenario 2
No Food Waste in Germany

In Germany alone, some 13 million metric tons of food is wasted every year [29]. This equates to around 85 kilograms per capita and corresponds to about one third of food produced. Let us assume that food waste in Germany – currently around 30 per cent of the total – is [30] reduced to zero; food waste in other countries, including those importing food products from Germany, would remain unchanged. Accordingly, the assumption only impacts the food products produced for domestic consumption and the resulting external costs. Around 7.1 million hectares is occupied[17] for domestic consumption in Germany [4]. In our scenario, around one third of this would no longer be needed. Similarly, one third of the animals kept for domestic consumption would not be needed. This results in an overall reduction potential for external costs of around 15 percent.

17 For simplicity's sake, we assume that food waste from domestically produced food products and imported food products will decrease equally. The latter has no impact on the external costs incurred in Germany.

Scenario 3
Reduced Meat Consumption in Germany

Following the recommendations of the EAT-Lancet Commission for a healthy and sustainable diet, we assume for this scenario that German citizens will adjust their consumption. Here, we only consider the recommendations for meat consumption and the resulting effects on external costs. For an overall assessment of the EAT-Lancet recommendation with regard to external costs, other effects in changes in consumption would also have to be taken into account.

If German citizens' meat consumption were based on the EAT-Lancet recommendations, daily per capita consumption would be 45 grams [31]. Currently, daily per capita consumption is 164 grams, resulting in a savings potential of more than 70 percent for meat and sausage products produced for domestic consumption.[18] This therefore has an impact on the size of the feed areas used for domestic consumption of meat and sausages (around 6.5 million hectares) as well as on the animals kept for this purpose (around 60 percent of animals). All told, this scenario results in a reduction potential for external costs of around 25 percent.

Scenario 4
Agriculture Optimized for Domestic Consumption

If we now take the reduction potential of sustainable methods and measures of around 30 percent determined in Section 5 and combine all three scenarios on this basis, we are left with the external costs of an agricultural system optimized for domestic consumption. These costs amount to around 20 billion, which corresponds to a reduction in costs of around 75 percent. Conversely, however, this also means that, even under this optimized German agricultural system, which focuses on domestic consumption, considerable external costs are still incurred.

Although this consideration is purely a thought experiment – the limitations and simplifications of which have already been mentioned – it can nevertheless be concluded that it will not be possible to engage in agriculture in the near future without external costs. However, the scenario also shows that there is clear potential for improvement compared to today.

All four are equally applicable across other European countries, albeit our first scenario focused on exports will likely be different in other European countries which are often less focused on meat exports compared to Germany.

Courage to Change

The scenarios considered do not nearly cover all possible paths into the future. They are merely selective ideas. Across all scenarios, however, it appears that lower meat consumption and fewer meat exports are two highly effective and economically viable levers for an agricultural system with lower external costs. The scenarios also make clear that we need a fundamental debate in Germany and across the Europe on what our agricultural system should look like in the long term – and that we need the courage to make significant changes. As a society, we must discuss and decide together what exactly these changes should look like.

18 For simplicity's sake, we assume that the consumption of domestically produced meat and sausage products and imported meat and sausage products will decrease equally. The latter has no impact on the external costs incurred in Germany.

8. NOW IS THE MOMENT FOR ACTION!

Farmers around the world make an important contribution to society and they deserve our appreciation and support. In recent years, some have already managed to work much more efficiently and with less impact on resources.

Nevertheless, we need a clear shift toward sustainable agriculture in order to meet the growing environmental, economic and social challenges we are facing locally and globally. The annual external costs of agriculture in Germany alone demonstrate the scope of these challenges. The measures and methods described in this study can help us to reduce the negative impact on the environment and society. We are calling upon society, politics, associations, farmers and all other stakeholders to create the underlying conditions necessary for more sustainable agriculture and to ensure that the necessary measures can be implemented successfully in the long term.

Of course, it is not sufficient to consider Germany alone. Solutions must take account of the national context as well as the international networking of agriculture in European and global contexts. After all, other countries have similar tasks ahead of them. And the common agricultural policy (CAP) after 2020 needs to address these.

These future scenarios have demonstrated that it is possible, at least in principle, to significantly reduce the environmental external costs caused by agriculture. We as a society must now decide – together – the path we wish to take. To do so, we must to answer some important questions:

- What should sustainable agriculture look like in Germany, but also in the EU?
- How can this sustainable agriculture be purposefully promoted?
- What is this sustainable agriculture worth to us?
- How do we resolve the conflicting goals on the road to sustainable agriculture?

In any case, we must understand that the mere corrective mechanism of policy through laws and bans is just as inadequate as individuals' minimization of their own environmental footprint. What we need are systemic solutions to changing patterns of consumption and behavior on a grand scale – and the time to develop these solutions is **NOW!**

9. APPENDIX

Calculation of External Costs

A large number of scientific studies form the basis for the calculation of external costs. These include studies whose findings relate directly to Germany (e.g. on deriving the costs of GHG and air pollutant emissions) and studies which consider other geographical regions and whose findings we have, where possible, applied to Germany.

TABLE 1 | Derivation of external costs for the environment

		External costs[1] in billions of €		REFERENCE				
	Cost drivers		Year	Region	Value	Assumptions	Sources	Reference
Eco-system services	Loss of ecosystem services	~47.0	2018	World	~3% of GDP	• GDP Germany 2018: €3,388 billion • Costs for losses from ecosystem services. GER ~€100 B • Agricultural surface area, Germany: ~47%	EU Commission (Biodiversity Strategy 2020)	[35]
Climate	GHG, agriculture	~19.0	2017	Germany	~104 Mt CO_2e[3]	• Climate costs per metric ton of CO_2e: €180	German Federal Environment Agency	[15], [52]
	GHG, mineral fertilizer production	~1.0	2018	Germany	~5.5 Mt CO_2e	• Production of N mineral fertilizer (CO_2e factor: ~7.6), phosphate mineral fertilizer (~1.3) & lime fertilizer (~0.3) • Input quantities in Germany (2018) as basis for CO_2e emissions • Climate costs per metric ton of CO_2e: 180 €	Probas database, IVA, German Federal Statistical Office, German Federal Environment Agency	[19], [52], [53], [54]
	GHG, pesticide production	~0.1	2018	Germany	~0.4 Mt CO_2e	• Input quantities in Germany as basis for CO_2e emissions • CO_2e factor: ~12.4 • Climate costs per metric ton of CO_2e: €180	Probas database, German Federal Environment Agency	[52], [55]
	GHG, import of mineral fertilizers	~1.5	2018	Germany	~8 Mt CO_2e	• Incl. N mineral fertilizer (63% import) & phosphate mineral fertilizer (94% import) • CO_2e emissions (and costs) as with domestic (see above)	IVA, Probas database, German Federal Environment Agency	[19], [52], [53], [54]
	GHG, import of soy feed	~2.5	2017	Germany	~14 Mt CO_2e	• ~3.4 Mt soy imports (2017); CO_2e factor: ~4.1 (incl. land-use changes)	German Federal Ministry of Food and Agriculture, Germanwatch, German Federal Environment Agency	[52], [56], [57]
	GHG, import of rapeseed feed	~0.2	2017	Germany	~1 Mt CO_2e	• ~1.7 Mt rapeseed imports (2017); CO_2e factor: ~0.6 (excl. land-use changes)	German Federal Ministry of Food and Agriculture, Germanwatch, German Federal Environment Agency	[52], [56], [57]
Air	Fine dust pollution/ air pollutants	~17.5	2017	Germany	PM_{10}, NOx, NMVOC, NH_3 emissions and cost rates	• Air pollutant emissions from agriculture (2017) • Cost rates for emissions (health care costs) in Germany acc. to Methodological Convention 3.0	German Federal Environment Agency	[52], [58]
Water	Potable water treatment	~0.6	2017	Germany	633 Mio. €	• Medium scenario with nitrate target value 37.5 mg/L	German Federal Environment Agency	[59]
	Potable water monitoring	~0.1	2017	Germany	Nitrate €0.008/m^3 Plant prot. prod. €0.006/m^3	• ~5.2 billion m^3 Water extraction for public water supply (2016)	German Federal Statistical Office, German Federal Environment Agency	[59]
	Eutrophication	~0.2	2008	UK[2]	GBP 0.03 billion	• Germany ~500% Surface area of stagnant water bodies vs. UK[1]	Pacini et al., German Federal Statistical Office	[60], [61], [62]
Soil	Erosion	~0.9	2006/ 2012	EU-13	€6.7 billion, 150 million ha	• German agriculture with ~11% of EU-13 surface area	EU Soil Thematic Strategy	[63]
Live-stock farming	Spread of epidemics	~0.06	2016	Germany	€0.12 billion	• Incl. foot-and-mouth disease, European swine fever, African swine fever • Cost per outbreak per disease ~€0.5 billion • Return period 10 (ESF, ASF) or 20 years (FMD) • 50% of the costs are borne by the German federal state	Agricultural multi-risk insurance for Germany, Lower Saxony Epizootic Fund	[64], [65]
	AB[4] resistances (hospital stays)	~ 0.1	2009	EU	€1.5 billion	• Germany with ~24% of EU health expenditure • AB resistances by food: ~22%	ECDC/EMEA, CDC	[66], [67], [68]
	AB resistances (Research)	~ 0.01	2017	EU	€0.033 billion	• AB resistances by food: ~22%	JPIAMR, CDC	[69]

[1]Inflation adjusted for 2018 [2]England and Wales [3]incl. 38 Mt CO_2e land-use changes [4]AB = Antibiotics
Source: BCG

In general, we have always calculated conservatively, which means that the actual external costs are likely higher. The costs have been adjusted for inflation and are stated in 2018 prices.

An overview of the calculation bases and assumptions is provided in Table 1.

When calculating the external costs, direct payments take into account the EU's existing funding commitments for the current funding period – which runs until 2020. In addition, we refer to the 2018 target values for the costs of agricultural social policy and other administrative costs in the German Federal Ministry of Food and Agriculture. Some of the figures for the 2019 draft budget are higher. The other costs concern State co-financing and subsidies. (Table 2).

TABLE 2 | Derivation of external costs from direct payments, subsidies and other government expenditures

	Cost drivers	Costs in billions of €	Year	REFERENCE Region	Value	Assumptions	Sources	Reference
Direct payments	EU CAP[1] Pillar 1	4.85	2014–2020	Germany	€33.95 billion	• Annual average for funding period 2014–2020	BMEL[2]	[70]
	EU CAP Pillar 2	1.35	2014–2020	Germany	€9.44 billion	• Annual average for funding period 2014–2020	BMEL	[70]
	Co-financing by the German states for Pillar 2	0.67	2014–2020	Germany	€4.7 billion	• Planned use of funds by the German states to promote rural development, 2014–2020	BMEL	[71]
	Additional national funding for Pillar 2	0.39	2014–2020	Germany	€2.7 billion	• Voluntary additional German federal state funds for the promotion of rural development, 2014–2020	BMEL	[71]
Other aid	EU sales promotion	0.19	2018	Germany	188.5 Mio. €	• EU information and promotion measures for agricultural products	BMEL	[72]
Subsidies	Lower tax revenues, agricultural diesel	0.45	2018	Germany	450 Mio. €	• Tax losses due to agricultural diesel fuel	German Federal Ministry of Finance	[73]
	Exemption of agricultural vehicles from vehicle tax	0.06	2012	Germany	60 Mio. €	• Tax exemption for agricultural vehicles from vehicle tax	German Federal Environment Agency	[74]
Agricultural social policy and other administrative costs	Agricultural social policy	3.95	2018	Germany	€3.95 billion	• Target 2018 (Section 1001), incl. old-age provision (€2.3 billion), health insurance (€1.4 billion), etc.	2019 BMEL draft budget	[75]
	Special Framework Plan for Rural Development	0.01	2018	Germany	€0.01 billion	• Target 2018 (element in Section 1003)	2019 BMEL draft budget	[75]
	Market organization, emergency preparedness measures	0.16	2018	Germany	€0.16 billion	• Financing of loans, emergency provisions, etc. (Section 1004)	2019 BMEL draft budget	[75]
	Sustainability, research and innovation	0.38	2018	Germany	€0.38 billion	• Renewable raw materials, promotion of innovation, federal program for rural development, etc. (Section 1005)	2019 BMEL draft budget	[75]
	Institutes	0.38	2018	Germany	€0.38 billion	• Friedrich Loeffler (€112 million), Julius Kühn (€95 million), Thünen (€85 million), etc. ("business division")	2019 BMEL draft budget	[75]

[1]EU Common Agricultural Policy [2]BMEL= German Federal Ministry of Food and Agriculture
Source: BCG

Distribution of External Costs to Different Food Products

In order to allocate external costs to different food products, we have allocated the individual cost items from the calculation of external costs to the respective food products. For greenhouse gas emissions, dedicated statements are sometimes provided that allow a direct allocation of costs to the respective food products. For those cost drivers for which such an exact allocation is not possible, we have allocated the costs via the respective proportional land use or the respective livestock units. We have also allocated subsidies and direct payments via land use. For the producer quantities and prices of the respective goods, we have not differentiated between different production methods, in particular conventional versus organic (Table 3).

TABLE 3 | Assumptions regarding the distribution of external costs among selected food products

	Food products of animal origin	Food products of plant origin	References
Land use in Germany	9.5 million hectares	4.5 million hectares	[4]
Land use in Germany at product level	Land used for animal feed (2017) • Beef: 3.2 million hectares • Pork: 1.3 million hectares • Poultry: 0.8 million hectares • Milk: 3.8 million hectares • Eggs: 0.3 million hectares	BMEL cultivation statistics (2018) • Apples: 0.03 million hectares • Wheat[1]: 1.9 million hectares • Carrots: 0.01 million hectares • Potatoes: 0.3 million hectares	[4], [76], [77], [78], [79]
Production quantities (2018)	• Beef: 1.1 million metric tons • Pork: 4.8 million metric tons • Poultry: 1.8 million metric tons • Milk: 33.0 million metric tons • Eggs: 13.6 million eggs (0.9 million metric tons)	• Apples: 1.2 million metric tons • Wheat[2]: 12.8 million metric tons • Carrots: 625,375 metric tons • Potatoes: 8.9 million metric tons	[79], [80], [81], [82], [83], [84], [85], [86]
Producer price (2018)	• Beef: €3.6/kg • Pork: €1.5/kg • Poultry: €1/kg • Milk: €0.3/kg • Eggs: 7 ct/egg	• Apples: €1.4/kg • Wheat: €0.2/kg • Carrots: €0.7/kg • Potatoes: €0.1/kg	[87], [88], [89], [90], [91]
Ecosystem services Soil Water	Distribution of proportionate external costs via land use		
Climate	• Emissions from soil, LULUCF, fertilizer and plant protection products via land use • Emissions from livestock farming according to 2018 GHG statistics • Emissions from feed imports through feed requirem. (determined in line with consumption in Germany)	• Emissions from soil, LULUCF, fertilizer and plant protection products via land use	[15], [92]
Air	• Emissions from soil and fertilizer exceed land requirements • Emissions from livestock farming, farm manure mgmt via LU or statistics	• Emissions from soil and fertilizer exceed land requirements	[46], [47], [58], [93]
Livestock farming	• Disease costs directly allocated to animals (distribution via LU for cattle) • AB resistance according to use (distribution via LU in cattle/dairy cows) and poultry/laying hens)	• N. a.	[92], [94]
Subsidies	Distribution of proportionate external costs via land use		

[1]Total area under cultivation ~3 million ha, of which ~40% for animal feed (German Federal Ministry of Food and Agriculture statistics 15/16)
[2]Total harvest 20.2 million metric ton, of which ~40% feed (German Federal Ministry of Food and Agriculture statistics 15/16)
[3]BMEL=German Federal Ministry of Food and Agriculture
Source: BCG

For the distribution of air pollutant emissions, we have used data from the German Federal Environment Agency (cf. [46] and [47]), the following additional assumptions were made:

- Share of agricultural soils in NOx emissions: ~90%
- Share of agricultural soils in NMVOC emissions (by spreading manure on soil): ~45%
- Share of storage of manure in NMVOC emissions: ~45%

Explanation of High-impact Methods and Measures for the Reduction of External Costs

In “Effect of methods and measures”, we have explained in greater detail those sustainable methods and measures to which we attribute a high potential for reducing external costs. However, an exact quantification of each potential is not possible given the scientific findings, which, in our view, are not clear.

EFFECT OF METHODS AND MEASURES

1. Wide crop rotations: We consider compliance with further crop rotations as having a high impact on reducing external costs in terms of soil. Wide crop rotations contribute to the recovery of the soil structure through nutrient and humus build-up in the soil as well as to the promotion of soil organisms. The humus build-up in the soil also reduces the erosivity of the soil and the risk of soil compaction. In addition, the use of pesticides can also be reduced by reducing the number of weeds and pests.

2. Undersown seeds and catch crops: The cultivation of catch crops contributes to improving soil fertility and preventing soil erosion.

3. Reduction in the use of pesticides: Reduced use of pesticides has a particularly positive effect on biodiversity, soil and water. The habitat of species in the agricultural landscape and soil fertility are less polluted. In addition, there is a reduced input of pesticides into groundwater and surface waters.

4. Reduction in the use of fertilizers: The effect of reduced fertilizer use is directly reflected in the external costs for soil, water and climate. By reducing the nitrogen surplus in agricultural soils, soil fertility is improved while also reducing the leaching of nitrate into groundwater and the emissions of nitrous oxide from the soil. The climate effects of the production of mineral fertilizers can also be minimized by reducing production quantities.

5. Cultivation of fodder grass and legumes: The cultivation of fodder grass and legumes has a particularly positive effect on the soil and climate. The carbon structure can improve the humus balance in the soil. Higher humus content strengthens the soil for extreme weather conditions. In addition, fodder grass and legumes can increase the domestic supply of fodder.

6. Land-based livestock farming: Land-based livestock farming is primarily accompanied by a reduction in the number of livestock. Fewer animals lead to a reduced amount of slurry and manure and this, in turn, leads to a lower nitrogen load in soil and water. In addition, reduced livestock numbers lead to reduced emissions of greenhouse gases and therefore to a better climate balance for livestock farms. Positive effects on the climate can also be expected from the cultivation and feeding of domestic feed.

7.-8. Creation of fallow land & extensive grassland: The creation of fallow arable land and extensive grassland has a particularly positive effect on the preservation of biodiversity in the agricultural landscape. These areas provide habitats for numerous animal species.

32. Agroforestry systems: The impact of agroforestry systems lies initially in improving soil fertility through the interaction of arable crops and woody plants and protection against soil erosion through the formation of deep roots. The root system of these woody plants can also absorb excess nitrate from the soil and therefore contribute to groundwater protection. In addition, there are positive effects on species diversity, as trees and woody plants are habitats for numerous species.

33. Precision farming and livestock farming: Precision techniques in arable farming (precision agriculture) and livestock farming (precision livestock farming) use sensors and data to optimize production processes and management. Using such techniques in arable farming supports area-specific, target-oriented management of useful space and can contribute to environmental relief. In terms of livestock farming, animal-related data is collected to optimize nutrition and husbandry both economically and with regard to animal health and welfare.

34. Smart farming: These methods are still comparatively new and create a positive effect through the digitalization and networking of existing processes. The use of intelligent agricultural technology and modern data technologies facilitates efficient production processes and helps farmers make decisions. Positive effects on external costs are possible at the environmental, economic and social levels. Innovative solutions such as the use of autonomous field robots and drones can, for example, reduce the use of fertilizers and pesticides.

Source: BCG

Explanation of the Derivation of Potentials through the Use of Methods and Measures to Reduce External Costs

To calculate reduction potentials using selected methods and measures, we have used existing analyses of specific savings potentials, for example for carbon storage, as well as existing assumptions and targets for the reduction of surpluses and land use.

Where possible, we have modeled impacts on all categories for all methods and measures. In some cases, we have made simplistic assumptions about the proportionality of these impacts. We have also refrained from considering interactions and interdependencies between these impacts in the overall view. In our estimation, however, this does not result in any significant difference.

TABLE 4 | Derivation of the reduction potentials of methods and measures

Potential	Category	Potential savings (in b€)	Derivation and assumptions	Sources	References
Carbon storage	**Total**	**~3.0**	• Carbon storage on low-humus mineral soils (~2 million ha) through humus buildup • Conversion of organic arable land into grassland (~1.3 million ha) • Rehydration of 50% grassland	Öko-Institut 2019	[25]
	Eco-system services	~0.5	• Assumption: Improvement of soil biodiversity through increased humus content (more C stored) compared to ACTUAL: 20% • Assumption: Average share of soil in ecosystem services 22% • Assumption: Loss of biodiversity as a proxy for loss of ecosystem services	Agricultural Report 2017 (Switzerland), McBartney et al. (2017), Newbold 2018	[95], [96], [97]
	Climate	~2.4	• CO_2 binding through humus buildup in mineral soils: 2.2 million metric tons CO_2e (2 million ha) • Conversion of organic arable land into grassland: 3.0 Mt CO_2e (1.3 million ha) • 50% conversion of grassland from deeply drained to weakly drained: 7.9 Mt CO_2e (0.7 million ha)	Öko-Institut 2019	[25]
	Soil	~0.04	• Assumption: Reduced risk of silting and erosion on humus-rich soils: 25% • Area with reduced risk: 3.3 million ha (grassland + mineral soils) • Area without risk of erosion: 0.7 million ha (rehydrated marshland)	Soil Atlas 2015, Bavarian State Research Center for Agriculture 2019	[98], [99]
	Water	~0.04	• Assumption: Improved storage capacity on humus-rich soils: 25% • Area with improved storage capacity: 3.3 million ha (1.3 million ha grassland + 2 million ha mineral soils)	Soil Atlas 2015	[98]
Land-based livestock farming	**Total**	**~2.4**	• Upper limit of 1.5 livestock units at county level (i.e. reduction of livestock by approx. 7%)	Öko-Institut 2019	[25]
	Eco-system services	~0.3	• Assumption: Reduction of air pollutant emissions from livestock farming by 7% (NH_3, PM10, NMVOC) • Biodiversity cost rate for air pollutant emissions: NH_3 10,400 €/t, PM10 0 €/t, NMVOC 0 €/t • Assumption: Loss of biodiversity as a proxy for loss of ecosystem services	German Federal Environment Agency, Newbold 2018	[52], [58], [97]
	Climate	~0.6	• Reduction of emissions from livestock farming (nitrous oxide and methane) by 2.48 million metric tons of CO_2e • Reduction of emissions from feed imports (rapeseed and soy) by 7%	Öko-Institut 2019, German Federal Environment Agency	[15], [25]
	Air	~1.4	• Assumption: Reduction of air pollutant emissions from livestock farming by 7% (NH_3, PM_{10}, NMVOC) • Cost rate for damage to health for air pollutant emissions: NH_3 21,700 €/t, PM_{10} 41,200 €/t, NMVOC 1,100 €/t	German Federal Environment Agency	[46], [47], [52], [58], [93]
	Livestock farming	~0.01	• Assumption: Proportional reduction of external costs through AB resistance and animal diseases	Simplified assumption	

Potential	Category	Potential savings (in b€)	Derivation and assumptions	Sources	References
Input optimi-zation	**Total**	**~15.9**	• Reduction of N surplus through slurry treatment and preparation & exhaust air cleaning in stables to 50 kg/ha • Reduction of plant protection products by 70% (e.g. through optimized application and application techniques)	Öko-Institut 2019, EU Parliament Research Service (2019), Zerger and Holm-Müller 2008	[25], [26], [27]
	Eco-system services	~14.6	• Assumption: N-surplus share of biodiversity losses: 20% • Assumption: Share of PPP in biodiversity loss: 30% • Assumption: Loss of biodiversity as a proxy for loss of ecosystem services	Sanchez-Bayo & Wyckhuys 2019, Newbold 2018	[97], [100]
	Climate	~1.2	• Reduction of N surplus to 50 kg/ha: 5.4 million metric tons of CO_2e • Assumption: Reduction of external costs for plant prot. prod. production: 70%	Öko-Institut 2019, simplified assumption	[25]
	Water	~0.1	• Proportion of reactive nitrogen compounds in the environment: ~67% • Assumption: Percentage of N-compounds in water in the environment: 50% • Assumption: Proportional reduction of external costs for nitrate limit compliance by 16%	Öko-Institut, German Federal Environment Agency	[101], [102]
Nature conservation structural measures	**Total**	**~3.1**	• Area of new fallow land compared to today: 0.96 million ha (10% quota for all farms with an area of at least 15 ha)	WWF target	
	Eco-system services	~2.5	• Assumption: Improvement of biodiversity on fallow land compared to ACTUAL: 90% • Assumption: Loss of biodiversity as a proxy for loss of ecosystem services • External costs for biodiversity on fallow land: 284 €/ha (vs. regular 2,843 €/ha)	ZALF, Newbold 2018	[97], [103]
	Climate	~0.3	• Assumption: Emissions from fallow land: 0 (vs. regular 26.6 million metric tons of CO_2e to 16.7 million ha)	Simplified assumption	
	Air	~0.3	• Assumptions for share of air pollutant emissions from agricultural soils: PM_{10} = 57%, NO_x = 90%, NMVOC = 48%, NH_3=16% • Assumption: Air pollutant emissions on fallow land: 0 • Cost rates for air pollutant emissions for damage to health	German Federal Environment Agency, simplified assumption	[46], [47], [52], [58], [93]
	Soil	~0.05	• Assumption: Risk of erosion on prioritized nature conservation areas: 0 • Proportional reduction of erosion costs for additional prioritized nature conservation areas	Simplified assumption	

Source: BCG

Explanation of the Derivation of Yield Losses through the Use of Methods and Measures to Reduce External Costs

The methods and measures used to reduce external costs are accompanied by a decline in yield. We have modeled these separately for food products of plant and animal origin (see Figure A6). It would only be possible to consider the overall impact if an assumption were made as to how high the proportion of yields from food products of animal origin is commensurate to overall yield in Germany.

TABLE 5 | Loss of earnings due to potential

FOOD PRODUCTS OF PLANT ORIGIN

Potential	Drivers	Assumption	Sources	Earnings effect driver/ surface area	Earnings effect on total	References
Carbon storage	Conversion from arable to grassland (0.4 million ha)	• Loss of yield approx. 50% measured by average nutritional value of primary feed and grassland fodder	Own calculation[1]	~-50%	~-1%	
	Rehydration of marshlands (0.7 million ha)	• Marshlands are taken out of agricultural use, i.e. 100% loss of yield	n. a.	-100%	~-4%	
	Increased humus content on mineral soils (2.4 million ha)	• If the humus content is low, doubling the humus content (+100%) through catch crops and optimizing crop rotation leads to a 20% increase in yield; assumption here: Increase humus content by ~80%	Bavarian State Research Center for Agriculture (2019)	~+16%	~+3%	[104]
Input optimization	Reduction of pesticide use through precision farming	• No harvest reduction, as reduction potential assumed achievable mid-to-long-term through precision techniques	EU Parliament Research Service (2019), Zerger, Holm-Müller (2008)	0%	0%	[26], [27]
	Reduction of N surpluses (cf. organic farming)	• Organic farming with ~80% yield potential from conventional farming; assumption here: Optimized use of fertilizers and reduction of use to organic farming standards with yield potential of ~90%	Ponisio 2015	~-10%	~ -10%	[105]
Nature conservation structural measures		• Areas are taken out of agricultural use, i.e. 100% loss of yield	n. a.	-100%	~-6%	
Total					**~-18%**	

FOOD PRODUCTS OF ANIMAL ORIGIN

Potential	Drivers	Assumption	Sources	Earnings effect driver/ surface area	Earnings effect on total	References
Land-based livestock farming	Reduction in livestock units	• Yield potential for food products of animal origin is reduced proportionally	n. a.	-7%	-7%	
Total					**-7%**	

[1]Approximation of the energy content of primary feed. Arable land (wheat, barley, grain/silage maize, rapeseed) ~97,000 MJ NEL/ha vs. Grassland fodder ~47,000 MJ NEL/ha (source: LKSH, Bavarian State Research Center for Agriculture, Öko-Institut, own calculations)
Source: BCG

Derivation of Reduction Potentials for the Scenarios Used

To model each of the scenarios used, we have in some cases made highly simplified assumptions in order to be able to represent the reduction potentials of each thought experiment. To carry out these calculations, we have used the land requirements for domestic land for domestic consumption as well as for the export of food products.

Depending on the scenario, we applied the reduction potentials proportionally to the respective cost drivers of the external costs. This means, for example, that in scenario 1, if we stop exporting, we would need around seven million hectares less domestic land. This corresponds to a reduction in agricultural land in Germany (16.7 million hectares) of around 40 percent, and all land-related costs would be reduced by this factor.

TABLE 6 | Calculation basis and assumptions for modeling the scenarios used

Used in scenario	Input variable	Value	Sources	References
1 4	Domestic land requirements for export of food products (2017)	6.94 million hectares	Destatis[1] 2019	[4]
1 4	Export quota of food products of animal origin (2014)	~40%	BMEL[2] statistics 2017	[2]
2 4	Food waste in Germany	~30%	WWF 2012, UBA 2019	[30]
3 4	Annual meat consumption per capita	60 kg	BVDF[3] 2018	[106]
3 4	Land requirements for domestic consumption of meat and sausages	6.6 million hectares	Destatis 2019	[4]

[1]Destatis=German Federal Statistical Office [2]BMEL=German Federal Ministry of Food and Agriculture [3]BVDF= National Association of German Meat Products Industry
Source: BCG

Bibliography

[1] **German Federal Statistical Office**, Statistisches Jahrbuch 2018: Land- und Forstwirtschaft, 2019

[2] **German Federal Ministry of Food and Agriculture**, Agrarexporte 2017 – Daten und Fakten, 2017

[3] **German Federal Ministry of Food and Agriculture**, Landwirtschaftliche Gesamtrechnung, https://www.bmel-statistik.de/landwirtschaft/landwirtschaftliche-gesamtrechnung, 2018 [last accessed 9/24/2019]

[4] **German Federal Statistical Office**, Umweltökonomische Gesamtrechnungen: Flächenbelegung von Ernährungsgütern 2010–2017, 2019

[5] **German Federal Environment Agency**, Ökologischer Landbau, https://www.umweltbundesamt.de/daten/land-forstwirtschaft/oekologischer-landbau#textpart-1, 2019 [last accessed 9/24/2019]

[6] **Thünen Institut**, Thünen Working Paper 100, Entwicklungen des Obstbaus in Deutschland von 2005 bis 2017: Obstarten, Anbauregionen, Betriebsregionen und Handel, 2018

[7] **Thünen Institut**, Steckbriefe zur Tierhaltung in Deutschland: Ein Überblick, 2018

[8] **Eurostat**, Output of the agricultural industry - basic and producer prices, https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tag00102&plugin=1, 2018 [last accessed 9/24/2019]

[9] **Federal Ministry of Food**, Agriculture and Consumer Protection, Agricultural Policy Report, 2019

[10] **German Federal Agency for Nature Conservation**, Indikator Artenvielfalt und Landschaftsqualität, https://www.bfn.de/themen/monitoring/indikatoren/indikator-artenvielfalt-und-landschaftsqualitaet.html, 2019 [last accessed 9/24/2019]

[11] **WWF**, Boden Bulletin: Landbau in Zeiten der Erderhitzung, 2018

[12] **German Federal Environment Agency**, Nährstoffeinträge aus der Landwirtschaft und Stickstoffüberschuss, https://www.umweltbundesamt.de/daten/land-forstwirtschaft/naehrstoffeintraege-aus-der-landwirtschaft#textpart-1, 2019 [last accessed 9/24/2019]

[13] **Bauernverband**, Situationsbericht 2018/19: Umwelt und Ressourcenschutz in der Landwirtschaft, 2019

[14] **German Federal Ministry of Food and Agriculture**, Nitratbericht 2016, 2017

[15] **German Federal Environment Agency**, Nationaler Inventarbericht zum Deutschen Treibhausgasinventar 1990–2017, 2019

[16] **Climate Protection Forum WZW TUM**, Climate Protection Forum, School of Life Sciences, Technical University of Munich, Land use and Agriculture (Box 7), http://www.climate.wzw.tum.de/forum.html, 2019 [last accessed 9/24/2019]

[17] **German Federal Ministry of Food and Agriculture**, Lagebild zur Antibiotikaresistenz im Bereich Tierhaltung und Lebensmittelkette, 2018

[18] **Vexcash**, Ausgaben für Lebensmittel: Das geben wir für Essen aus, https://www.vexcash.com/blog/internationale-ausgaben-fuer-lebensmittel, 2017 [last accessed 9/24/2019]

[19] **German Federal Ministry of Food and Agriculture**, Statistisches Jahrbuch 2018: Kapitel C Landwirtschaft, 2018

[**20**] **Bauernverband**, Situationsbericht 2016/17: Agrarstruktur, 2017

[**21**] **German Federal Environment Agency**, Bodenbelastungen: Verdichtung, https://www.umweltbundesamt.de/themen/boden-landwirtschaft/bodenbelastungen/verdichtung#textpart-5, 2019 [last accessed 9/24/2019]

[**22**] **German Federal Government**, Climate Action Programme 2030, https://www.bundesregierung.de/breg-en/issues/climate-action/klimaschutzprogramm-2030-1674080, 2019 [last accessed 9/24/2019]

[**23**] **IPCC**, Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems, 2019

[**24**] **Joint Research Centre of the European Commission**, World Desertification Atlas, 2018

[**25**] **Scheffler**, Margarethe and Wiegman, Kirsten, Öko-Institut, Quantifizierung von Maßnahmenvorschlägen der deutschen Zivilgesellschaft zu TH-Minderungspotenzialen in der Landwirtschaft bis 2030, 2019

[**26**] **European Parliamentary Research Service**, Farming without plant protection products, 2019

[**27**] **Zerger**, Corinna and Holm-Müller, Karin, Forschungsbericht Nr. 156: Gemeinwohl steigernde Leistungen der Landwirtschaft, 2008

[**28**] **European Court of Auditors**, Special Report 21, Greening: a more complex income support scheme, not yet environmentally effective, 2017.

[**29**] **University of Stuttgart**, Neue Forschungsergebnisse der Universität Stuttgart zu Lebensmittelabfällen, https://www.uni-stuttgart.de/universitaet/aktuelles/presseinfo/Neue-Forschungsergebnisse-der-Universitaet-Stuttgart-zu-Lebensmittelabfaellen/, 2019 [last accessed 9/24/2019]

[**30**] **German Federal Environment Agency**, Lebensmittelverschwendung: Wider die Verschwendung, https://www.umweltbundesamt.de/themen/wider-die-verschwendung, 2019 [last accessed 9/24/2019]

[**31**] **EAT-Lancet Commission**, Healthy Diets From Sustainable Food Systems, 2019

[**32**] **Braat**, L., ten Brink, P. et al., Alterra-rapport 1718, The Cost of Policy Inaction: The case of not meeting the 2010 biodiversity target, 2008

[**33**] **Helmholtz Centre for Environmental Research**, Naturkapital Deutschland – TEEB DE (2012): Der Wert der Natur für Wirtschaft und Gesellschaft – Eine Einführung, 2012

[**34**] **Hansjürgens**, B. et al., Helmholtz Centre for Environmental Research, Naturkapital Deutschland – TEEB DE (2018): Werte der Natur aufzeigen und in Entscheidungen integrieren – eine Synthese, 2018

[**35**] **European Parliament**, European Parliament resolution of 20 April 2012 on our life insurance, our natural capital: an EU biodiversity strategy to 2020 (2011/2307(INI)), 2011

[**36**] **TEEB**, Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB, 2010

[**37**] **Leonhardt**, Sara Diana, Gallai, Nicola et al., Basic and Applied Ecology (vol. 14), Economic gain, stability of pollination and bee diversity decrease from southern to northern Europe, 2013

[**38**] **Hansjürgens**, Bernd, Schröter-Schlaack, Christoph and Settele, Josef, Natur und Landschaft (vol. 94), Zur ökonomischen Bedeutung der Insekten und ihrer Ökosystemleistungen, 2019

[**39**] **EU Commission**, European Union, The EU Biodiversity Strategy to 2020, 2011

[**40**] **Losey**, J.E. and Vaihan, M., BioScience (vol. 56), The Economic value of Ecological Services Provided by Insects, 2006

[**41**] **German Federal Office for Agriculture and Food**, Statistischer Monatsbericht MBT-0104130-0000, Bodennutzung 2018, 2019

[**42**] **Minasny**, Budiman et al., Geoderma (vol.292), Soil carbon 4 per mille, 2017

[**43**] **Thünen Institute**, Thünen Report (No. 64), Bodenzustandserhebung Landwirtschaft, 2018

[**44**] **Batjes**, Niels H., Land Degradation and Development (vol. 30), Technologically achievable soil organic carbon sequestration in world croplands and grasslands, 2018

[**45**] **Lal**, Rattan, Global Change Biology (vol. 24), Digging deeper: A holistic perspective of factors affecting soil organic carbon sequestration in agroecosystems, 2018

[**46**] **German Federal Environment Agency**, Emission flüchtiger organischer Verbindungen ohne Methan (NMVOC), https://www.umweltbundesamt.de/daten/luft/luftschadstoff-emissionen-in-deutschland/emission-fluechtiger-organischer-verbindungen-ohne#textpart-1, 2019 [last accessed 9/24/2019]

[**47**] **German Federal Environment Agency**, Stickstoffoxid-Emissionen, https://www.umweltbundesamt.de/daten/luft/luftschadstoff-emissionen-in-deutschland/stickstoffoxid-emissionen#textpart-2, 2019 [last accessed 9/24/2019]

[**48**] **German Federal Environment Agency**, Eutrophierung, https://www.umweltbundesamt.de/themen/wasser/gewaesser/meere/nutzung-belastungen/eutrophierung, 2010 [last accessed 9/24/2019]

[**49**] **Forster**, P., Ramaswarmy, V., Artaxo, P. et al, Cambridge University Press, Changes in Atmospheric Constituents and in Radiative Forcing [authors], Solomon, S. and Qin, D., Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007

[**50**] **Thünen Institute**, Betriebliche Stoffstrombilanzen für Stickstoff und Phosphor – Berechnung und Bewertung, 2017

[**51**] **Greifswald Mire Centre**, MoorWissen – Informational platform about mires and climate protection, Paludiculture - agriculture and forestry on rewetted peatlands, https://www.moorwissen.de/en/paludikultur/paludikultur.php, 2017 [last accessed 9/24/2019]

[**52**] **German Federal Environment Agency**, Methodological Convention 3.0, 2019

[**53**] **Industrieverband Agrar**, Wichtige Zahlen: Düngemittel – Produktion, Markt, Landwirtschaft, 2013

[**54**] **German Federal Environment Agency**, ProBas: Prozessorientierte Basisdaten für Umweltmanagementsysteme, 2019

[**55**] **German Federal Environment Agency**, Pflanzenschutzmittelverwendung in der Landwirtschaft, https://www.umweltbundesamt.de/daten/land-forstwirtschaft/pflanzenschutzmittelverwendung-in-der#textpart-1, 2019 [last accessed 9/24/2019]

[**56**] **German Federal Office for Agriculture and Food**, Futteraufkommen im WJ 2017/18, 2019

[**57**] **Reichert**, Tobias and Reichardt, Marion, Forum Umwelt & Entwicklung, Saumagen und Regenwald, 2011

[**58**] **German Federal Environment Agency**, Luftschadstoff-Emissionen in Deutschland, https://www.umweltbundesamt.de/daten/luft/luftschadstoff-emissionen-in-deutschland, 2019 [last accessed 9/24/2019]

[**59**] **German Federal Environment Agency**, Quantifizierung der landwirtschaftlich verursachten Kosten zur Sicherung der Trinkwasserbereitstellung, 2017

[**60**] **Food and Agriculture Organization of the United Nations** (**FAO**), United Kingdom: Hydrography and limnology, http://www.fao.org/3/t0798e/T0798E16.htm, 1991 [last accessed 9/24/2019]

[**61**] **German Federal Statistical Office**, Floor area [sic] total according to types of use in Germany, https://www.destatis.de/EN/Themes/Economic-Sectors-Enterprises/Agriculture-Forestry-Fisheries/Land-Use/Tables/areas-new.html, 2017 [last accessed 9/24/2019]

[**62**] **Jacobs UK Ltd.**, Environmental Accounts for Agriculture: Report to Defra, Welsh Assembly Government, Scottish Government. London: Department of Agriculture and Rural Development, 2008

[**63**] **European Commission**, The implementation of the Soil Thematic Strategy and ongoing activities (/* COM/2012/046 final */), 2012

[**64**] **German Insurance Association** (**GDV**), Landwirtschaftliche Mehrgefahrenversicherung für Deutschland, 2016

[**65**] **Lower Saxony Epizootic Fund**, Jahresbericht 2017, 2018

[**66**] **U.S. Department of Health and Human Services**, Antibiotic Resistance Threats in the United States, 2013

[**67**] **European Centre for Disease Prevention and Control**, The bacterial challenge: Time to react, 2009

[**68**] **Eurostat**, Current healthcare expenditure 2016, https://ec.europa.eu/eurostat/statistics-explained/index.php/Healthcare_expenditure_statistics, 2019 [last accessed 9/24/2019]

[**69**] **JPIAMR**, AMR Research Funding Dashboard, https://www.jpiamr.eu/amr-research-funding-dashboard, 2019 [last accessed 9/24/2019]

[**70**] **German Federal Ministry of Food and Agriculture**, Grundzüge der Gemeinsamen Agrarpolitik (GAP) und ihrer Umsetzung in Deutschland, https://www.bmel.de/DE/Landwirtschaft/Agrarpolitik/_Texte/GAP-NationaleUmsetzung.html, 2019 [last accessed 9/24/2019]

[**71**] **German Federal Ministry of Food and Agriculture**, Entwicklung des ländlichen Raumes 2014–2020, https://www.bmel.de/DE/Laendliche-Raeume/03_Foerderung/Europa/_texte/Foerderung2014-2020.html?nn=5774216&notFirst=true&docId=5493798, 2019 [last accessed 9/24/2019]

[**72**] **German Federal Ministry of Food and Agriculture**, EU-Informations- und Absatzförderungsmaßnahmen für Agrarerzeugnisse, https://www.bmel.de/DE/Landwirtschaft/Foerderung-Agrarsozialpolitik/_Texte/EU-Absatzfoerderung.html, 2019 [last accessed 9/24/2019]

[**73**] **German Federal Ministry of Finance**, 26th Subsidy Report, 2017

[**74**] **German Federal Environment Agency**, Umweltschädliche Subventionen in Deutschland, 2016

[**75**] **German Federal Ministry of Food and Agriculture**, Regierungsentwurf Haushalt 2019, 2018

[**76**] **German Federal Office for Agriculture and Food**, Bericht zur Markt- und Versorgungslage: Kartoffeln, 2019

[**77**] **German Federal Ministry of Food and Agriculture**, Obsternte 2018, 2019

[**78**] **Statistisches Bundesamt**, Acreage, yield per hectare and harvest volume of selected crops in a time comparison, https://www.destatis.de/EN/Themes/Economic-Sectors-Enterprises/Agriculture-Forestry-Fisheries/Field-Crops-Grassland/_node.html, 2019 [last accessed 9/24/2019]

[**79**] **German Federal Office for Agriculture and Food**, Anteil der Futtererzeugung an der landwirtschaftlichen Produktion, 2017

[**80**] **German Federal Ministry of Food and Agriculture**, Kartoffelernte 2018: kleine Menge – knappe Marktversorgung, https://www.bmel-statistik.de/landwirtschaft/ernte-und-qualitaet/kartoffelernte, 2018 [last accessed 9/24/2019]

[**81**] **German Federal Office for Agriculture and Food**, Marktbericht: Obst, Gemüse, Südfrüchte, 2018

[**82**] **German Federal Ministry of Food and Agriculture**, Gemüseanbau in Deutschland 2018, 2019

[**83**] **German Federal Office for Agriculture and Food**, Erzeugung von Milchfett und Milcheiweiß in Deutschland, 2019

[**84**] **German Federal Office for Agriculture and Food**, Versorgung mit Fleisch in Deutschland im Kalenderjahr 2018, 2019

[**85**] **German Federal Office for Agriculture and Food**, Geflügelfleischerzeugung in Deutschland, https://www.praxis-agrar.de/tier/gefluegel/gefluegelfleischerzeugung, 2019 [last accessed 9/24/2019]

[**86**] **German Federal Office for Agriculture and Food**, Versorgungsbilanz Eier, 2019

[**87**] **German Federal Ministry of Food and Agriculture**, Preise und Löhne: Marktpreise für inländische Getreide, 2019

[**88**] **German Federal Ministry of Food and Agriculture**, Milchpreise und Milchmengen, https://www.ble.de/SharedDocs/Downloads/DE/BZL/Daten-Berichte/MilchUndMilcherzeugnisse/JaehrlicheErgebnisse/Deutschland/Dt_Grundlagen/Erzeugung_Milchfett_Milcheiweiss_406003001_12.html, 2019 [last accessed 9/24/2019]

[**89**] **Top Agrar**, Erzeugerpreise für Geflügel über Vorjahr, https://www.topagrar.com/gefluegel/erzeugerpreise-fuer-gefluegel-ueber-vorjahr-10136233.html, 2018 [last accessed 9/24/2019]

[**90**] **Agrarmarkt Austria**, Europäische Union: Eierpreise in EUR/100 kg, 2019

[**91**] **Rhineland-Palatinate Chamber of Agriculture**, Marktbericht: Eier/Geflügel, Eierpreise Gewichtsklasse L Bodenhaltung, https://www.lwk-rlp.de/de/markt-statistik/marktbericht/marktbericht/news/detail/News/eiergefluegel, 2018 [last accessed 9/24/2019]

[**92**] **German Federal Ministry of Food and Agriculture**, Landwirtschaftliche Betriebe mit Viehhaltung nach Großvieheinheiten, 2016

[**93**] **German Federal Environment Agency**, Emission von Feinstaub der Partikelgröße PM10, https://www.umweltbundesamt.de/daten/luft/luftschadstoff-emissionen-in-deutschland/emission-von-feinstaub-der-partikelgroesse-pm10#textpart-1, 2019 [last accessed 9/24/2019]

[**94**] **NRDC**, Turkey Is Bad on Antibiotics – Pork and Beef, Even Worse, https://www.nrdc.org/experts/david-wallinga-md/analysis-high-intensity-antibiotics-us-beef-pork, 2018 [Last accessed 9/24/2019]

[**95**] **Swiss Federal Office for Agriculture FOAG**, Agrarbericht 2017, http://2017.agrarbericht.ch/de/umwelt/biodiversitaet/bodenbiodiversitaet, 2017 [last accessed 9/24/2019]

[**96**] **McBartney et al.**, Global Soil Security, The Value of Soil's Contributions to Ecosystem Services, 2017

[**97**] **Newbold**, Tim, Proceedings of the Royal Society B (vol. 285), Future effects of climate and land-use change on terrestrial vertebrate community diversity under different scenarios, 2018

98] **Heinrich Böll Foundation**, Soil Atlas 2015: Facts and figures about earth, land and fields, 2015

[**99**] **Bavarian State Research Center for Agriculture**, Bedeutung des Humus für die Bodenfruchtbarkeit, https://www.lfl.bayern.de/iab/boden/031125, 2019 [last accessed 9/24/2019]

[**100**] **Sanchez-Bayo**, Francisco and Wyckhuys, Kris A.G, Biological Conservation, Worldwide decline of the entomofauna: A review of its drivers, 2019

[**101**] **German Federal Environment Agency**, Reaktiver Stickstoff in Deutschland, 2015

[**102**] **Repenning**, Julia, et al., Folgenabschätzung zu den ökologischen, sozialen und wirtschaftlichen Folgewirkungen der Sektorziele für 2030 des Klimaschutzplans 2050 der Bundesregierung, 2019

[**103**] **Leibniz Centre for Agricultural Landscape Research**, Kleinflächige Ackerstillegungen als Vorrangflächen für den Naturschutz, 2002

[**104**] **Bavarian State Research Center for Agriculture**, Ertragswirkung unterschiedlicher Humusgehalte, https://www.lfl.bayern.de/iab/boden/031146, 2019 [last accessed 9/24/2019]

[**105**] **Ponisio**, Lauren C. and Leithen, K.M'Gonigle, Mace, Kevi C., Proceedings of the Royal Society B (vol. 282), Diversification practices reduce organic to conventional yield gap, 2015

[**106**] **Bundesverband der deutschen Fleischindustrie**, Fleischverbrauch und Fleischverzehr je Kopf der Bevölkerung, https://www.bvdf.de/in-zahlen/tab-05, 2018 [last accessed 9/24/2019]

[**107**] **Eurostat**, https://ec.europa.eu/eurostat/statistics-explained/index.php/Performance_of_the_agricultural_sector

[**108**] **Eurostat**, https://ec.europa.eu/eurostat/statistics-explained/index.php/Farmers_and_the_agricultural_labour_force_-_statistics

[**109**] **Eurostat**, https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_greenhouse_gas_emissions

TO THE READER

The authors

Dr. Torsten Kurth is a Managing Director and Senior Partner at the Berlin office of Boston Consulting Group. He leads BCG's agriculture topic in Europe.

Dr. Holger Rubel is a Managing Director and Senior Partner at the Frankfurt office of Boston Consulting Group.

Alexander Meyer zum Felde is an Associate Director and expert on total societal impact, sustainability, and circular economy at the Hamburg office of Boston Consulting Group.

Jörg-Andreas Krüger is the President of the Nature and Biodiversity Conservation Union (NABU) and is a former member of management at the WWF Germany, where he was responsible for conservation and ecological footprint.

Sophie Zielcke is a Project Leader with a focus on sustainability at the Berlin office of Boston Consulting Group. She spearheaded this study.

Dr. Michael Günther is a Consultant at the Düsseldorf office of Boston Consulting Group.

Prof. Dr. Birte Kemmerling is a BCG alumna. She teaches business administration with a specialization in marketing at the University of Applied Sciences in Bremerhaven.

Acknowledgements

First, we would like to thank all the farmers with whom we conducted highly informative interviews and whose honest perspectives we found to be very enriching for our study.

We would also like to thank everyone who, in their roles as representatives of agricultural research institutes, agricultural associations and agricultural policy, made significant contributions to the preparation of this study with their helpful and constructive comments.

We are particularly grateful to the members of the WWF Germany team for their extensive and constructive input, support in the evaluation of analyses, and intensive discussions of implications: Michael Berger, Rolf Sommer, Benthe Libner, Prof. Diana Pretzell, Christoph Heinrich, and Tanja Draeger de Teran.

Finally, we would like to thank Lida Lottko for her support in interviewing farmers, Jan-Frederik Jerratsch, and Kati Fuisz-Kehrbach for their contributions to this report, Anne Goergen for her assistance in composing the study, and Ellen Felder, Simone Schuldlos, and Gerd Meyer for their support with organization, editing, and graphics.

Contact information

For further information, please contact the authors of this study.

Dr. Torsten Kurth
Managing Director and Senior Partner
BCG Berlin
+49 30 2887-1185
Kurth.Torsten@bcg.com

Dr. Holger Rubel
Managing Director and Senior Partner
BCG Frankfurt
+49 69 9150-2302
Rubel.Holger@bcg.com

Alexander Meyer zum Felde
Associate Director—total societal impact, sustainability, and the circular economy
BCG Hamburg
+49 40 3099-6238
Meyer.zum.Felde.Alexander@bcg.com

Jörg-Andreas Krüger
President
Nature and Biodiversity Conservation Union (NABU)
+49 30-284984-0
Joerg-Andreas.Krueger@NABU.de

Sophie Zielcke
Project Leader
BCG Berlin
+49 30 2887-1220
Zielcke.Sophie@bcg.com

Dr. Michael Günther
Consultant
BCG Düsseldorf
+49 211 3011-3398
Guenther.Michael@bcg.com

Prof. Dr. Birte Kemmerling
Professor of business administration with specialization in marketing
University of Applied Sciences Bremerhaven
+49 471 4823-202
bkemmerling@hs-bremerhaven.de

Further informations you will find on our webpage www.bcg.de

Follow us on Facebook and Twitter.

11/2019

bcg.com