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Regenerative agriculture

Ecological and economic added value in the food production industry – using the grain supply chain as an example

pwc Klim

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Prefaces

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How can agriculture, the processing industry, and the food retail industry work together to reduce greenhouse gas emissions and, at the same time, guarantee a sustainable, economically viable food supply? In order to develop effective and pragmatic solutions to this question, PwC has sought dialogue with farmers and food retailers together with Klim. The direct exchange with players in the value chain, as well as an example based on a detailed analysis of an arable farm in Germany, have provided crucial insights for the journey towards a sustainable transformation with regenerative practices. The results clearly show that successful implementation is only possible with the help of all involved parties. With this guide, we would like to promote an open dialogue which both sides wish to have urgently, to create future-ready and sustainable solutions together. We thank all those involved for their openness, engagement, and constructive discussions.

Tino Ryll
Farmer

The predominant contemporary challenges in agriculture include extreme weather conditions, and the rethinking of previous agricultural practices. Regenerative agriculture is a complex system with many building blocks that must work together to make soil more fertile again. It's a process that takes a lot of time, and patience is needed, but it's worth it. A clear advantage of regenerative practices is that farmers relearn how natural cycles, and the laws of nature, work. But first, a balance in the distribution of profits must be achieved throughout the whole value chain. Society demands sustainability, especially in agriculture. But the question is: who pays for that? Concepts are needed to make it possible, and communication between all players is vital. Only like this can a system be created that everybody is happy with.

Silke Düwel-Rieth
Director Sustainable Business & Markets, WWF Germany

Terms like “regenerative agriculture” and “carbon farming” are linked to big hopes to promote agriculture adapted to climate change, and at the same time to help greatly with climate protection by deploying carbon sinks. As an environmental protection organisation with decades of experience in the field of land use and climate protection, we welcome these approaches. But we shouldn’t forget to focus on the reduction of emissions. Climate protection mainly means reducing emissions. The build-up of carbon sinks, especially the build-up of humus, is linked to great challenges – and it’s not easy to make that possible. To avoid greenwashing, strict criteria must be observed in the implementation of, and communication surrounding the contribution of carbon sinks. The Science Based Targets Initiative (SBTi), and the Greenhouse Gas Protocol help with that. Climate protection and a more sustainable agriculture form one joint task within the whole value chain, a fact which is well-illustrated in this guide.

Prof. Dr Alexander Bassen
Chair of the Independent Standards Board, Greenhouse Gas Protocol & Professor, University Hamburg

Regenerative agriculture stands for a new era in which ecological responsibility and economic profitability go hand in hand. This guide isn’t just a tool, it’s an invitation to go on this journey together. Considering climate change, the degradation of the soil and increasing demands for sustainability, regenerative practices offer a perspective that transcends today. A central element of this transformation is the usage of the Greenhouse Gas (GHG) Protocol, which enables transparency and comparability for the accounting of emissions. This guide shows how a sustainable future can be created: through innovative approaches, sound analyses, practical recommendations, and effective collaboration between all players in the value chain. Let’s work together to make sure regenerative agriculture doesn’t remain a vision – let’s make it reality.



Aim of this guide

Climate change presents considerable challenges to agriculture. Quite often, there's a tension between agriculture, which generates greenhouse gas emissions (GHG), and the processing and food retail industries, which account for these emissions and partially finance reductions. This is particularly clear when listening to different views on roles and responsibilities. Willingness to implement measures to reduce emissions also varies greatly among agricultural players, which can make collaboration more difficult.

The concept of regenerative agriculture is a promising approach to tackle the challenges of climate change. Even though the term itself is relatively new, it is based on proven agricultural principles. Both conventional and organic farming systems can implement regenerative practices into their operations. The goal of these practices is to optimise soil health and fertility and to increase the resilience of the whole ecosystem of farms. This resilience can be of great importance when farmers have to deal with challenges such as yield pressure and uncertain income.

This guide analyses an example farm from Germany to evaluate the implementation of regenerative practices and the associated accounting of GHG. The relevant requirements for recording agricultural climate impacts are considered, and the collaboration among all players in the value chain is examined.

It becomes clear that targeted incentives are key to supporting the implementation of such practices.

The close collaboration of agriculture, and the processing and food retail industries promotes both climate protection and a stable productivity in value chains. Regenerative practices are the key to a more sustainable future, and this guide shows which basic principles pave the way to reach that goal.

Aim of the guide
To promote mutual understanding and a closer collaboration between agriculture, industries, and retail to reduce emissions and together ensure the long-term economic availability of food in a healthy ecosystem.

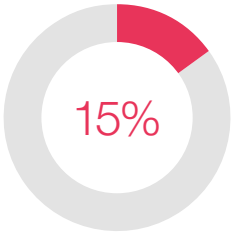


A

Introduction: Why regenerative practices are so important

1 The food and agriculture industries must act to ensure long-term food security and to respect the boundaries of our planet

Land agriculture and forestry both play a vital role in food production worldwide, which, at the same time, causes GHG emissions. With a share of around 15 percent[1] of the total global emissions, they are the second-largest source of emissions worldwide, right after the energy sector. In Germany, the share of agriculture of the total emissions in 2022 was 8 percent.[2] The degradation and leaching of soils, as well as the limited availability of natural soil resources, was particularly challenging. This also becomes clear when looking at the current status of the nine planetary boundaries, which provide an important insight into the ecological health of our planet Earth. Planetary boundaries designate nine ecological thresholds which, if exceeded, could endanger the stability of the Earth's ecosystems. These include processes and dimensions such as climate change, land use, and the conservation of the biosphere.[3] Many practices of the conventional agriculture have negative impacts on ecosystems. They contribute to exceeding planetary boundaries, for example through the decline in biodiversity and negative environmental impacts on natural water flows, as well asnitrogen and phosphorus cycles.[4]



Proportion of GHG emissions from agriculture and forestry to the global total amount

[1] cf. Ritchie et al., 2023.
[2] cf. Bundesministerium für Ernährung und Landwirtschaft, 2024.
[3] cf. Rockström, J. et al., 2009.
[4] cf. Umweltbundesamt, 2024c; Ritchie et al., 2023.

Promoting soil health, water availability, and biodiversity is so important to ensuring food supplies in the future. As a result, practices to protect ecosystems and strengthen climate resilience – the ability to withstand the impacts of the climate crisis and to make the business model resilient to climate change risks – are essential building blocks for a sustainable and productive agriculture.

Besides the challenges of climate change and insufficient soil fertility and productivity, farmers also have to deal with economic hurdles. Due to high land prices, it is difficult to buy agricultural land[5], and the prices of mineral fertilisers have dramatically risen in the last five years.[6]

As a result of this urgent need for action to protect our ecosystems and fight against climate change, the agricultural and food industries are coming into focus more and more. At the same time, so-called Scope 3 emissions (indirect emissions from farms belong to this group) are getting increasingly important. Companies in these sectors are faced with the task of reducing not only direct emissions from their own operations, but also indirect emissions in the value chain, including land use and land management.[7] Scope 3 emissions include all indirect emissions from a company's value chain that are not covered by Scope 1 or Scope 2. They often make up the majority of a company's total emissions and contain a total of 15 categories like products and services bought, transport and distribution, as well as use of products bought.

In order for Germany to achieve its climate goals by 2030, the agricultural sector must reduce its emissions by another around 5 percent.[8] That's a big challenge, as it is not only the direct emissions in the sector that are a problem, but also those caused by agriculture and accounted for in other sectors.

These indirect emissions include, for example, those from the energy consumption of machines and buildings, and from the production of synthetic fertilisers. The production of fertilisers in particular is very energy-intensive and contributes significantly to the overall balance, even though most of the time, it is not included in the official emission reports of the agricultural sector.[9]

Particularly important is the potential of soil as a carbon sink, which can help limit global warming.[10]

Companies of the food and agricultural industries are increasingly confronted with legal requirements that demand transparent reporting of their GHG emissions throughout the whole value chain. Additionally, more and more farmers are worried because the cost pressure is a risk for their farm and the use of more sustainable production methods is getting more urgent. Because of these challenges, a holistic strategy to reduce GHG emissions and to promote sustainable agricultural practices is crucial.



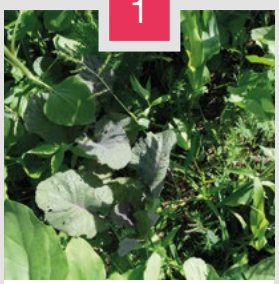
[5] cf. Bundesinformationszentrum, 2024.
[6] cf. Zinke, 2022.
[7] cf. Bundesministerium für Ernährung und Landwirtschaft, 2024.
[8] cf. Umweltbundesamt, 2024a.
[9] cf. ibid.
[10] cf. Marion Schrumpf et al., 2011.

2 Regenerative practices protect soil health, biodiversity, and climate

To overcome the challenges mentioned, the concept of regenerative practices proves to be a promising approach. Even though the term "regenerative agriculture" itself is quite new, it actually refers to proven agricultural principles.

The concept of regenerative agriculture focuses on promoting soil health and the stability of the whole ecosystem in the farm. It is a system of agricultural practices that aims at promoting biodiversity, increasing soil fertility, optimising the water cycle, carbon sequestering, and increasing the availability of nutrients. At the same time, stable yields should be guaranteed because of a climate-resistant way of cultivating. A central goal is to store carbon in the soil and in the biomass, which can reduce the CO_2 concentration in the atmosphere long-term. Regenerative practices not only enable higher yields but can also help to increase the capability of agriculture to adapt to the impacts of climate change.[11]

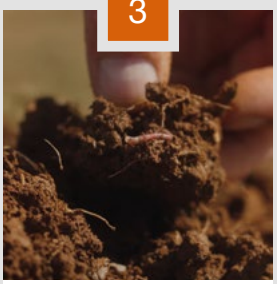
To make the concept of regenerative agriculture easier to understand, it is helpful to divide it into five basic principles:



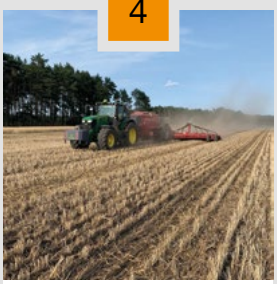
Permanent soil coverage



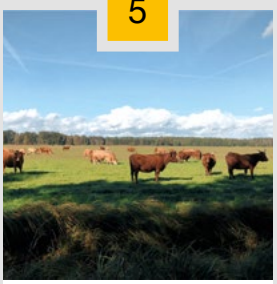
Permanent rooting



Funding of biodiversity



Minimum soil disturbance



Integration of livestock

Both conventional and organic farming systems can integrate regenerative practices into their operations. By doing so, they contribute to addressing the climate crisis and improving their economic viability and resilience.

By promoting natural ecosystem processes like nutrient cycling or pest and weed control, regenerative practices help strengthen the ecosystem of the farm. This doesn't only increase the productivity of the farm, but also reduces dependence on external inputs for disease and pest control, and to manage nutrient deficiencies.

Protecting and strengthening healthy soils are core elements of regenerative agriculture that are gaining more and more importance in the regulatory context. Regenerative agriculture focuses not only on yield and plant health but also on promoting and maintaining healthy soils.[12]

[11] cf. Lipper et al., 2014.
[12] cf. Klim, 2024.



Humus: the key to soil health and sustainable carbon sequestration
Soil vitality, as well as its water, air, and nutrient balance, depend greatly on its humus content. Humus can be seen as a kind of universal storage in the soil. It can store up to five times its own weight in water. Cultivated crops benefit from this high soil water balance, especially during periods of drought.[13]

Humus also plays a vital role in carbon storage. It binds CO_2 from the atmosphere by storing carbon and contributes to reducing GHG as a result.[14]

The vitalisation of soil is necessary to achieve stable profitability and to increase resilience to climate change. Vegetables, fruit, grain, meat, drinking water: 95 percent of our food comes from the soil. In Germany, around 52 percent of land is used for agriculture.[15]

3 The importance of regenerative agriculture is increasing thanks to legal regulations

Regenerative practices are relevant for regulatory frameworks, particularly with regard to sustainability reporting.

The introduction of the Corporate Sustainability Reporting Directive (CSRD) is changing the way companies report on sustainability. Newly created reporting standards (European Sustainability Reporting Standards, ESRS) make the disclosure of sustainability information comparable.

An important component is the quantification of the impact on climate change with corporate GHG inventories. The calculation serves as the basis for formulating climate targets by 2030 or 2050, for example. Thus, many companies are forced to publish their environmental metrics and to report on the state of their reduction measures.

The Science Based Target initiative (SBTi) is seen as a “best practice standard” for defining climate goals. The agriculture, forestry, and land use sector is, with its estimated 23 percent of anthropogenic GHG emissions worldwide, one of the main sources.[16] As it is a relevant lever for achieving the 1.5 degree goals of the Paris Agreement, the SBTi has created a specific FLAG (forestry, land, and agriculture) guide for companies in land-intensive sectors.[17]

Companies that meet the criteria specified by the SBTi must set a FLAG-specific emission reduction goal as part of the SBTi validation. This includes companies where FLAG emissions are more than 20% of their Scope 1 to Scope 3 emissions. Additionally, companies from the following industries are included: food production (agricultural production, animal sources), food and drink processing, food retail, and the tobacco industry. To reach FLAG SBTi goals, measures to reduce emissions are to be determined. This can be done by using regenerative agricultural practices, amongst other methods.

[13] cf. Amelung et al., 2018.
[14] cf. Umweltbundesamt, 2024b.
[15] cf. Agroscope, 2018.
[16] cf. Science Based Targets, no date.
[17] cf. ibid.



B

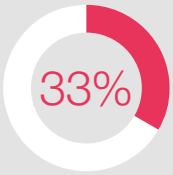
Background of the given example

1 The importance of grain products as a staple food

Grain products play a central role in our community, and they are vital for our diet. They are not only the base of many types of foods, but also important for the animal feed industry.

High land coverage

High land coverage Around a third of the total arable land in Germany is used for growing grains. The products achieved form the basis of the diet of people in Germany and, additionally, they are important raw material for the animal feed industry.[18]



Grain

Staple food

Grain includes important staple food like wheat, corn, and rice, which are essential for the diets of people worldwide. Wheat, durum wheat, rye, barley, and oat play an especially important role in Germany as they are needed for bread and brewed products.

[18] cf. Bundesministerium für Ernährung und Landwirtschaft, 2024.

Increasing demand
In 2022/2023, the domestic consumption of grain was at around 40.5 billion tons, and, thus, 1.2 million tons higher than the year before. Around one fifth of it was used for food.[19] In 2023, one household in Germany consumed 40.7 kg of bread and baked goods on average.[20]



40.7 kg

Climate change
The negative impact of climate change on agriculture requires innovative and regenerative cultivation methods to guarantee having enough grain in the future. The grain report 2024 already shows a reduction of the harvested amount of grain by 9.1 percent (without grain). 2023's wet autumn during sowing time particularly reduced yields because farmers had to reduce the cultivation area –9.1 %.[21]



–9.1%

2 Describing the example and the exemplary modelling

To demonstrate the integration of regenerative practices in real life, we will simulate the changes with an example farm. The example is based on the detailed analysis of a farm in Germany. The usage of regenerative practices is simulated over six years and the ecological and economic impacts will be quantified. The results of the example are just a guide for other farms in Germany which cultivate grain. They can also be used to create industry-wide strategies on the funding of regenerative agriculture.

All calculations and statements are based on the following data:

- Farm in Saxony-Anhalt
- Agriculturally used area of the farm: 423 ha (average area in farms in Saxony-Anhalt in 2023: around 280 ha)
- 20 to 40 soil products
- Average yearly temperature of 9.7 degree Celsius and a yearly rainfall of 575 mm between 1991 and 2020

State and land use of the example before the integration of regenerative practices:

Tab. 1 Areas and yields of different crop types in the example

Crop	Area in ha	Yield in dt/ha
Sugar beet	45	700
Winter wheat	53	55
Winter barley	68	60
Winter rye	175	61
Winter rapeseed	82	31
Simple catch crop	45	–

[19] cf. Bundesinformationszentrum, 2024.
[20] cf. Zentralverband des Deutschen Bäckerhandwerks e. V., 2024.
[21] cf. Bundesministerium für Ernährung und Landwirtschaft, 2024.

In our example, a diversification of crop rotation, cultivation of catch crops, undersowing, and reduced tillage are used as regenerative practices (you can find a detailed explanation of the regenerative practices in attachment III).

The impact on the economic efficiency and the reduction and sequestration of CO_2 will be analysed.

The change of the crop rotation and its land use during the six years:

Tab. 2 Change of the land use for different measures within six years

Management changes	Year 1: Area in ha	Year 2: Area in ha	Year 3: Area in ha	Year 4: Area in ha	Year 5: Area in ha	Year 6: Area in ha
Direct sowing	50	100	200	200	423	423
Sunflower	0	0	0	20	40	40
Peas	0	0	0	45	45	45
Grain corn	–	–	40	40	40	40
Simple catch crop	30	15	0	0	0	0
Complex catch crop	15	30	85	150	170	170
Undersowing	0	0	0	20	40	40

Modelling of reduction and sequestration of carbon

To evaluate, we need to distinguish between emission sequestration and emission reduction:

- Practices like the cultivation of catch crops and undersowing increase the amount of carbon in the soil and are part of GHG emission sequestration methods. Avoiding the natural degradation of organic carbon in the soil compared to the baseline scenario will be taken into account. Regional weather data can also influence the carbon models in the soil to calculate carbon sequestration, to more precisely evaluate the carbon build-up and degradation using natural factors.
  - Catch crops and undersowing provide additional biomass to the main crop and, thus, bind additional carbon.
  - Grain corn, sunflower, and peas replace a type of crop from the original cultivation plan. Their sequestration performance can be proportional to the one of the original crops.
- Part of the reductions are savings in the form of mineral fertiliser, and a lower fuel consumption due to the reduced tillage. External service providers can make these digitally measurable with respective soil carbon models.

Please note that these estimations can vary based on the specific agricultural practices, local conditions, pest pressure, type of machines, fuel efficiency, type of pesticides used, and other factors. Ideally, data on the respective farm will be used. This is quite difficult in reality, though. To effectively reduce GHG emissions and handle all of the complex requirements regarding data capture, processing and validation, farmers can use specialised service providers.

These specialised service providers normally use digital solutions to help farmers make the transition to regenerative practices as easy as possible and to reduce the bureaucratic efforts. Collaboration with service providers enables a cost-effective and quick entry into regenerative agriculture without having to build internal capacities for the development and digitisation of soil carbon models.

For example, they help with the following:

- Farmer onboarding (scalable and digital transmission of data to the site, cultivation practices, as well as the use of pesticides and fertilisers)
- Implementation of regenerative practices (financial support, regional agronomic experts)
- MRV – Monitoring, Reporting, Verification (primary data, satellite images, and remote sensing provide data to verify the reduction and sequestration of GHG emissions)
- Reporting (processing of data for transparent reporting that adheres to the standards)

Cooperating food retailers and service providers contact a chosen supplier and farmers to implement regenerative practices and to document primary data. This data will then be evaluated and verified regarding the reduction and sequestration of GHG emissions. The service provider reports the results to the food retail industry, CPGs, or companies from the processing industry.[22]

3 Challenges of the players in the value chain of grain products

The implementation of regenerative practices addresses current challenges faced by relevant players in the value chain and highlights the need to make agriculture more resilient.

Note
In this chapter, the value chain is presented in a simplified manner by considering only three parties. Roles of other intermediaries like agricultural trades, which are common practice, will be omitted from the presentation.

Fig. 1 Simplified representation of the main requirements across players in the value chain of grain products in Germany

Requirements for farms, the processing industry, and the food retail industry based on legal requirements and the expectations of end consumers:
1. Products that guarantee the protection of the environment and respect social standards to reach climate goals



[22] Based on the example.

3.1 Agricultural challenges

Agriculture is facing major challenges due to climate change, soil degradation, loss of biodiversity, and economic factors.

The latter include high costs for mineral fertilisers, which have risen greatly over the past years and reached a new all-time high in 2022. These price increases make fertilisers one of the most expensive inputs in grain cultivation and represent an extreme financial burden. At the same time, farms need to offer their products at competitive prices in order to find buyers.

The use of fertilisers has decreased in Germany in the past 30 years;[23] however, unbound nitrogen in the form of nitrate continues to enter groundwater and surface water, or, as ammonia or nitrous oxide, to get into the atmosphere.[24] This leads to acidification and eutrophication of soil and water.

Additionally, intense tilling increases the risk of wind and water erosion. In Germany, around 25 percent of fields are at risk from wind erosion and one third of all arable land is at medium or high risk from water erosion. The fertile topsoil, which contains humus reserves, soil carbon, and nutrients, is removed here. Thus, the nutrients needed for plant growth are missing where they are needed.

Climate change intensifies the challenges for agriculture: increasingly occurring extreme weather conditions, drought, frequent heavy rain, and changed rainfall patterns put the yields as well as the harvest quality at risk and increase the possibility of erosion. These events are difficult to predict and are expected to increase as climate change progresses.

Solution approaches to overcome the challenges in agriculture can be found in the following chapters:

- C.1 Motivational factors and economic backgrounds for the use of regenerative practices
- C.2 Chances for the implementation of regenerative practices and incentives as a solution
- C.4 Importance of cooperation in the value chain

Fig. 2 Value chain flour and baked goods – Farms

Requirements of the processing industry and the food retail industry for farms:
1. High-quality products
2. Products available all over the year and stability in the supply chain
3. Competitive prices



Dependency of farms on the processing and food retail industries:
1. Constant product demand and consumption
2. Difficulties in marketing products without the food retail industry
3. Willingness to fair pay and contract conditions

[23] cf. Statista, 2020.
[24] cf. Umweltbundesamt, 2023.



3.2 Challenges within the processing industry

Besides agriculture, the processing industry is also facing challenges caused by climate change.

Mills and big bakeries have a central position in the grain value chain of the processing industry.[25] They are important players in the processing of grain into a variety of end products that go beyond food production. Besides the production of flour, mills also produce byproducts. Big bakeries are in direct contact with the food retail industry and end consumers because they process the ground grain into baked goods and distribute them. Overall, the grain processing industry is a complex network that is closely linked to agriculture, and beyond food production, it is an essential player in the value chain of many products.

Its central contribution to the supply and stability of subsequent industry branches makes the processing industry particularly vulnerable to fluctuations in grain quality and availability. Within the processing industry, mills and bakeries have to deal with central challenges because of soil degradation, fluctuating crop yields and declining product quality, as well as fluctuating grain prices. These factors put the production and quality of end products at risk mid- and long-term.

Therefore, companies must win over all players in the grain value chain for a sustainable transformation and support farmers on their transformation journey together, as only they have a direct impact on grain cultivation methods.

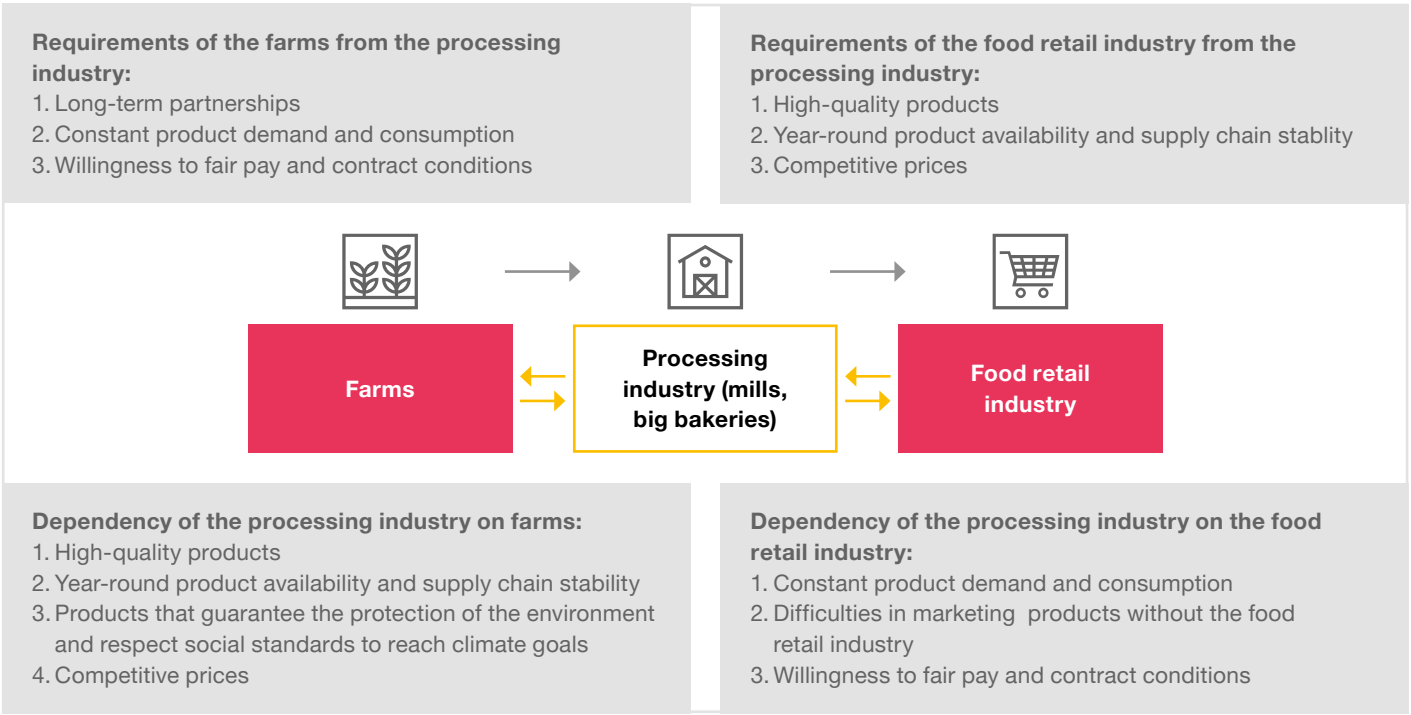
Only through joint efforts can stable and high-quality grain yields be ensured in the long-term. In order to promote this collaborative approach, it is important to understand the roles and contributions of all players.

Solution approaches to overcome the challenges in the processing industry can be found in the following chapter:

- C.4 Importance of cooperation in the value chain

[25] cf. Bundesanstalt für Landwirtschaft und Ernährung, 2023.

Fig. 3 Value chain flour and baked goods – Processing industry



3.3 Challenges within the food retail industry

The food retail industry plays a key role in the value chain of the food industry – from the farmer to the food manufacturer, and then finally to the end consumer. Agriculture, mills, and big bakeries depend on food retailers to sell their products.

The food retail industry is currently dealing with many challenges that are often difficult to reconcile. One of the biggest challenges is inflation and price fluctuations.[26]

The price-driven sales trend only allows for low investments, which may lead to sustainable transformations within the industry coming to a halt.[27]

The challenges in the value chain are mainly delivery difficulties. In June 2023, almost 80 percent of retailers reported delivery bottlenecks, an increase of around 66 percent compared to the previous month. This is mainly the result of extremely difficult negotiations between manufacturers and retailers over price increases and conditions, which can lead to delivery stops and delisting of specific products.[28]

The regulatory requirements for sustainability and transparency in the value chain are another challenge for the food retail industry. Their multitude, especially in the areas of the protection of the environment and social standards, combined with a lack of data, makes compliance complex. Investments in sustainable transformation, as well as transparent processes and data in the whole value chain, are needed.[29]

[26] cf. Destatis, 2024.
[27] cf. EHE Retail Institute, 2024.
[28] cf. Ifo Institut, 2023.
[29] cf. Umweltbundesamt, 2022.

In addition, it's important to reconcile consumer demands regarding quality, price, and sustainability. An increasing demand from end consumers for sustainable products, along with a high level of price sensitivity, puts pressure on the food retail industry to develop cost-effective solutions and to ensure high quality standards.[30]

Another problem is the lack of unified measurement methods to record GHG emissions and GHG reductions. This makes it difficult to compare and implement measures for climate protection.

These diverse challenges highlight the urgent need for a close collaboration between all players in the value chain. The food retail industry can help promote regenerative practices thanks to its central position, and can thus ensure long-term soil fertility and security of supply. To reach this, an effective data flow is a must.

Solution approaches to overcome the challenges in the food retail industry can be found in the following chapters:

- C.3 Challenges and opportunities of a uniform GHG accounting of agricultural climate impacts
- C.4 Importance of cooperation in the value chain

Fig. 4 Value chain flour and baked goods – Food retail industry

Requirements of the processing industry for the food retail industry:
1. Long-term partnerships
2. Marketing measures to market the produced goods
3. Willingness fair to pay and contract conditions



Dependency of the food retail industry on the farms and the processing industry:
1. High-quality products
2. Year-round product availability and supply chain stability
3. Products that guarantee the protection of the environment and respect social standards to reach climate goals
4. Competitive prices

[30] cf. PwC, 2024.



C

Results and interpretation of the example

In order to relate the example of the use of regenerative practices to the concrete experiences of relevant players, two additional groups were interviewed: six farmers and four representatives of the food retail industry. The following analysis takes into account both the results of the example (see the box on the right, and the results of the modelling in attachment II) and the experiences of the interviewed companies.

Disclaimer
The example is just meant for illustrative purposes and is based on assumptions and simplifications. Results and recommendations should be viewed with caution. Opportunity costs resulting from fluctuations in input and producer prices are not taken into account. The assumption is that prices and yields were constant during the whole observation period. It should also be noted that soil carbon content can vary over the years and it is influenced by many factors, like weather and soil conditions. To make well-informed decisions, conducting one's own research is recommended. We don't accept any liability for damage resulting from the use of the information provided here.

1 Motivational factors and economic backgrounds for the use of regenerative practices

The integration of regenerative practices into grain cultivation brings many ecological and economic advantages. Regenerative practices promote sustainable production in agriculture and strengthen the resilience in the value chain and, thus, the security of supply. The application of regenerative practices improves soil health and increases the ability to store water in the soil through humus build-up. Changes in the use of inputs are to be seen as positive, as costs can be saved by reducing intensive tillage and the use of fertilisers and pesticides.

Given these diverse benefits, farms also increasingly rely on regenerative practices for the following reasons:

- Cost and availability of fertilisers: the high cost and limited availability of fertilisers, intensified by the Russia–Ukraine war and political changes, led farmers to use more organic fertilisers and to rely on their own circular economy, including the use of their own compost.
- Increase of the economic efficiency and reduction of pesticide resistance due to diverse crop rotation: the use of diverse crop rotation reduces the susceptibility to pests and diseases, which minimises the use of pesticides. At the same time, diverse crop rotation reduces the economic risk because the dependency on fluctuating prices of individual crops decreases.
- Reduction of the use of inputs and increase of the harvest quality: Establishing regenerative practices also aims to reduce the use of inputs in the long-term and, at the same time, to increase the quality and quantity of cultivated crops. The workload is reduced by the minimised use of pesticides and fertilisers and minimization of tillage.[31]

Analysis of the modelling and results of the example

These motivations can also be seen in the results of the example. The regenerative practices shown here haven't only had a positive impact on soil health and the ability to store water – they have also had a positive impact on the operational and economic efficiency.

When considering the following results, it should be noted that farms can be structured very differently, and they are dependent on site and weather conditions. The following statements cannot be generally applied to a large number of farms in Germany.

Cost analysis

The calculations of the contribution margins for agriculture and the cultivated crops in Saxony-Anhalt are based on data from the "Kuratorium für Technik und Bauwesen in der Landwirtschaft" (KTBL) for 2018 to 2022.

The KTBL data is a basic orientation; however, it was compared with the actual yields of the arable farm mentioned (farm survey in June 2024) and adjusted accordingly. These adjustments were necessary because the standardised KTBL yields could not always reflect the real operating conditions. There were both positive and negative deviations from the original contribution margins.

Tab. 3 Economic metrics of the arable farm

Nitrogen per kg	€1.25
One litre Diesel	€1.30
Labour cost per hour	€50
Simple catch crop	€140/ha
Complex catch crop	€180/ha
Undersowing	€140/ha
Direct sowing machine, investment cost	€110,000
Direct sowing machine, yearly depreciation (over 8 years, from the additional investment; reinvestment after 8 years)	€61,000
Working hours Seeds Direct sowing machine	0.3 h/ha
Working hours Pneumatic drilling machine	0.6 h/ha

[31] Based on expert interviews with six farmers.



In our example, additional costs are first triggered by catch crops and undersowing. As the contribution margin of legumes as the main crop is lower, profit losses have been documented. However, they have already been compensated for because mineral fertilisers have been saved due to the nitrogen supply of the legumes for the subsequent crop and the linked positive fertilising effect. Then, there are the new main crops, grain corn and sunflowers, which have a higher contribution margin. In combination with monetary support under the Common Agricultural Policy (CAP) and remunerated GHG reduction and sequestration by external service providers, the change in management is profitable.[32]

The implementation of the practices is based on the following assumptions:

1. The previously used simple catch crop will be replaced by a catch crop mixture. The original cost factor increases because the seed costs more.
2. Undersowing will be used for the first time and its additional cost factor is calculated from the variable machine costs, wages, and seed costs. There are no additional investment costs because existing machines will be used.
3. The cultivation of legumes initially leads to yield losses because lucrative crops such as wheat, barley, rye, or rapeseed cannot be cultivated.
4. The transition to direct sowing leads to investment costs which are depreciated over this period until reinvestment after eight years. When comparing the cost points of the pneumatic drilling machine and the direct seed machine in regards to working time and fuel consumption, it is clear that direct seeding leads to savings in both factors.
5. In the long-term, profits increase from the fifth year after implementation, even if the GHG savings are not compensated for by an external service provider. These compensations will be explained in more detail in chapter C.4. Profits increase mainly because of the positive and high contribution margins of the crops added to the crop rotation during the mentioned period, and because of the positive fertilising effect of legumes.

[32] Based on the example.

More positive effects from the use of regenerative principles

Thanks to the implementation of these practices, the farms interviewed have been able to record further positive effects or expect them in the future in addition to the economic benefits described here:

- Better soil structure: Regenerative agriculture has led to a clearly improved, finer soil structure which has a positive impact on soil fertility.



- Reduced Diesel consumption:Because of the reduced use of machines, the Diesel consumption was reduced noticeably, which not only leads to savings in cost and emissions but also protects the climate.



- Local reputation: The transition to regenerative principles has also gained recognition in the local community, increasing the reputation and understanding of the farms.[33]



Yield development

Based on the average yield of the farm, no increase in yield (t/ha) can be expected after implementing the practices. But there's a stabilisation of the yield amount and an increase in monetary yields (€/ha) because the same output can be expected for a lower input. Overall and in combination with the excellent contribution margins of the newly cultivated crops, additional profits of around 11,000 euros can be achieved after a period of six years. Including the funding under the GAP and the revenue from carbon credits, the total sum is around 24,000 euros.

In the first year after the transition, the yields may be slightly lower – until the resilience of the system is strong enough. During this time, regular discussions with advisory institutions and other farmers who have more experience with regenerative practices can be helpful. You will find more information on this in chapter C.4.

Carbon sequestration and reduction

The CO_2 values relate to indirect and direct emissions and include production emissions (for example when producing fertiliser), so they cover Scope 1 to Scope 3.

Carbon sequestration: Carbon sequestration includes the increase of carbon in the soil as a result of the implementation of the practices described. Avoidance of the natural degradation of organic carbon in the soil compared to the baseline scenario will be taken into account. For the calculation, a scientifically based, independently verified soil carbon model of an external service provider was used, which takes into account regional soil and weather data and the build-up of soil carbon after the successful application of regenerative practices.

This table shows the effect of the agricultural practices and crops on the average carbon sequestration performance per hectare per year. For catch crops and undersowing, there's an additional carbon sequestration that occurs from the build-up of biomass compared to the main crops. For grain corn, sunflowers, and peas, the table shows the difference of the carbon sequestration compared to the average sequestration performance of the originally cultivated crops. Positive values stand for a higher carbon sequestration compared to the reference crops, negative ones for a lower.

Tab. 4 Carbon sequestration and CO_2e savings with the help of different measures

Measure	Change of the carbon sequestration compared to the originally cultivated crops
Simple catch crop	2.1 t/ha
Mixture of the catch crop	2.4 t/ha
Undersowing	1.7 t/ha
Grain corn	0.96 t/ha
Sunflower	0.97 t/ha
Peas	–0.63 t/ha
Diesel	1.13 kg CO_2/l Diesel saved

[33] Based on expert interviews with six farmers.

Extending the crop rotation over six years shows an impressive development of the estimated carbon sequestration, based on primary data and soil carbon models. In the first year, a moderate sequestration of 4.5 t CO_2e will be reached, which will already double itself in the second year. From the third year, the sequestration increases significantly and is more than 16-times higher than in the second year. In the following years, it stabilises at around three times the level of the third year. This development highlights the potential sustainable and long-term effects of the crop rotation on the carbon sequestration in the soil. For notes on the implementation of the measure, see table 2 in chapter B.2 Describing the example and the exemplary modelling.

Part of GHG reduction is the reduced use of mineral fertilisers and fossil fuels due to reduced soil cultivation.

The fertiliser savings result in a continuous increase in GHG reductions over the years, starting at a moderate 6.3 t CO_2e in the second year and increasing to about 16 times higher CO_2e reductions in years five and six. The stabilisation at this high level shows that the fertiliser savings make a significant contribution to reducing GHG emissions in the long term.

The fuel savings lead to a steady but moderate reduction in greenhouse gases over the years. It starts with a low reduction of around 0.15 t CO_2e in the first year, increasing to more than eight times the amount in years five and six. The stabilisation at a higher level shows that optimised fuel use makes a small but constant contribution to reducing GHG emissions in the long-term.[34]

See insight 1

2 Chances of the implementation of regenerative practices and incentives as a solution

Many farmers are initially hesitant when it comes to the concept of regenerative practices because it is not clearly and uniformly defined. At the same time, this flexibility can also be an advantage. The approach can be adapted to the specific needs and circumstances of an individual company. Traditional knowledge and proven methods like ploughing often hinder the acceptance of new practices. There's also a lack of precise information and up-to-date know-how. Economic uncertainty and high initial costs hinder the implementation, and the high training effort and foreign weed infestation have a discouraging effect.

Even though many regenerative agriculture practices are viewed positively, there are some that farms see critically:

- Scepticism towards scientifically unfounded practices: There's general scepticism regarding methods such as compost tea, which are considered to be insufficiently scientifically based.
- Effort and feasibility: Certain practices like the cultivation of catch crops and undersowing are considered to be too much work and costly, which makes their implementation difficult.
- Trust in soil samples and recommendations: In one case, there was distrust regarding soil samples and the recommendations based on them, which leads to a certain reluctance to use such measurement methods. Careful analysis and targeted advice can help increase confidence in these methods and clearly communicate their advantages to the farm.[35]

[34] Based on the example.
[35] Based on expert interviews with six farmers.

To convince more farmers of regenerative agriculture, different types of incentives are needed (Fig. 5).

The food retail industry can also play a vital role to motivate farmers to switch to regenerative agriculture:[36]

Fig. 5 Approaches to find solutions in agriculture

1. Scientific basics

- Provision and use of scientifically based information
- Focus on field trials and practical examples

2. Educational opportunities and knowledge exchange

- Improved educational opportunities and targeted training in the field of regenerative agriculture
- Exchange of experiences among farmers
- Experienced farmers as advisors for newbies

3. Building a network

- The lack of direct contact between food retailers and farmers is a significant barrier to the collaboration and implementation of regenerative practices.
- This hurdle can be overcome by involving external service providers, non-governmental organisations (NGOs), and universities.
- External service providers can be funded through cooperation with players in the value chain.

4. Political and financial frameworks

- Clear political guidelines and financial incentives are needed to overcome economic hurdles, including the promotion of cover crops and the reduction of bureaucracy.
- Funding programmes of the federal states of Germany under the GAP and the Ökoregelung 2 (Eco-Regulation 2) should be used.
- The risk almost solely lies on the shoulders of the farmer. That's why a risk distribution and financial funding is very important:
  - An initial funding for regenerative practices by players in the value chain could cushion investments and secure long-term benefits.
  - External service providers could verify carbon sequestration and reduction, and pay farmers based on the improvements they've made compared to the baseline.

5. Establishing standards

- Clear standards and incentives from the food retail industry should promote the demand for food from regenerative agriculture. They would showcase the added value of the products and increase the payment willingness of customers.

6. Practical and individual measures

- Practical tests of the regenerative practices are a must to identify the most appropriate approaches for each farm.
- Solutions should be adapted individually to specific conditions and requirements of the farms.

[36] Based on expert interviews with six farmers and four representatives of the food retail industry.

Recommendation for farmers at the beginning of their implementation of regenerative practices

Farmers who consider implementing regenerative practices should think about the following approaches:

- Start small and increase gradually: starting with small test fields and minor interventions helps minimise risks and make adjustments. It makes it easier for farmers to verify efficiency and enables them to expand their practices gradually.
- Consider the structure of your farm: the specific structure of the farm, for example livestock or machinery at hand, influences the selection and implementation of practices. Adaptations should be made according to the situation of the farm.
- Be patient and courageous: success often becomes visible after several years. It's important to be patient and to learn from mistakes. Being in the mood for experiments promotes innovation and enables farmers to develop more effective approaches.

Targeted incentives are needed to overcome barriers to the implementation of regenerative agriculture and its practices. This includes financial support, scientifically based information, advice from experienced farmers, and targeted continuing training. Through this, farmers can get motivated to successfully implement regenerative methods and to profit from their advantages.[37]

See insight 2

3 Challenges and opportunities of a uniform GHG accounting of agricultural climate impacts

In order to reliably monitor and demonstrate the achievement of climate targets, high-quality data is a must. However, the food retail industry sees the current availability and quality of data for the GHG accounting as inadequate. A major shortcoming is that the primary data is only partially available at supplier and producer level, so that GHG accounting is based on average values, and specific reductions are difficult to verify. To correctly document the progress, comparative data is necessary that captures the status before and after the implementation of the measures. This data must be verifiable or confirmed by external audits to ensure its reliability. Unified accounting rules and standardised methods like the Greenhouse Gas (GHG) Protocol make it easier to accurately record these savings.[38]

Measures to reduce and sequester greenhouse gases are taken into account in the GHG Protocol. For this, reporting based on FLAG regulations is needed. Emissions from the food retail sector are typically Scope 3 emissions, as indirect emissions in the whole value chain must be taken into account.

Note
In our analysis, we only considered Scope 1 and Scope 2 emissions, i.e. direct and indirect emissions from the purchase of grid-bound energy from agricultural activities. This data (scope 1 and scope 2 of farms) the food retail industry can use as part of their Scope 3 calculations (in category 3.1 of the GHG Protocol "Goods and services bought").

[37] Based on expert interviews with six farmers.
[38] Based on expert interviews with four representatives of the food retail industry.

To calculate the climate impact of regenerative agricultural practices, the intervention approach was used and two scenarios were developed. The approach refers to the implementation of practices aimed at reducing or sequestering GHG emissions. It is usually compared with the baseline scenario after three to five years. The first scenario is the business-as-usual scenario, which takes into account the usual agricultural practices. In the second scenario, new regenerative agricultural practices are included.

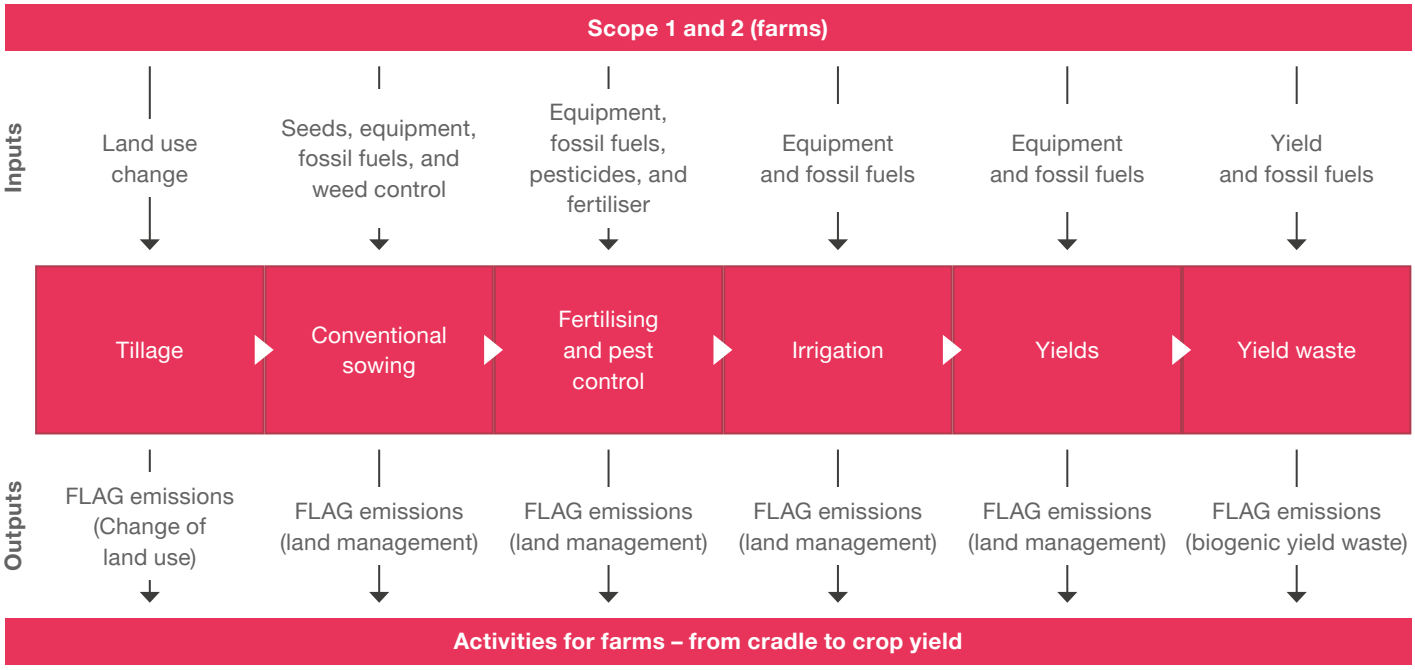
The system boundaries of this example are defined as "from seed to store counter". That includes all processes from the extraction of the raw material (including inputs like seeds, mineral fertilisers, and pesticides) through cultivation and harvesting to the transport of the products to the store counter. This also includes FLAG and non-FLAG emissions which are linked to regenerative agricultural practices.

Scenario 1 – Business-as-usual
Scenario 1 (Fig. 6) shows an input-output-diagram of the conventional activities of a farm, oriented on the GHG Protocol Scoping Classification.

In this example, we concentrate on the Scope 1 and Scope 2 activities of the farm.

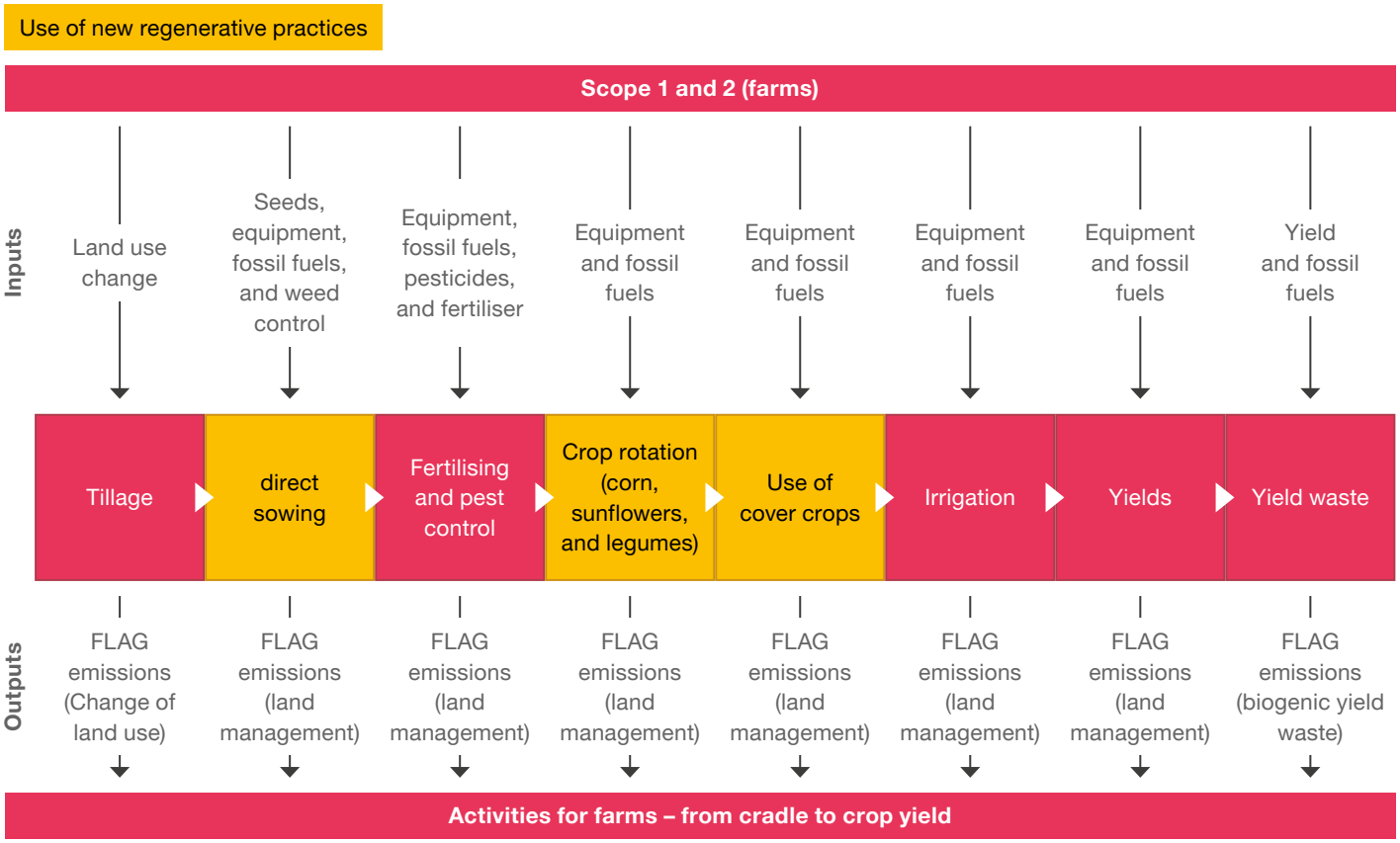
The impacts of FLAG and non-FLAG emissions from tillage, sowing, fertilisation, pest control, irrigation, harvesting, and straw management are taken into account.

Fig. 6 Scenario 1, Business as usual – limitations of the case study



Scenario 2 – Integration of regenerative practices
Scenario 2 (Fig. 7) includes regenerative agricultural practices like direct sowing, crop rotation (with corn, sunflowers and legumes), and the use of cover crops (for example undersowing and catch crops). These practices have a direct influence on the use of fossil fuels, fertilisers and pesticides, as well as the quality of the soil.

Fig. 7 Scenario 2, Integration of new regenerative practices – limitations of the case study



Based on the assumptions of the example, as explained in chapter B.2 and additionally used exemplary assumptions, simulated FLAG emissions can be shown as follows in GHG accounting:

Tab. 5 Impact of the practices on GHG emissions (tonnes CO_2e) – example

Impact of the practices on GHG emissions	FLAG emissions [t CO_2e]	Non-FLAG emissions [t CO_2e]	Total emissions [t CO_2e]
GHG emissions (Scope 1 and 2) scenario 1	122.94	92.11	215.04
GHG emissions (Scope 1 and 2) scenario 2	94.59	92.19	186.78
Change scenario 1 to scenario 2	–29.97%	0.09%	–15.13%

This table shows the results of the example accounting of GHG emissions from agricultural activities (Scope 1 and Scope 2 – typically these are part of Scope 3 emissions of the food retail industry) in two scenarios over one year with a special focus on FLAG emissions relating to GHG reductions.

When comparing the two scenarios, a significant reduction in FLAG emissions of 29.97 percent through the implementation of regenerative practices is visible. The non-FLAG emissions increased slightly by 0.09 percent. This relates back to the higher Diesel consumption, which occurred during crop rotation activities through different tillage practices as well as the additional effort for the cultivation and ending of cover crops. The total emissions decreased by 15.13 percent.

These exemplary results show that the implementation of scenario 2 reduces the FLAG emissions and, thus, also reduces the total carbon footprint (CFP). The slight increase of the non-FLAG emissions shows that further measures may be needed to further reduce these emissions. The analysis highlights the importance of a targeted use of regenerative practices in the FLAG sectors to effectively reduce the GHG emissions.[39]

See insight 3

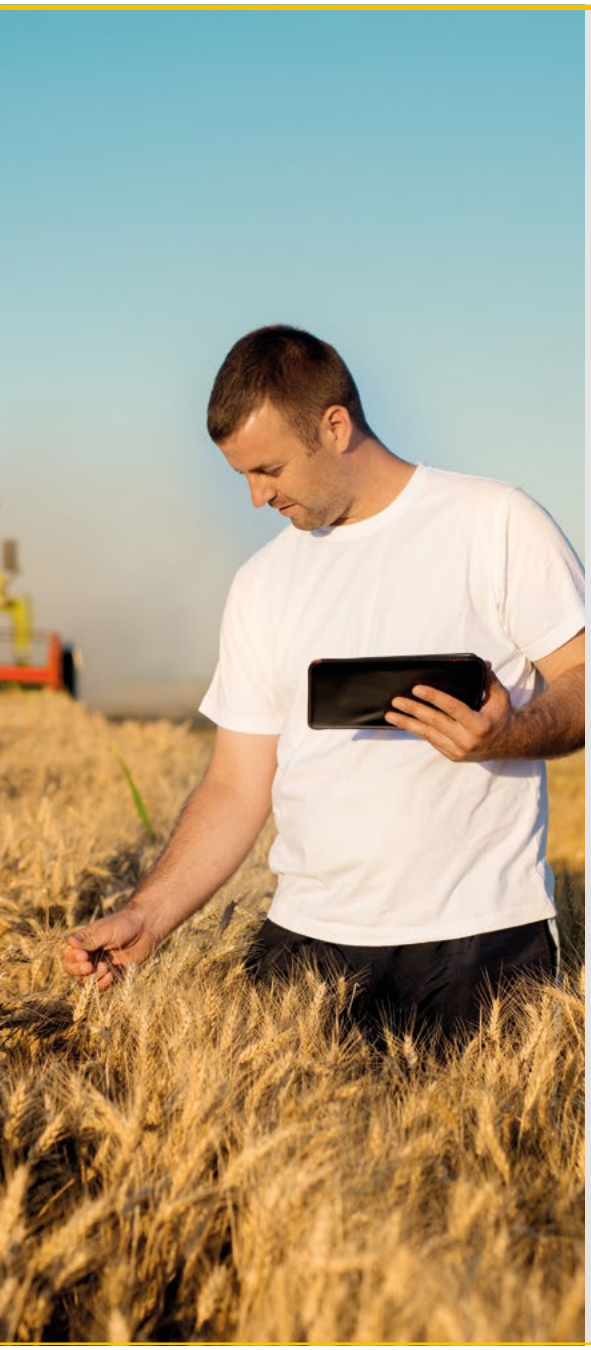
Most important results:

- Scenario 1, business-as-usual: the complete GHG emissions are 215.04 tonnes CO_2e, while 57.17 percent are for FLAG emissions and 42.83 percent for non-FLAG emissions.
- Scenario 2, using regenerative practices (direct sowing, crop rotation with corn, peas, and sunflowers; cover crop complex and undersowing): The complete GHG emissions are 186.78 tonnes CO_2e, while 50.64 percent are for FLAG emissions and 49.36 percent for non-FLAG emissions.



[39] Based on the example.

4 Importance of cooperation in the value chain



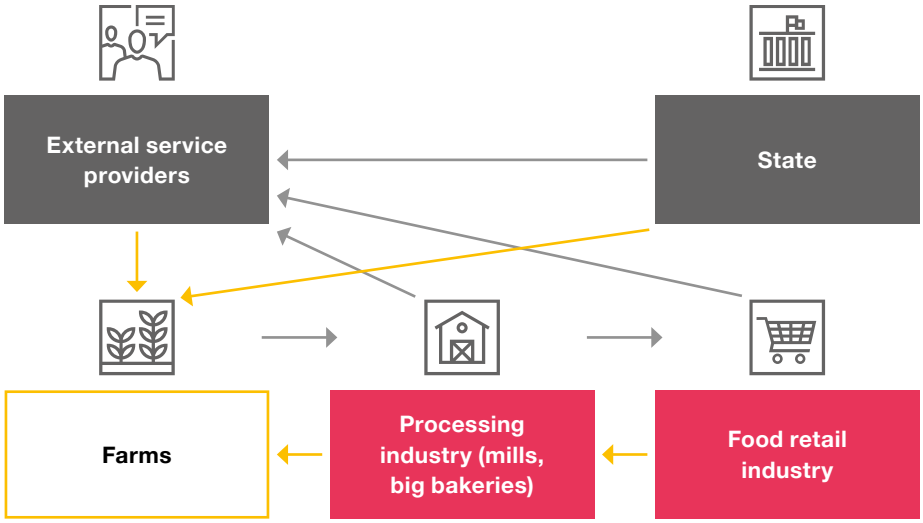
Collaboration in the value chain between farms and the processing industry, as well as food retail, is essential to implementing regenerative practices. The cooperation of all players is very important to render the value chain efficient and climate-adapted, and to ensure the additional effort on the agricultural side resulting from regenerative practices is measurable, recognised, and remunerated.

- Long-term cooperation and joint initiatives: long-term partnerships and planning security are important, because they are the basis for a sustainable cooperation between all involved parties. To promote this success, it's important to develop a common understanding and clear goals that clearly show the benefits of regenerative agriculture. A first step might be to initiate lighthouse projects that are scalable through standardisation. In this context, multi-stakeholder initiatives are a must, as they promote the exchange between different stakeholders and create platforms for cross-sector collaboration. Additionally, a close cooperation with organisations and ministries is especially important to implement measures in a targeted manner and ensure their long-term success.
- Direct communication between players: farmers want a direct exchange and visits with food retail companies, as well as regional cooperation with mills. Important aspects are price security, long-term relationships, and a better placement of regional, regeneratively produced products. The retail sector can be a catalyst because it can promote cross-industry partnerships and demand regenerative practices.
- Optimisation of processes and data management: automated processes could make the collaboration between suppliers and food retailers more efficient and more scalable. They make it possible to centrally support and integrate initiatives of suppliers instead of developing and accompanying individual projects for each supplier. A common data platform would be helpful to enable the access to relevant data and to work together on progress.
- Support by politics and economy: political participation can also be helpful and improve the structural framework. The measures should be made in such a way that they create economic incentives for farmers, while at the same time meeting the requirements of international competition. Possible options include the implementation of international certification standards, financial incentives, and the promotion of educational initiatives. Clear guidelines and rules are needed to make such requirements transparent. Comprehensive solutions, like a nutritional transition, should also be promoted.[40]

[40] Based on expert interviews with six farmers and four representatives of the food retail industry.

Fig. 8 Regenerative agriculture can only be successfully implemented through the active participation of all players in the value chain

Support from external service providers for farms:
1. Financial support from external service providers, financed by the food retail or the processing industry
2. Support from agricultural experts regarding the implementation of measures and the expansion of knowledge
3. Deployment and introduction of supporting technologies for data capture and recording
4. Verification of GHG sequestration and the reduction of practices



State support for farms:
1. Establishing support programmes like CAP, Eco regulation 2, and the Strategic Dialogue on the Future of the EU Landscape
2. Educational offers for farms and training institutions that correspond to the latest scientific findings
3. Practical and individual solutions with as little bureaucratic effort as possible

Support of farms with the help of the processing industry and the food retail industry:
1. Risk distribution, especially when introducing new cultivation methods that offer less cultivation security
2. Financial support for farms that use both new and existing regenerative practices
3. Joint exchange on-site in the farms with players of the value chain to support the implementation of practices, and discuss problems and opportunities

See insight 4



D Conclusion: The four most important insights

The introduction of regenerative agricultural practices needs financial incentives, long-term partnerships, and a close collaboration in the value chain to realise ecological and economic advantages, to reduce GHG emissions, and to promote its acceptance among farmers and consumers.

1 Insight 1: Using regenerative practices can increase profitability.

The integration of regenerative practices in crop cultivation has long-term ecological and economic advantages. These include, among other things, better soil health, greater ability to store water in the soil, and lower operating costs because of the reduced use of fertilisers, pesticides, and working hours. These positive effects motivate farmers despite initial investment costs and possible yield fluctuations to transition to regenerative practices. The yields stabilise themselves long-term, which can increase profits. At the same time, the initial investment in new practices and machinery often pays off within a few years because of long-term savings.

See chapter C.1

2 Insight 2: Targeted incentives are needed to effectively implement regenerative practices.

Sceptical feelings in regards to regenerative practices often occur because of missing definitions, economic uncertainties, and lack of knowledge. To motivate farmers to implement regenerative practices, financial support through funding programmes and external providers that pay for GHG savings can play a vital role. A gradual introduction with small test areas and consideration of the individual company structure are important steps. Patience and continuing education are important for long-term success. Targeted incentives and science-based information can additionally help motivate farmers to implement regenerative practices.

See chapter C.2

3 Insight 3: Regenerative practices can greatly reduce GHG. Their accounting, though, is a challenge.

Measures for the reduction of emissions and carbon sequestration are to be documented precisely, according to the GHG Protocol and FLAG regulations. The implementation of regenerative practices in our example simulates a significant reduction of FLAG emissions by around 30 percent as well as a total GHG reduction by around 15 percent. Specialised service providers can handle the data capture and processing (calculating Scope 3 emissions) and help with the reporting.

See chapter C.3

4 Insight 4: Regenerative agriculture can only be successfully implemented through the active participation of all players in the value chain.

Sustainable transformation of agriculture requires careful analysis and understanding of the current situation of farmers as well as scientific evidence showing the effectiveness of regenerative practices. Only this way farmers can become convinced. At the same time, it's important to identify the factors (information) that end customers need to increase their interest in regeneratively produced products. Close collaboration between farmers, the processing industry, and the food retail industry is a must for a successful implementation. Initial investment costs and an increased workload need financial support and distribution of risks. Direct communication and long-term partnerships play just as important a role as the targeted placement of regeneratively produced products in retail. Politics can promote this process, for example with the help of better framework conditions or educational initiatives.

See chapter C.4

The food retail industry plays a key role because it can act as a catalyst by fostering partnerships and supporting the implementation of regenerative practices. This contributes to a sustainable transformation and increases the acceptance of these products among consumers.



E

Outlook: Required frameworks and adaptations

For the successful transition of agricultural practices towards regenerative practices, it is a must not only to implement technical solutions, but also to create supportive financial and regulatory structures.

Financing regenerative practices

Implementation of regenerative practices requires long-term investments. The implementation is easily possible with sufficient financial support. The recently published final report of the "Strategic Dialogue on the Future of EU Agriculture" offers a promising outlook: additional funding should be made available to promote sustainable approaches in agriculture.[41]

At the same time, political support mechanisms should be adapted to ensure long-term success, as suggested by the European Court of Auditors' report on the agricultural policy in the EU.[42]

[41] cf. European Commission, 2024.
[42] cf. European Court of Auditors, 2024.

Adaptation to market requirements

At the same time, pressure is growing on farms to adapt more to market needs. The demand for low-emission raw materials from food retailers and the processing industry is expected to grow, as these sectors seek to meet their climate targets, which in turn is important to secure economic stability in a changing market environment. A strategic adaptation to market trends helps improve competitiveness even in times of financial uncertainty.[43]

Flexible models of emission recording with intervention and inventory approaches additionally offer the flexibility needed to meet different requirements.

Regulations for emission accounting

Regulations play a central role in reducing and binding Scope 3 emissions because they enable comparability and provide valuable impulses for the development of suitable solutions. This needs the following:

- Sufficiently available, detailed activity data to distinguish between FLAG and non-FLAG emissions;
- The identification and efficient allocation of relevant emission factors that meet the requirement of the SBTi-FLAG regulation;
- The use of synergies between the requirements of the European Deforestation Regulation (EUDR), the Biodiversity Strategy, and the Taskforce on Nature-related Financial Disclosures (TNFD); these synergies are optional but can help companies to reduce the effort and resources required for reporting under different standards.

In summary, the implementation of regenerative practices represents a significant investment in the future of soils and ecosystems while also strengthening the economic resilience of complete supply chain systems. Using targeted support, regenerative practices can be established that offer ecological and economic benefits. The guide shows that mutual understanding and cooperation between agriculture, the processing industry, and the food retail industry is essential to reduce emissions and ensure the long-term economic availabillity of food in a healthy ecosystem together. It's important to create the necessary framework and to support farmers on this journey. An open dialogue and close cooperation between all players in the value chain are crucial for overcoming the complex challenges in the supply chains.

[43] cf. Bundesministerium für Ernährung und Landwirtschaft, 2024.

Attachment for the example

1 Exemplary modelling of the ecological and economic added value

Calculation scheme:
The contribution margins were calculated according to the following scheme:

1. Determining company-specific revenues: the real returns were multiplied according to the relevant market prices of KTBL.
2. Deduction of variable costs: the average variable costs of the respective crop, derived from the data of KTBL, were deducted from the revenues. This made it possible to get near the actual contribution margin of the company.

When determining the costs for tillage equipment, it was assumed that the existing equipment would remain on the farm in order to maintain operational flexibility. The advantage of monetary changes in soil tillage is considerably influenced by which methods were previously used. The savings are particularly high if the transition involves intensive tillage methods.

Financial changes during the observation period:

Tab. 6 Financial impacts of the adaptations and the achieved CO_2 reduction and carbon sequestration

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
CO_2e reduction (t)	0.15	6.6	18.5	90.9	102.1	102.1
Carbon sequestration (t)	4.5	9.0	148.06	329.13	430.55	430.55
Cost	61,600€	1,200€	9,000€	39,029€	45,429€	45,429€
• Mixture of the catch crop	600€	1,200€	9,000€	20,700€	24,300€	24,300€
• (Direct seed machine)	(61,000€)					
• Depreciation	7,625€	7,625€	7,625€	7,625€	7,625€	7,625€
• Undersowing				2,800€	5,600€	5,600€
• Difference contribution margin legumes				15,529€	15,529€	15,529€
Services	3,350€	7,450€	16,680€	45,925€	64,106€	64,106€
• Direct sowing (time and resources)	3,350€	6,700€	13,400€	13,400€	28,341€	28,341€
• Fertiliser effect of catch crop/undersowing		750€	2,125€	4,000€	5,250€	5,250€
• Difference contribution margin grain corn			1,156€	1,156€	1,156€	1,156€
• Difference contribution margin sunflowers				1,989€	3,979€	3,979€
• Funding legumes				25,380€	25,380€	25,380€
Oversowing/undersowing	–4,875€	–1,375€	56€	–729€	11,052€	11,052€
Oversowing/undersowing (With funding of carbon credits)	–4,638€	–759€	4,331€	9,250€	24,154€	24,154€

2 Explanation about the applied practices

The regenerative practices selected in the practical example are the following:

Diversification of crop rotation

The expansion of the existing crop rotation in the practical example to include crops such as grain corn, sunflowers, and peas offers many advantages. The constant rotation of crops loosens the soil because the individual plant species have different root depths and types. It also promotes different microbial populations with the help of different nutrients. The integration of legumes also optimises the nitrogen and carbon cycles and supports the humus formation. The inclusion of crops that leave behind organic matter in the form of crop residues also supports the build-up of humus. This optimises the soil structure and infiltration and promotes species-rich soil biodiversity. Alternative crops like sunflowers can also produce more reliable yields in dry periods because they are better adapted to them.

Long-term studies in Europe and North America have shown that more diversity in crop rotation can increase yields and reduce the need for mineral fertilisers.[44] The yield benefits were the clearest when using very little mineral fertiliser. This relates to optimised soil health and increased functional diversity, which optimises the nutrient cycles.

Catch crops

Catch crops form a link between two main crops within crop rotation. They correspond to the principle of soil cover around the year and promote humus build-up when they stay in the area as green manure. Due to the complete coverage of arable soil, factors like erosion and evaporation are inhibited as well. The soil structure is loosened by the rooting over the year, enabling increased infiltration and rootability for subsequent crops. In addition, the catch crop mobilises nutrients that are available for subsequent crops. The expansion of crop rotation by another crop also improves biodiversity.

The choice of catch crops should take into account the location, crop rotation, and requirements of pest management. Integration into grain crop rotation carries the lowest risk of incompatibilities. Rapid growth should be ensured, however, to prevent weeds and erosion. Legumes, as well as different summer and winter crops, are suitable as catch crops.

Legumes have the valuable trait of locking nitrogen from the air into the soil both for their own growth, and that of subsequent crops. An optimal nitrogen supply is an essential basis for a healthy and productive crop/plant growth. The natural process of nitrogen fixation helps save mineral fertilisers and reduces the nitrate pollution of groundwater.[45] A 36-year long experiment in Puch, Bavaria investigated the nitrogen effect of a pea-Vicia mixture compared to mustard as a catch crop.[46] The nitrogen efficiency for winter wheat was on average 15 kilogrammes of nitrogen per hectare, and led to a yield increase of 7 percent. Soil fertility also gets increasingly improved, as organic matter in the form of crop and root residues remains in the soil, and a positive carbon-nitrogen ratio is created which promotes humus build-up. A leafy crop such as a legume is particularly suitable as a grain catch crop as it builds up valuable humus and fixes nitrogen.

A catch crop can only consist of one type or diverse components. As part of the research project CATCHY, these are being investigated for their agricultural and ecological impacts.[47] Because of the results obtained so far, it can be said that microbial diversity, aggregate stability, and water balance increase alongside an increase in the number of mixture partners. Diverse mixing partners also form root systems of varying depths and mobilise different nutrients to promote a balanced nutrient balance.

[44] cf. Bowles et al., 2020.
[45] cf. Umweltbundesamt, 2023.
[46] cf. Hege; Offenberger, 2006.
[47] cf. Gentsch; Guggenberger, no date.

Undersowing

Undersowing offers an opportunity to protect the soil against erosion, build up biomass and humus, and increase the biodiversity in the fields even while the main crop is being cultivated. Additionally, water efficiency and drought tolerance are strengthened because, taking into account all water balance components (evaporation, transpiration, surface runoff, formation of seepage water, infiltration capacity), the three loss factors – evaporation, surface runoff, and formation of seepage water – are reduced to such an extent that the water requirements of both the undersowing and the catch crop can be compensated.[48] The leaching of nutrients is also reduced and, in case of legume undersowing, nitrogen is made available for the main crop.

Reduced tillage

Reduced tillage in the form of strip-till, direct sowing, or mulch sowing promotes a more original soil structure with a greater aggregate stability, and a pore system that enables greater water infiltration and storage.[49] The build-up of humus is promoted by these more stable conditions in the soil structure and the plant residues which lie on top. The decomposition of organic matter through processing erosion and increased decomposition by microbes through oxygen are prevented.

Even fuel consumption[50], machine cost, and associated emissions decrease. Additionally, less carbon fixed in the soil is released because the organic matter in the soil is mineralised to a lesser degree. The fuel consumption[51] can be reduced by 42 percent in reduced tillage systems and by 85 percent in direct sowing.

Adapting the measures to the specific local conditions is crucial. Reduced soil tillage without accompanying measures like catch crops or undersowing legumes could potentially lead to an increase in nitrous oxide emissions.[52]

However, the combination of reduced tillage and the cultivation of catch crops, organic fertilisers, and diverse crop rotations shows positive results. Avoiding tillage combined with diverse crop rotations and cover crops reduced nitrous oxide emissions by 11 percent, especially in humid climates and on soils with a lower carbon content. Cover crops, especially legumes, contribute to an improved nitrogen cycle because of their nitrogen fixation capacity, without increasing nitrous oxide emissions.[53]



[48] cf. Bodner et al., 2011.
[49] cf. Forschungsinstitut für biologischen Landbau (FiBL), 2017.
[50] cf. Forschungsinstitut für biologischen Landbau (FiBL), 2014.
[51] cf. Szalay et al., 2015.
[52] cf. Thünen Institut, 2023.
[53] cf. Li et al., 2023.

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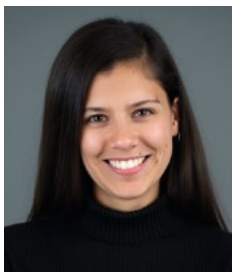
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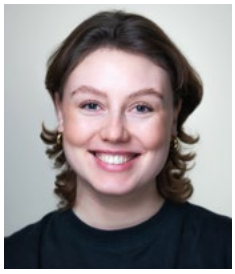


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Information on PwC Germany

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Information on Klim GmbH

The AgriTech company Klim is creating a joint movement of farmers and companies to spread regenerative practices as quickly as possible. The goal is to reduce CO_2 emissions sustainably and to improve soil fertility and biodiversity. By doing this, Klim is making an important contribution to achieving decarbonisation goals and securing the long-term food supply. Klim's digital platform enables farms to document their measures, to receive financial incentives, and to access expert knowledge. Companies can support regenerative agriculture both inside and outside their value chain. Klim acts as a project developer, manager, and provider of MRV (monitoring, reporting, verification), advises farmers on the application of regenerative practices, and helps the food industry to implement regenerative projects in the value chain, make them measurable, and scale them. Klim GmbH was founded by Dr Robert Gerlach, Nina Mannheimer, and Adiv Maimon in Berlin in 2020.
www.klim.eco/en

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