The Case for Regenerative Agriculture in Germany—and Beyond

March 2023

By Torsten Kurth, Benjamin Subei, Paul Plötner, Felicitas Bünger, Max Havermeier, and Simon Krämer

BCG + NABU

Boston Consulting Group partners with leaders in business and society to tackle their most important challenges and capture their greatest opportunities. BCG was the pioneer in business strategy when it was founded in 1963. Today, we work closely with clients to embrace a transformational approach aimed at benefiting all stakeholders—empowering organizations to grow, build sustainable competitive advantage, and drive positive societal impact.

Our diverse, global teams bring deep industry and functional expertise and a range of perspectives that question the status quo and spark change. BCG delivers solutions through leading-edge management consulting, technology and design, and corporate and digital ventures. We work in a uniquely collaborative model across the firm and throughout all levels of the client organization, fueled by the goal of helping our clients thrive and enabling them to make the world a better place.

Founded in 1899, NABU (Nature And Biodiversity Conservation Union), is one of the oldest and largest environmental associations in Germany. The association encompasses more than 875.000 members and sponsors.

NABU's most important tasks are the preservation of habitat and biodiversity, the sustainability of agriculture, forestry and water management and, last but not least, climate protection. The communication of nature experiences and the promotion of natural history knowledge are among NABU's central concerns.

About 40,000 volunteers play an active role in practical nature conservation work, with great success: This is something that is unique to NABU. These active NABU members look after more than 110,000 hectares of valuable protected reserves in Germany. NABU also has volunteer groups working on an international level to conserve nature and combat poverty in Africa, Eurasia, and the Caucasus. This work is supported by professionals at our regional offices and at our national headquarters in Berlin, who take care of public relations, project development and management, and political lobbying. NABU is part of BirdLife International.

www.NABU.de

www.birdlife.org

Contents

Foreword

In its recent 2022 publication "Earth for All – A Survival Guide for Our Planet," the Club of Rome calls for nothing less than "the next agricultural revolution."

And there is plenty of reason for such urgency.

Over the past two decades, the prospect of accelerating climate change and declining biodiversity has evolved from a warning issued by scientists to the frightening reality of dramatically reduced agricultural yields in Germany—the result of increasingly frequent and intense extreme weather events such as droughts and torrential rains.

Agriculture is among the industries hardest hit by climate change—and a key contributor to global warming and biodiversity loss. The current speed and scope of positive change in the agri-food system, both in Germany and in the world, is insufficient to reverse its footprint on the planet while also providing livelihoods and healthy diets for billions of people.

In 2020, more than 3 billion people worldwide could not afford a healthy diet, and that number is rising sharply. The Club of Rome and the most recent Intergovernmental Panel on Climate Change report stress that only a regenerative pathway through 2050 can adequately transform agriculture, change people's diets, improve access to food, and minimize waste.

If we are to create a healthy agri-food system for people and the planet, we must entirely rethink our current agri-food system, and embark on a path toward regenerative agriculture.

The aim of this report—a joint project of the Boston Consulting Group (BCG) and Germany's Nature and Biodiversity Conservation Union (NABU)—is to highlight the need for a regenerative transformation in Germany's agriculture, demystify regenerative agriculture and its practices, and, most importantly, showcase the benefits it can bring to all elements of agri-food system, including farmers, the entire food sector, and society at large.

This report is designed as a meta-study, building upon existing scientific work and practical experience on regenerative agriculture. At the core of the study is a constant and intense exchange with a community of farmers, agronomic experts and practitioners to calibrate the outlined pathway for the German agriculture context.

We hope that this report will inspire farmers to take steps toward a regenerative transformation of their land and that it will encourage food producers and retailers to make regenerative farming the new normal in their supply chains. We also urge educational institutions, advisory bodies, and policymakers to support and enable the regenerative transformation of farming. Only by taking rapid, collective, and decisive action will we be able to establish the future-proof agri-food system that our own and future generations so critically need.

Jörg-Andreas Krüger
President
Nature and Biodiversity Conservation Union

Torsten Kurth
Managing Director and Senior Partner
Boston Consulting Group

Executive Summary

The global agri-food system's contribution to climate change and biodiversity loss is immense, and it is among the industries most adversely affected by these ecological crises. In Germany, economic, social, and regulatory pressure on the agriculture system is especially intense. Agriculture contributes 12.5% of the country's total Scope 1 greenhouse gas (GHG) emissions. Farmers must cope with the increasing intensity and frequency of extreme weather events—in the form both of droughts and of torrential rains—that wreak havoc on crops yields, even as they struggle to meet the increased cost of land and farming inputs. Meanwhile, regulators are imposing limits on GHG emissions and requiring changes in land use, and consumers are demanding healthier, cheaper food.

Regenerative agriculture is the only approach to farming that can significantly reduce the industry's negative impact on our land and climate, increase its positive impact, and offer economic benefits to the entire agri-food system—from farmers to food manufacturers to retailers to consumers. Although this report focuses on Germany, we believe that the unique potential of regenerative agriculture holds true in virtually every mature agriculture market around the world.

We define regenerative agriculture as "an adaptive farming approach applying practically proven and science-based practices, focused on soil and crop health aimed at yield resilience and a positive impact on carbon, water, and biodiversity." Healthy soil is a key enabler for productive agriculture, and most regenerative practices are designed to support the soil's positive functions by protecting and feeding its biodiversity. To that end, regenerative agriculture depends largely on three essential principles:

- No-till farming, including direct seeding
- Permanent coverage of the soil with plants
- Promotion of biological diversity, including wider crop rotation

Regenerative agriculture has long been associated in the popular imagination with lower yields and shrinking profits for farmers. Our analysis, however, shows that it can increase farm profits by up to 60%, compared to conventional farming, as a result of lower input costs, operational savings, and greater resilience in severe weather conditions.

In addition, downstream food producers, distributors, and retailers can reduce their supply chain risks by up to 50% in years marked by weather-induced supply shocks such as droughts or excessive rain. Society as a whole can benefit, too. We estimate that the ecological benefits of lower carbon emissions and their effects on water availability and quality would total €8.5 billion per year in Germany alone.

Regenerative agriculture is thus a triple win. Nevertheless, effectively promoting it will require a concerted effort by all stakeholders in Germany's food supply, including agriculture input companies, academic experts, agronomic advisors, and regulators, as well as downstream food producers, distributors, and retailers. The return on investment of regenerative practices is high—for Germany's farmers; for the companies that make, distribute, and sell food; and for the country's consumers and society at large, which will benefit from a healthier, more sustainable, and more secure food supply.

The Case for Regenerative Agriculture

As the pressures on Germany's agriculture and food sectors mount, it has become increasingly clear that the current system is not sustainable. In the face of rising costs, the increasingly heavy toll exacted by climate change, and demands from consumers and regulators for change, the country can no longer rest assured that it has access to a stable, secure supply of inexpensive agricultural products. Regenerative agriculture offers a sustainable, practical solution to the industry's challenges.

The Status Quo

Germany's food system and the farmers who grow the country's food are under considerable pressure from all sides. Consumers are demanding that the food they buy be healthier, more affordable, and more sustainably grown. Regulators are determined to reduce the country's carbon footprint and as a result are placing increasingly stringent requirements on how farmers grow food. Meanwhile, input costs are rising, and climate change is dramatically affecting the country's weather patterns, and thus farmers' yields. (See Exhibit 1.)

Rising Input Costs. Although input costs were already rising steadily over the previous several years, the war in Ukraine triggered especially steep increases in the cost of fertilizers and fuel. Higher prices for grains and other agricultural goods were enough to offset the additional costs in 2022, but they are unlikely to be sustainable for all farmers in the long term.[1]

[1] Eurostat, 2022: EU's agricultural labour productivity up by 13% in 2022.

Exhibit 1 - The Pressure on Farmers Is Heating Up

Source: BCG analysis.
Note: COP 15 = fifteenth session of the Conference of the Parties, a UN conference on biodiversity held in December 2022.

Increasing Land Competition. Competition for land is also on the rise. As demand for renewable energy increases, more and more land is likely to be given over to solar panels and wind turbines. The pressure on agricultural land will only increase as the value of carbon credits rises and as carbon credit markets become more mature. The impending transformation of road transport from internal-combustion engines, which require a significant share of biofuels, to battery electric or hydrogen-electric vehicles could reduce the need for energy crop production, and hence lower agriculture's overall carbon footprint. But concurrent increasing demand for bio-based materials and synthetic air fuel will likely require continued production of energy crops.

Worsening Climate. Weather in Germany is increasingly affected by climate change, leading to more frequent and more severe weather events, including droughts, heavy rain, and storms. (See the sidebar "The Climate Change Paradox.")

Supply Insecurity. The current geopolitical situation has put a premium on securing Germany's food supply, especially for core food crops, through local production. Recently, the government has revised regulations to set aside environmentally friendly policies and instead increase short-term production targets, making farmers' efforts to plan for medium-term production goals and associated investments highly unpredictable. At the same time, the current inflationary environment has increased pressure to keep the price of food affordable for consumers.

Societal Pressure. Even as food prices rise in line with recent inflationary pressure, consumers are increasingly demanding healthier and more sustainable food that continues to meet high German standards. "Grow more with less" has long been a slogan in the agri-food industry, typically for marketing purposes rather than as a call for decisive action. But with the industry stretched to its limits, a transformation toward regenerative agriculture is essential to improve the resilience, ecological efficiency, and profitability of the country's agriculture industry.

Regulatory Tightening. Germany's agriculture sector contributes a considerable portion of the country's greenhouse gas (GHG) emissions. In 2021 alone, Germany's agriculture sector directly generated 54.8 million tons of carbon dioxide equivalents (CO_2e), representing 7% of the country's total of 728.7 million tons in Scope 1 GHG emissions. Methane, an especially potent GHG, was responsible for more than half of the agriculture sector's emissions, primarily from the digestion and manure management of farm animals. Nitrous oxide (N_2O), another very potent GHG from fertilizers and soil tillage, accounted for nearly

40% of agricultural emissions. An additional 36.5 million tons of CO_2e emissions in 2020 were attributed to land use and land-use changes of cropland and grassland, mostly driven by CO_2e emissions caused by unsustainable soil use. Altogether, these emissions represent approximately 12.5% of the country's total Scope 1 GHG emissions.[2]

In response, governments and regulators in Germany and the EU continue to tighten regulations governing such farming practices as input usage and how farmers work their land. Germany's Federal Climate Protection Act, passed at the end of 2019, requires the agricultural sector to reduce its Scope 1 and Scope 2 emissions by around 10% from its 2020 baseline levels by 2030.[3] With the 2022 reporting, however, new emission factors were used for the first time to calculate N_2O emissions. As a result, emissions from the cultivation and fertilization of agricultural soils were around 5 million tons of CO_2e lower than in 2021. The target value, meanwhile, has not yet been adjusted.

At the European level, the regulatory environment is guided by the EU Green Deal, its Farm to Fork and Biodiversity strategy, and its Fit for 55 package. These guidelines include commitments to reduce emissions, fertilizer use, and pesticide use, which became global targets through the Global Biodiversity Framework, signed by more than 200 countries at COP 15 in Montreal in December 2022. However, by continuing to fund the region's agriculture by offering farmers direct payments that are only partially tied to their ecological impact, the EU Common Agricultural Policy stands largely at odds with these transformative goals, at least until the next revision is due in 2027.[4]

Cumulatively, the pressure on Germany's agriculture sector is intense. Besides regenerative farming practices, various new technologies, innovations, and demand-side changes can help relieve some of the pressure. Digital and precision farming technologies promise to increase the efficiency of inputs, while biological innovations from breeding may create more resilient and stress-tolerant crop varieties.

Changing the German agriculture business model—which today fosters the production and export of animal proteins, including dairy products and meat from hogs—toward lower-intensity livestock could also play a significant role. Promoting shifts in diets, supported by regulations such as taxes on meat, could encourage the replacement of animal products with alternative proteins.

The Narrative for Regenerative Agriculture

Despite the increasingly stringent regulatory environment, regulation of the German agri-food system will not produce the necessary changes to the kinds of food produced in Germany, and to the ways it is grown, distributed, and paid for, quickly enough.[5] In fact, many policies and regulations affecting the industry have been put on hold or even temporarily reversed in the near term, with the stated intention of producing enough food to compensate for the current production decline in Ukraine.

And while key stakeholders in the agri-food system are taking significant steps to improve the sustainability and lower the cost of food in Germany, they are not moving fast enough. Several consumer packaged goods companies have launched programs to promote more sustainable agriculture practices, but these are still at the pilot stage. Farmers are changing their farming practices slowly and are not yet wholeheartedly embracing more sustainable approaches. After all, most German farmers were brought up in a conventional farming system and were educated and trained in a curriculum that focused on optimizing the use of synthetic inputs as ultimate problem solvers. More regenerative methods and practices have not generally been a core part of their education.

Given the current regulatory and economic trajectory, the situation in Germany is not likely to improve any time soon. And while regenerative agriculture offers a real opportunity to change direction, there is little regulatory incentive or support in the food value chain to undertake major changes. Currently, the rate of farmers shifting to organic agriculture is decreasing, despite their greater willingness to adapt in the face of climate change. As for consumers, although their attitudes toward the health and environmental friendliness of the food they eat are evolving, they have not generally shown themselves to be willing to pay the price for more responsibly grown food.[6]

In short, the status quo is not sustainable. Unless agricultural practices and attitudes change, farmers will pass on to future generations a situation in which soils are depleted, yields are uncertain due to a lack of resistance to global warming, and the range of alternatives continues to narrow in the face of unfavorable regulation.

The only way to bring about the necessary changes is through widespread adoption of regenerative agriculture—a triple win that offers benefits for farmers, other players in the agri-food system, and Germany's consumers.

[2] German Federal Environment Agency, 2022: Contribution of agriculture to greenhouse gas emissions.

[3] German Federal Environment Agency, 2022; Germany's greenhouse gas reduction targets.

[4] Naturschutzbund, 2022: New CAP Unpacked . . . and Unfit.

[5] German Federal Environment Agency, 2022, Germany's greenhouse gas reduction targets.

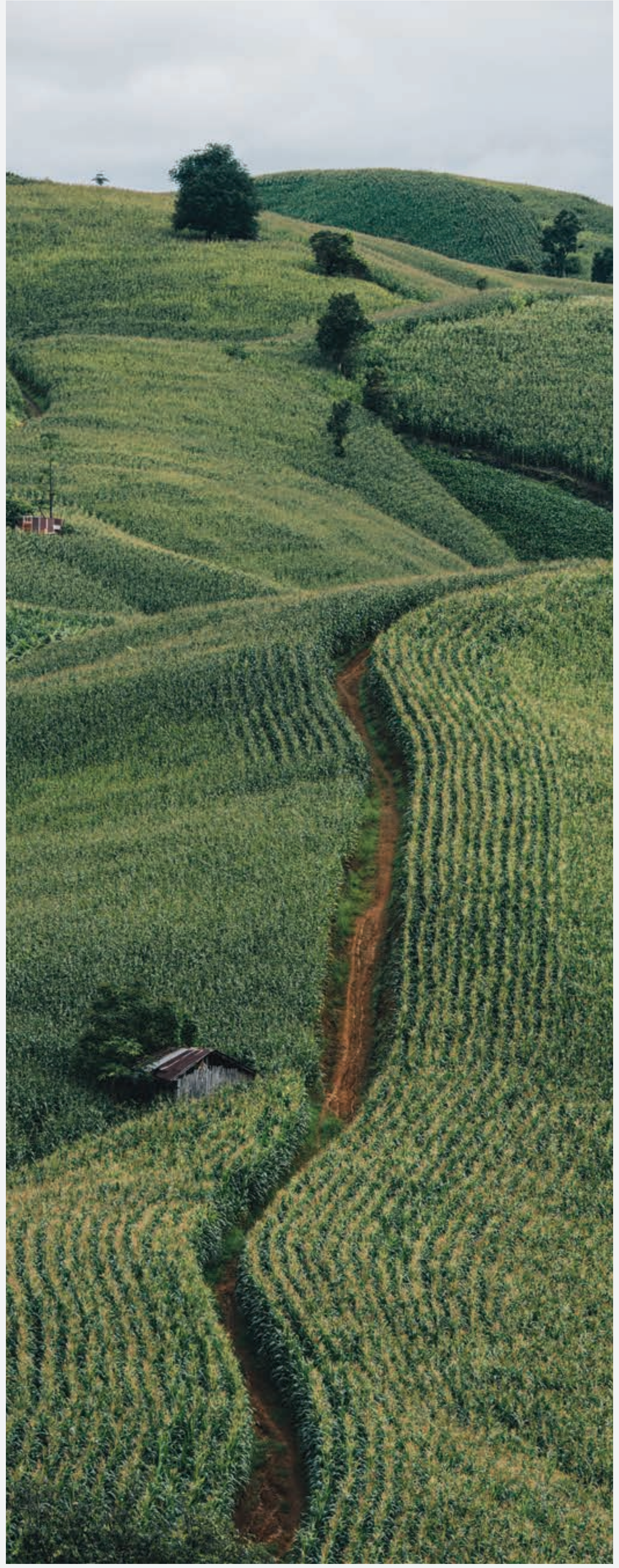
[6] E.g., Aschemann-Witzel & Zielke, 2015: Can't Buy Me Green? A Review of Consumer Perceptions of and Behavior Toward the Price of Organic Food, *Journal of Consumer Affairs*.

The Climate Change Paradox

The impact of climate change on agriculture in Germany is growing, as is the sector's impact on climate change. Extreme weather events in Germany are increasing in both frequency and magnitude. Heat and drought in 2018 and 2019 cost the country's agriculture sector €7.8 billion in lost yield, and recent studies concur that droughts are likely to become even more frequent and more severe in the future.[1]

Similarly, severe weather events such as heavy rain have more than doubled in Germany from 2001 to 2020.[2] The damage that such events cause is amplified by the decreased ability of dry and compacted agricultural soils to take up and hold water or to route it efficiently into the groundwater, amplifying flash floods like those that occurred in 2021.[3] And increasingly severe droughts and heavy rain aren't the only adverse effects. Warmer winters will foster the growth of new pathogens and plant varieties, complicating crop protection efforts.[4]

In short, as weather—especially droughts and heavy rain—becomes more variable, the agricultural paradigm must change from "maximum yield under perfect conditions" to "yield resilience under more severe weather."



[1] Grillakis, 2019: Increase in severe and extreme soil moisture droughts for Europe under climate change, *Science of the Total Environment*. Samaniego, Kumar & Zink, 2013: Implications of parameter uncertainty on soil moisture drought analysis in Germany, *Journal of Hydrometeorology*.

[2] 2021: Adaptation to Climate Change.

[3] https://www.prognos.com/sites/default/files/2022-07/Prognos_KlimawandelfolgenDeutschland_Kurzzusammenfassung_Extremwetter-sch%C3%A4den%20seit%202018_AP2_3d_.pdf.

[4] Velásquez, Castroverde & He, 2018: Plant-Pathogen Warfare under Changing Climate Conditions, *Current Biology*.

Regenerative Agriculture as Contextual Transformation

The key to regenerative agriculture lies in understanding that it is not a rigid, highly structured farming practice. Rather, its implementation depends heavily on the nature of each farm to which it is applied, the specific crops being grown, and the prevailing farming conditions. This chapter offers a definition of regenerative agriculture, outlines typical regenerative practices, and presents a picture of how they could be implemented in Germany.

Defining Regenerative Agriculture

There is no broadly agreed-upon definition of *regenerative agriculture*, although people often associate the term with various buzzwords, initiatives, and best practices.[7] (See the sidebar "Myths ... and Reality.") Common to all definitions is the idea that regenerative agriculture is not a one-size-fits-all approach. Rather, it is a context-specific journey that depends for its specific implementation on the type and condition of the soil, the local ecosystem and microclimate, the crops to be grown, and other factors—a process that requires continuous on-farm innovation.

Regenerative agriculture describes an adaptive farming approach applying practically proven and science-based practices, focused on soil and crop health aimed at yield resilience and a positive impact on carbon, water, and biodiversity.

[7] Different definitions and descriptions include Gabe Brown's Five Principles of regenerative agriculture in "From Dirt to Soil." Also FAO, Unilever, Nestlé, etc.

Myths ... and Reality

Five Myths About Regenerative Agriculture Busted

Myths	Reality
Regenerative agriculture is **an esoteric ideology**	Regenerative agriculture is **nondogmatic,** rooted in **science,** and based on decades of best practice
Regenerative agriculture is just another new **trend** after **organic farming**	Regenerative agriculture leverages the **best of conventional and organic** farming
Regenerative agriculture is the same as **"carbon farming"**	It is a **holistic approach** with a focus beyond greenhouse gas management
It is an **all-or-nothing, unattainable** approach	Regenerative agriculture is an **adaptive approach,** with **no-regret moves** for every farming **context**
Regenerative agriculture **severely reduces farmers' profitability**	It is a **worthwhile investment that improves farmers' P&L** in the medium to long term

Sources: WWF; NABU; BCG analysis.

Regenerative agriculture is subject to a number of popular misconceptions, but these myths do not withstand scrutiny. (See the exhibit.)

Myth #1: Regenerative agriculture is an esoteric ideology.

Reality: Regenerative agriculture is nondogmatic, rooted in science and based on best practices. Framers need not fulfill any specific requirements; they can tailor their practices to their particular farm, and they are free to experiment and implement what works best.

Myth #2: Regenerative agriculture is just another new trend after organic farming.

Reality: Regenerative agriculture is based on conservation agriculture with decades of proven value and can be used to transform both conventional and organic farms.[1]

Myth #3: Regenerative agriculture is the same as "carbon farming."

Reality: Unlike carbon farming—which involves farm-level carbon sequestration efforts intended to create carbon credits—regenerative agriculture is a more holistic approach and does not focus solely on GHG management.

Myth #4: Regenerative agriculture is an all-or-nothing unattainable approach.

Reality: Regenerative agriculture is a continuous journey along an individual path of improvement, with no-regret moves that depend entirely on each farm's specific context. There is no checklist of practices and no defined final fully regenerative state—although it is certainly possible to identify best practices and practices that contradict the basic concept of regenerative agriculture. Currently, there is no widespread label or certification for regenerative agriculture in Germany.

Myth #5: Regenerative agriculture severely reduces farmers' profitability.

Reality: Regenerative agriculture is a profitable approach that does not typically lead to lower yields.[2] In most instances, farmers who adopt regenerative practices find themselves economically better off as a result, and any negative short-term impact is often the result of uninformed trial and error. The transition to regenerative agriculture brings other benefits as well, including reduced fertilizer, labor, and other input costs; new sources of income from carbon credits; higher yields due to greater resilience in case of extreme weather events; and ultimately increased land value due to healthier soils.

[1] Food and Agriculture Organization of the United Nations, 2020: Advances in Conservation Agriculture: Volume 2: Practice and Benefits, Burleigh Dodds Science Publishing.

[2] Kirchmann, 2019: Why organic farming is not the way forward, *Outlook on Agriculture*.

Key to the successful implementation of regenerative agriculture is a shift away from focusing solely on optimizing every season's crop yields and toward a longer-term consideration of the health of the soil in which the crops are grown, their potential contributions to yield resilience, biodiversity and ecosystem services—the regulating, provisioning, habitat providing, and acculturating functions that nature itself provides. In this sense, regenerative agriculture promotes and protects critical agricultural production factors.

Regenerative agriculture is based on three key principles:

- No-till farming, including direct seeding
- Permanent coverage of the soil with plants
- Promotion of biological diversity, including wider crop rotation

These principles share a single primary goal: to support the soil's functions by protecting and feeding its biodiversity. Regenerative agriculture does not otherwise follow any standardized prescriptions or regulated requirements, so it can be adapted in light of current farming practices and can be used to transform both conventional and organic farms.

In contrast, conventional farming—despite varying considerably in its methods from farm to farm—typically uses standard deep tilling, synthetic fertilizers, and herbicides and pesticides to maximize yield and short-term profits, and rarely calls for rotating crops. Unfortunately, conventional farming fails to ensure long-term soil fertility and does not provide sufficient yield resilience in the face of severe weather events and changing climate conditions. (See the sidebar "What's the Challenge of Conventional Farming")

What's the Challenge of Conventional Farming

Conventional farming is demonstrably harmful to the environment, disrupting natural carbon, water, and nitrogen cycles, among others; stripping the soil of key functions; and limiting the production potential of photosynthesis. Specifically conventional agriculture contributes to an eight-stage cycle of harm. (See the exhibit.)

1. A large share of precious water evaporates from soil when it is not covered after tillage. In addition, bare soil has a much lower capacity to absorb water during heavy rain than soil covered by vegetation has. The negative effects of this weaker absorption capacity include greater surface heating, lower soil moisture, and a heightened need for irrigation.

2. Depleted and compacted soils with lower soil organic matter (SOM)—a term that, for simplicity's sake, this report uses interchangeably with humus—cannot absorb or hold as much water as soils with a higher share of SOM, and thus further increases the need for irrigation.

3. Soil biodiversity is critical for overall crop health and for completing natural cycles, but it is not a factor in conventional agronomic practices. Tillage and synthetic inputs harm soil biodiversity.

4. The potential for photosynthesis to capture carbon from the atmosphere is not fully exploited when fields lie fallow without cover crops. This results in less root biomass production, which reduces the soil's ability to capture carbon and nitrogen.

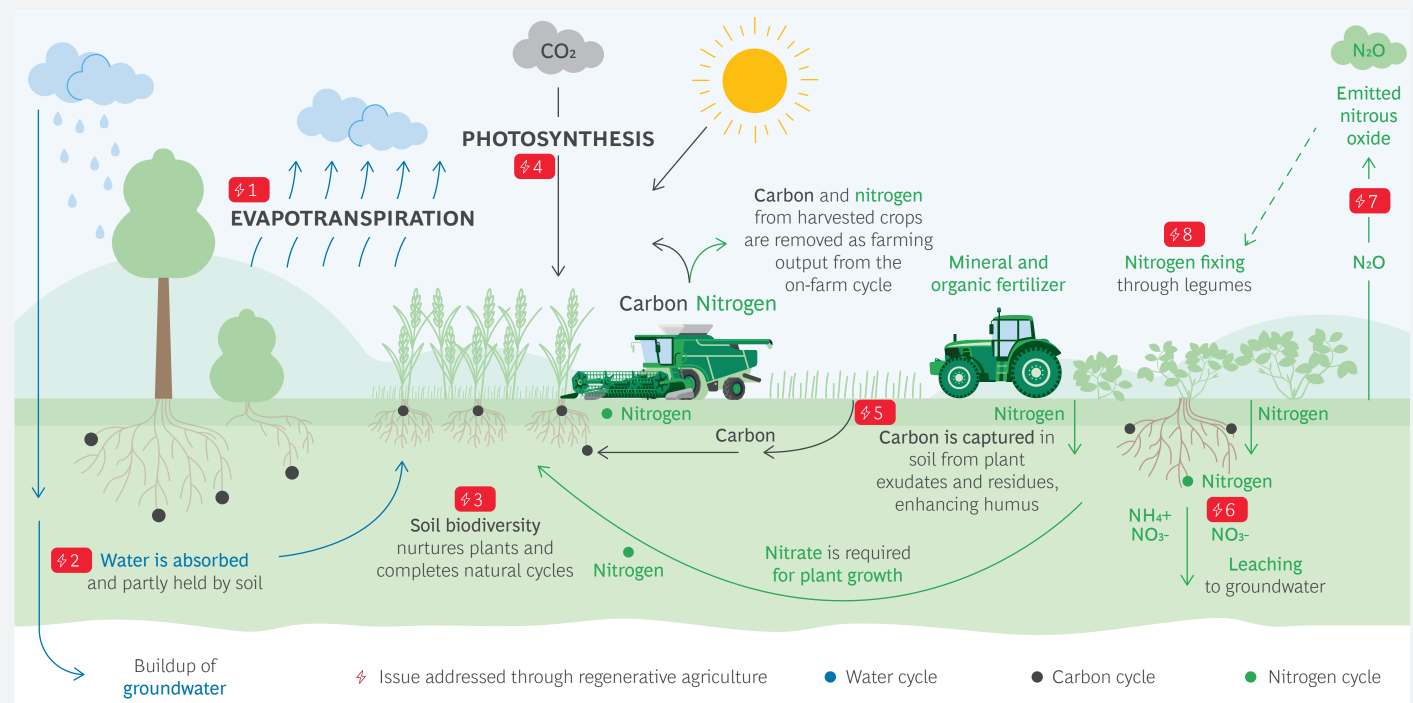
5. Depletion of soils' organic matter content causes a net increase in carbon emissions, and conventional agricultural practices fall far short of fully exploiting the potential of agricultural soil to sequester carbon.

6. Nitrates from the application of animal manure and nitrogen fertilizers leach into groundwater, polluting water and leading to algae blooms.

7. Nitrification processes partially convert nitrogen fertilizer and animal manure into nitrous oxide (N_2O), a powerful GHG with more than 250 times the climate impact of carbon dioxide (CO_2).[1]

8. Including few or no legumes in crop mixes limits the potential for natural nitrogen fixing, a missed opportunity to complete the nitrogen cycle and reduce the need for synthetic sources of nitrogen.

Natural Resource Cycles in Agriculture



Source: BCG analysis.

[1] German Federal Environment Agency, 2021: Nitrogen.

Organic farming tends to be more rigid, with strictly regulated requirements that include prohibiting all chemical inputs, rotating crops frequently, and mandating a transition period from conventional to organic practices. Food produced organically may be sold under different consumer-oriented labels, such as “EU Organic” and “Naturland,” depending on how strictly it complies with organic standards. Although it is less environmentally harmful than conventional agriculture, organic farming can disturb the soil’s natural structure and result in yields that fall short of conventional yields by as much as 40%.[8]

Transforming how we currently use land is critical to improving food security and restoring Germany’s ecosystem. (See the sidebar “How Germany Uses Its Land.”) Yet the opposing narratives of conventional and organic farming have led to a deadlock in these efforts. Regenerative agriculture can unlock the necessary transformation by providing a clear transition path for conventional farmers while modifying and complementing current organic practices.

Implementing Regenerative Agriculture

Our goal in this chapter is to explain appropriate regenerative practices for different types of crops. Although a wide range of methods may work well in various places around the world, this report focuses on practices that are most relevant for Germany and have the backing of a scientific consensus with regard to their potential positive impact.

[8] Kirchmann, 2019: Why organic farming is not the way forward, *Outlook on Agriculture*.

How Germany Uses Its Land

The first step in analyzing the potential impact of regenerative agriculture on Germany’s agriculture sector is to determine the addressable surface area. Fully 46% of the country’s land, about 16.3 million hectares, is used for agricultural purposes. Regenerative agricultural practices are capable of addressing 90% of that amount, about 14.8 million hectares. This figure excludes peatlands and nonscope crops. (See the exhibit.)

Although peatlands make up about 5% of agricultural land, they are more valuable when restored to combat global warming. Nonscope crops include perennial crops that require somewhat different regenerative practices than field crops do, as well as crops that account for less than 5% of Germany’s arable land, such as potatoes and beets. Quantifying in detail the impact of regenerative agriculture on such crops exceeds the scope of this report. Approximately 10% of Germany’s total agricultural area is used for organic farming. Our analysis of the overall impact of the transformation toward regenerative agriculture in Germany excludes this area, too, since organic farming already uses many regenerative practices and so should not be assessed as land operating under conventional production systems.

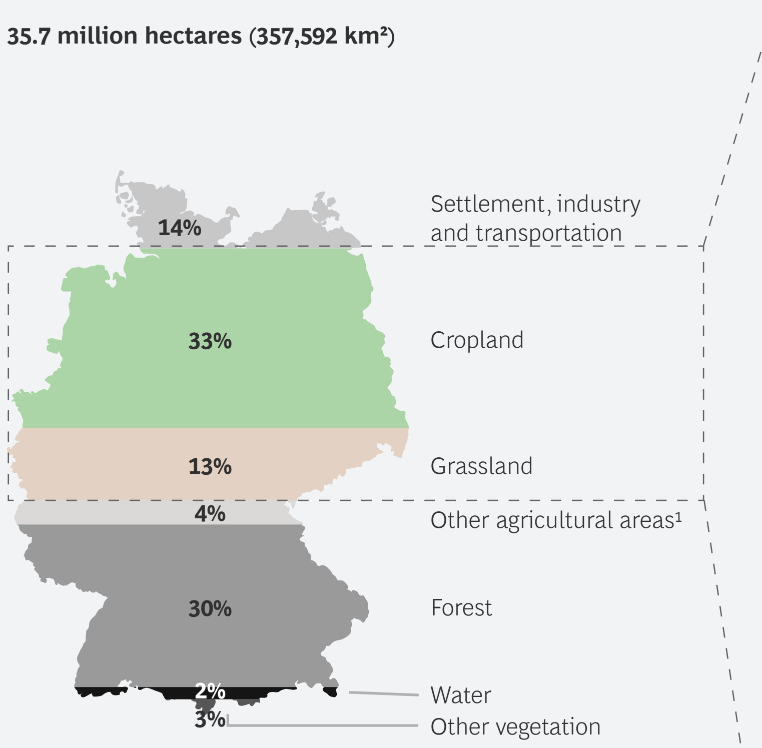
For the quantification performed in this study, we focused on 10 million hectares of cropland and another 3.3 million hectares of grassland.

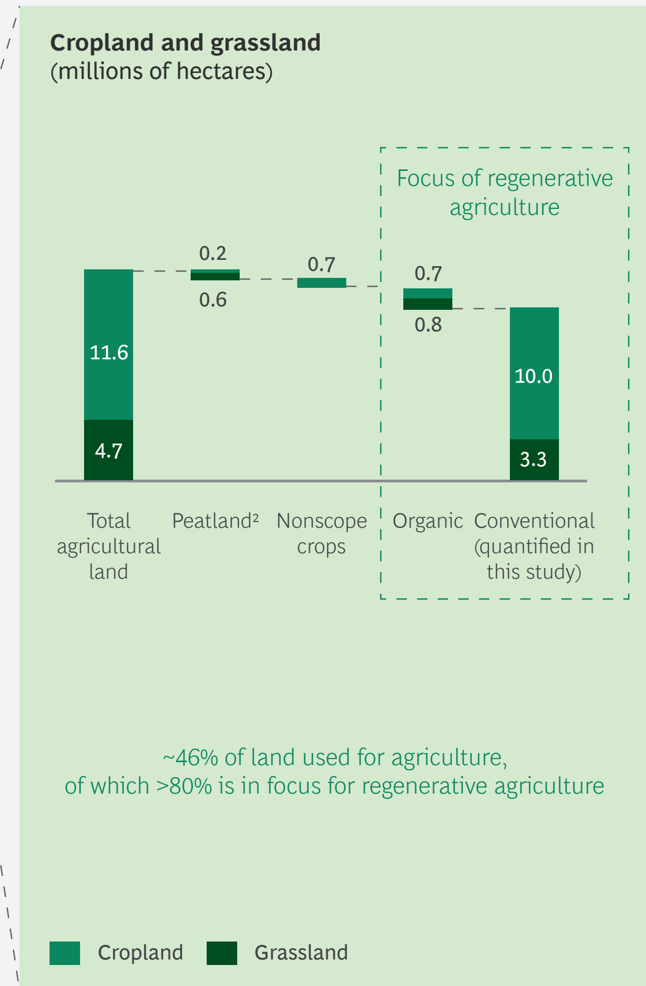
Germany’s agriculture sector is composed of many different types and sizes of farms. As a rule, the larger the farm, the greater the share of its land that is devoted to cropland rather than grassland. In order to reduce complexity, we defined three farm archetypes for this report.

German farms fall into three archetypes:

- **Small Farms**
  Occupying about 20% of the country’s agricultural land, small farms range up to 50 hectares, with a 50/50 split between cropland and grassland.
- **Mixed Farms**
  These farms, which account for approximately 45% of Germany’s agricultural land, average 300 hectares in size and are composed, on average, of two-thirds cropland and one-third grassland, including grazing land for cattle and grassland for feed.
- **Crop Farms**
  This archetype represents about 35% of agricultural land in Germany, with an average size of 1,000 hectares, and consists entirely of cropland, with no livestock.

Land Use in Germany





Sources: Destatis, German federal statistical office; BCG analysis.
¹ Other agricultural areas consist of land not directly used for agriculture (e.g., for economic, social, or other reasons), buildings, yard areas, roads, etc.
² Peatland that cannot be restored (e.g., owing to bad conditions or to settlements that would be affected) is not taken into account.

We have chosen not to include practices and technologies that already receive regulatory support, such as wildflower strips, that are as yet novel and untested, or that continue to stir significant debate as to their impact, such as the use of genetically modified organisms.[9]

Our description of the journey to regenerative agriculture identifies three implementation stages for practices on both cropland and grassland: basic, intermediate, and advanced. Each stage is further subdivided into what we call the CIS framework, consisting of cultivation, inputs, and structure (See Exhibit 2):

- **Cultivation** refers to practices that have direct effects on how crops are grown and managed, such as no-till and cover crops.
- **Inputs** are products added to the soil and to crops in the field, a category most frequently associated with fertilizers and plant protection.
- **Structure** consists of changes that affect the composition of land use, including such factors as evolving crop cycles, changing aerial structures, and integrating agroforestry.

Implementing regenerative agriculture begins with adopting practices that are fundamental and easy to perform, and builds on them toward practices that may take many years to fully implement, are more capacity- and investment-intensive, and may be applicable only in special circumstances.

As noted earlier, individual farms may require different regenerative practices, depending on context and past practices. Although carrying out the basic Stage 1 practices together will achieve the best results, the implementation of intermediate and advanced practices need not follow a strict predefined order; instead, each farmer should consider the full range of prevailing conditions and then decide which practice is most appropriate to try out and measure. Regenerative agriculture is a continuous process that requires time to fully understand each farm's context. The key is to reflect, adapt, and regenerate. (See the sidebar "The Farmer's Path to Regenerative Agriculture.")

Exhibit 2 - Regenerative Agriculture Involves Changes in Cultivation, Inputs, and Farm Structure, and Can Be Carried Out in Three Stages

Application type / Stages	1 Basic implementation	2 Intermediate implementation	3 Advanced implementation
Cultivation How we cultivate the land	No-till practices, including direct seeding (cropland) Minimal soil-disturbing subsoiling (cropland) Cover cropping (cropland) Interseeding (grassland)	Minimal soil-disturbing mulch system (cropland) Undersown cropping (cropland) Adaptive grazing or mowing (grassland)	Intercropping (cropland)
Inputs What inputs we put on land/crops	Soil analysis and balancing (cropland)	Biofertilizer/biostimulants and biological seed coating (cropland) *Optional: Bioleaching inhibitors and crop protection* (cropland)	Biologically activated biochar (cropland)
Structure Which structure we create	*No structural practices in basic implementation stage*	Legume crop rotation (cropland)	Agroforestry (cropland, grassland) Livestock integration (cropland) *Optional: Smaller aerial structure and keyline subsoiling* (cropland) *Optional: Pasture cropping* (grassland)

Regenerative farming practices

Applies to cropland — Applies to grassland

Source: BCG and NABU analysis.

[9] https://enveurope.springeropen.com/articles/10.1186/s12302-014-0034-1

The Basic Implementation Stage

The first steps toward regenerative agriculture should occur during an exploratory period, typically on a share of land. This is a time for learning, exchanging ideas with the regenerative agriculture community, and consulting others on context-specific practices and challenges.[10] At this stage, the goal should be to consistently apply the defined practices and to switch to no-till. It is important to measure early results, learn quickly, and draw conclusions from which to build future efforts. Basic measures include the following:

- **No-Till Farming, Direct Seeding, and Minimal Soil-Disturbing Subsoiling.** The focus of these practices is on alleviating compaction and minimizing damage to the soil in order to establish a basis for regenerating soil health and building up organic matter. Implementation should begin with subsoiling (using minimally intrusive methods to break up subsurface soil) to get soil in shape, followed by application of controlled traffic farming (restricting machinery loads to defined permanent traffic lanes). No further intervention should be undertaken.

- **Soil Analysis and Balancing.** The goal of these practices is to move away from wholesale dependence on chemical nitrogen, phosphorus, and potassium fertilizers and toward a more holistic view of all necessary soil nutrients, including secondary nutrients and micronutrients.

- **Cover Crops.** Planting diverse crops after harvesting the main crop helps protect soil from erosion, builds up organic matter, encourages soil biodiversity and—in the case of legume cover crops—helps fix nitrogen in the soil, thereby reducing the need for fertilizers.

- **Grassland.** The aim here is to reduce the use of synthetic nitrogen fertilizers and enhance the land's productivity and soil structure by interseeding other grasses, legumes, and herbs.

The basic stage requires no specific structural changes in farming practices.

The Intermediate Implementation Stage

This stage involves adopting practices that generally require more time or more experience to implement. Consequently, these practices typically demand longer-term planning.

Intermediate practices include the following:

- **Minimal Soil-Disturbing Mulch Systems.** This practice involves shredding the cover crop, and in certain circumstances working it into the soil, while only minimally disturbing the soil surface. If possible and feasible, biostimulants or biofertilizer can be added as well.

- **Undersown Cropping.** Although conceptually similar to cover crops, undersown crops are planted to overlap with the main crop, sometimes with permanent undersowing of plants beyond a single crop cycle.

- **Biofertilizer.** Producing and using biofertilizers predominantly from farm biomass— including compost extract, compost seed coatings, ferments, and foliar sprays—increases the circularity of farming operations.

- **Legume Crop Rotation.** Integrating legumes into the main crop cycle improves soil structure and fixes nitrogen in the soil. (See the sidebar "Living with Legumes.")

- **Grassland.** The intermediate stage for grassland involves use of adaptive grazing, allowing livestock to graze intermittently on defined parts of the land to foster alternating periods of trampling, grazing, and regrowing of grass. Adaptive mowing allows plants to recover faster after cutting and improves the root strength of the grass.

The Advanced Implementation Stage

The practices employed at this stage—including integrating livestock, redefining aerial structures, and adding hedges or agroforestry—are specific to each field and to the structure of the farm. Their implementation time can be lengthy, and they may require significant upfront investment, so achieving positive returns on investment is likely to take a relatively long time. Advanced practices include the following:

- **Intercropping.** This practice involves simultaneously growing two main crops, either in strips or side-by-side; its potential benefits depend to a large extent on the types of crops to be grown.

- **Biologically Activated Biochar.** Applying carbonized biomass that has been inoculated with microbes via fermentation can improve the structure and nutrient-holding capacity of soil.

- **Agroforestry.** Here, hedges or trees are integrated into cropland or grassland to increase biodiversity, provide shade, and reduce water evaporation.

- **Livestock Integration.** This practice entails raising livestock in conjunction with growing crops—for example, allowing livestock to eat cover crops in order to increase carbon capture and directly fertilize the soil.

One way to understand how regenerative agriculture compares with conventional farming approaches, is to track a typical crop cycle at a conventional farm against the crop

[10] Besides connecting with local farmers with experience, we would like to mention possible resources in Germany: Soilify.Org, GKB e.V. (Society for Conservation Tillage), annual event "Soil Evolution."

Living with Legumes

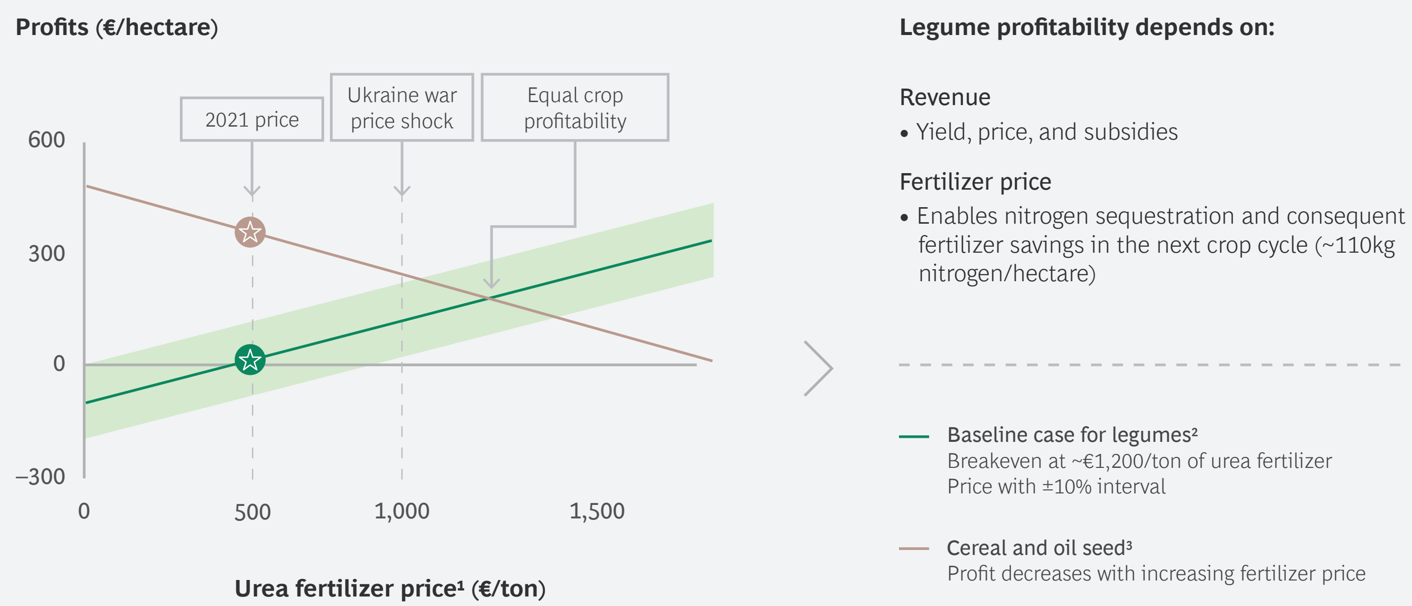
Legumes have many virtues in a carefully managed farm program, which makes them a key component of regenerative agriculture. Most notably, they can fix nitrogen in soil, reducing farmers' need to use of fertilizer. In addition, legumes send their roots deep into the soil, which helps the soil resist compaction and increases its organic matter content. The monetary value of nitrogen fixing, however, depends to a great extent on the price of nitrogen fertilizer, which has risen significantly in recent months, largely as a result of the war in Ukraine. Changes in the price of fertilizer will determine the economic attractiveness of legumes in comparison with other crops. (See the exhibit.)

As a cash crop, legumes are subject to strong regional variations in yield and in the prices paid for them. In some parts of the country, regional subsidies offer considerable benefits. For example, the Kulap program, which was in place in Thuringia from 2014 to 2022, offered farmers who planted legumes on at least 10% of their land a subsidy of €90 per hectare, among other measures to improve crop rotation. Calculated on the basis of the 10% legume share of the entire crop rotation program, this totals around €900 per hectare in subsidies for legumes, higher than the average profit from winter wheat.[1]

The net value of legumes also depends on the value of the cash crop they replace. Cereal and oil seeds, for example, currently yield around €355 per hectare, while legumes barely break even at €9 per hectare (before subsidies). On the other hand, farms that raise livestock can use legumes as fodder, which may lessen the immediate negative impact on profits that planting legumes may have.[2] And while relatively few German farmers today grow and sell legumes as a cash crop, increased demand for plant-based alternatives, often made from legumes, will likely lead to higher prices as populations turn away from meat protein.[3]

In any case, in the big picture, legumes represent not just a potential cash crop, but a crop that performs multiple services that are useful to farmers.

Legume Profitability Depends Heavily on Nitrogen Fertilizer Prices



Sources: Bundesgütegemeinschaft Kompost; Landwirtschaftsbericht 2021–2022; Bayerische Landesanstalt für Landwirtschaft; BCG analysis.
Note: Profitability estimates do not include any potential government subsidies.
[1] Urea fertilizer with 46% nitrogen content.
[2] Legume average for Germany in 2021: yield, 3.6 tons/hectare; price, €27/kg.
[3] 2021 cereal and oil seed profit: €355/hectare (2021 fertilizer prices), 120 kg nitrogen/hectare fertilization.

[1] https://umwelt.thueringen.de/themen/natur-artenschutz/foerderung/kulap

[2] https://www.proteinmarkt.de/fileadmin/bilder/fachartikel/2016/Proteinmarkt-KL-Rind-Gesamtfassung.pdf

[3] Morach, Witte, Walker, von Koeller, Grosae-Holz, Rogg, Brigl, Dehnert, Obloj, Koktenturk & Schulze, (2021): Food for Thought: The Protein Transformation, BCG.

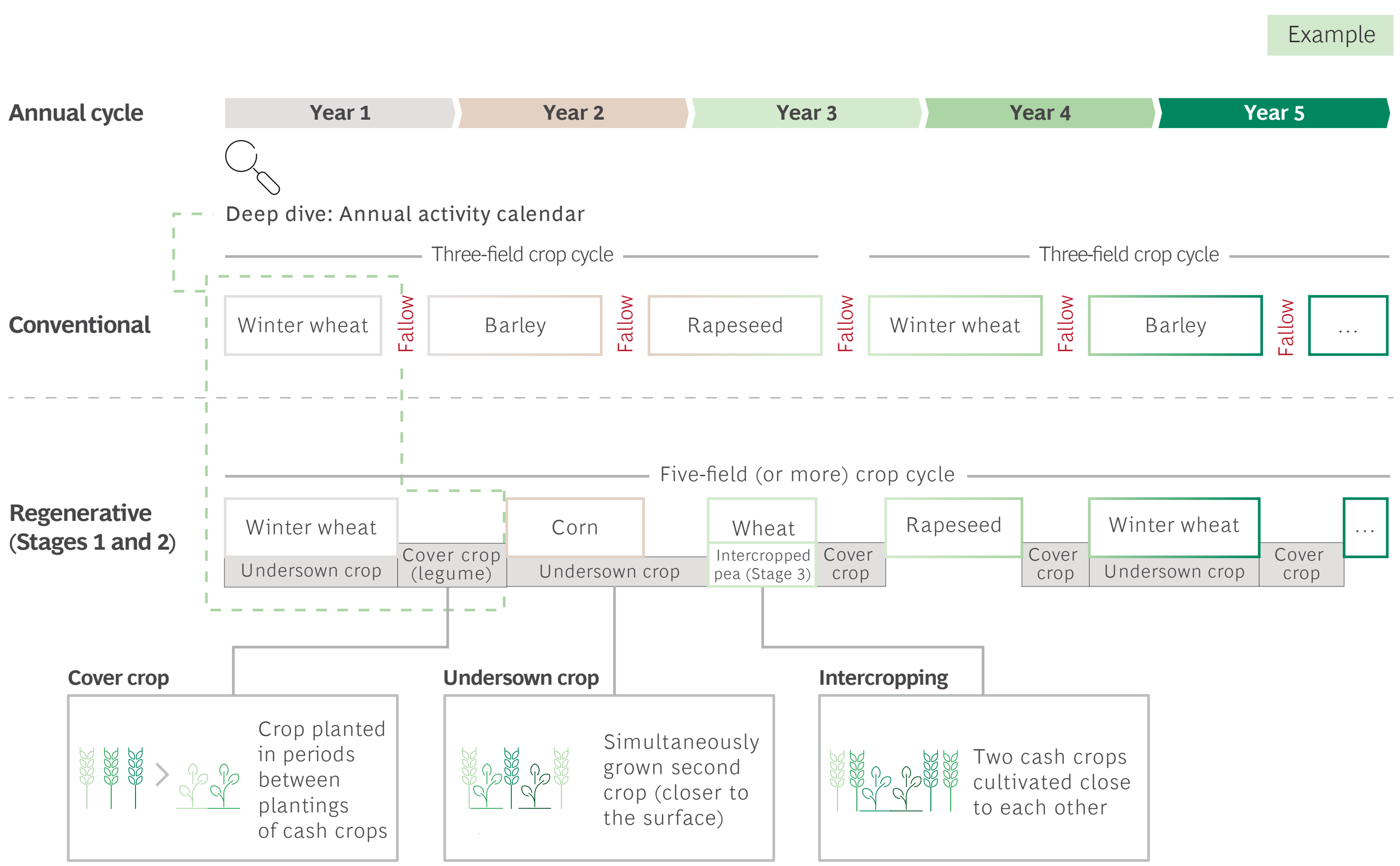
rotation practices at a regenerative farm at the field level. (See Exhibit 3.) On a conventional farm, fields lie fallow for an extended period each year, whereas on a regenerative farm, fields are always planted with either cover crops or undersown crops. The regenerative approach results in a constant soil cover and live roots that can prevent erosion, feed soil biodiversity, improve the soil's capacity to absorb water during heavy rain events and efficiently route it into the groundwater, and reduce evaporation of soil moisture during droughts. Exhibit 4 compares both conventional and organic practices to the goals of regenerative agriculture.

Digging deeper into the granular differences between conventional and regenerative agriculture, Exhibit 5 details the activities that a farmer planning to grow a crop of winter wheat might pursue in a typical year, from seeding in October to harvesting in July.

After seeding, conventional farmers add chemical fertilizers and pesticides over the course of the growing season, depending on the nature of the soil and the presence of specific diseases, weeds, and pests. After harvesting, they till the soil, add more herbicides, and then let the field lie fallow until replanting season arrives.

In contrast, intermediate-stage regenerative farmers begin the growing season by deploying an advanced mulching system on the existing cover or undersown crop. Applying compost fertilizer significantly reduces their need for fertilizer and herbicides, since management of weeds and crop residues occurs through plant competition among undersown plants and the shading effects of the mulching layer. Although completely eliminating crop protection chemicals is a long-term aspirational goal of regenerative agriculture, reductions in herbicide use tends to be gradual, as applying herbicides may still be necessary to control weed pressure from previous years, especially in the first years of the transition. After the farmer harvests the cash crop, the field, left untilled with the undersown crops in place, may also be planted with a cover crop, possibly including legumes, which are mulched at the beginning of the next growing season.

Exhibit 3 - Conventional Versus Regenerative Practices Across a Multiyear Cropping Cycle



Sources: NABU; BCG analysis.

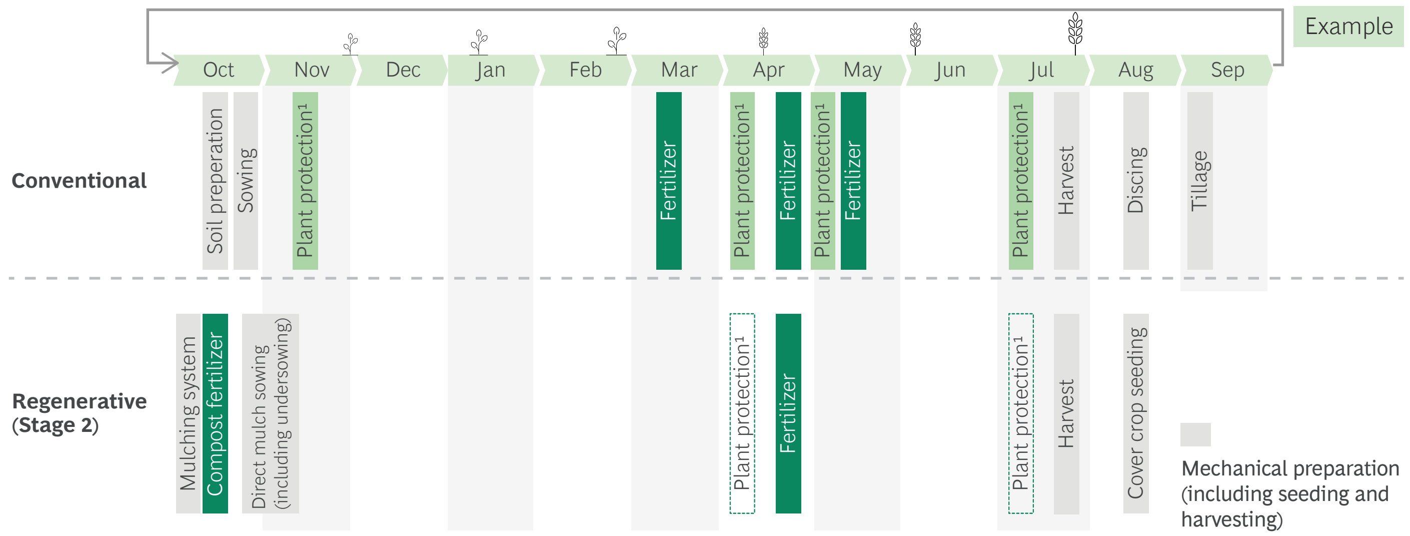
Exhibit 4 - Regenerative Practices Compared with Conventional and Organic Practices

		Conventional		Organic	
		Current status	Regenerative agriculture target	Current status	Regenerative agriculture target
Cultivation	No-till practices, including direct seeding				
	Minimal soil-disturbing subsoiling		Degressive use		Degressive use
	Cover cropping	Focus on cost effectiveness	Focus on diversity	Focus on cost effectiveness	Focus on diversity
	Minimal soil-disturbing mulch system				
	Undersown cropping	Limited trust in yield expectancy		Limited trust in yield expectancy	
	Intercropping				
	Interseeding				
	Adjusted grazing or mowing		Degressive use of mowing (grazing preferred)		Degressive use of mowing (grazing preferred)
	Soil analysis and balancing				
	Biofertilizer/biostimulants and biological seed coating	Based on availability			
	Leaching inhibitors (optional)			Not allowed (until biological products are available)	Not allowed (until biological products are available)
Structure	Biological crop protection (optional)	Rarely used (e.g., parastitic wasps)		Key technology	
	Biologically activated biochar	Low adoption due to high prices		Low adoption due to high prices	
	Legume crop rotation	Minimal, optimized for short-term profit		Often required for nutrient management	
	Livestock integration		When possible		When possible
	Smaller aerial structures (optional)				
	Keyline subsoiling (optional)				
	Agroforestry				
	Pasture cropping (optional)				

Applied · Partially aplied · Very limited / not applied · Applies to cropland · Applies to grassland

Sources: Expert interviews; BCG analysis.

Exhibit 5 - Conventional Versus Regenerative Practices Across One Growing Season



Sources: Teasgac Winter Wheat Guide; BCG analysis.
Note: This example tracks practices for a main crop (winter wheat) and an undersown crop. The cover crop mix after main crop harvest includes legumes.
[1] Plant protection includes herbicides, insecticides and fungicides. During Stage 2, the amount of plant protection required depends on disease and pest pressure and on the ability to manage plant residues of the prior season's crop through mulching rather than use of herbicides.

Adopting Regenerative Agriculture in Germany

Expanding regenerative agriculture in Germany is a multi-year process, and most of the country's farms are unlikely to reach Stage 3 in the 2020s. One of the goals of this study is to provide a realistic target picture of regenerative agriculture in Germany through 2035, along with a transition path for reaching that target.

Our analysis of what constitutes a realistic timeline and target for adoption—developed with input from farmers and academics, and through our own experience in change management efforts—varies by farm archetype and reflects the starting point, economics, capabilities, and implementation complexity of each farm. Although regulatory requirements and incentives will play an important role in the adoption of regenerative practices, our focus in this report is solely on the economic risks and benefits for farmers, regardless of any incentives that may emerge along the way.

Exhibit 6 presents the assumed adoption rates on cropland for each farm archetype and for all three regenerative agriculture stages in a realistic 2035 scenario. These rates reflect the average percentage of farmers who may be adopting regenerative practices at each stage. Exhibit 7 offers similar estimates of grassland adoption rates. In both cases, the adoption rate is linked to the scope of our study as outlined above, and not to the entirety of Germany's agricultural land.

Basic Implementation. Because basic regenerative practices are relatively easy to adopt, we believe that 80% to 100% of German farms could implement them by 2035, depending on archetype. Adoption rates for small farms are likely to be slightly lower than for mixed farms and crop farms, since certain practices, such as regular soil analysis and balancing, may not yet be economically feasible for them.

Intermediate Implementation. We project adoption of intermediate practices to fall in the range of 50% to 75% by 2035, primarily because these practices are more complex, require more significant changes in cultivation, and are subject to the influence of many factors that hamper efforts to reduce the use of synthetic inputs. The most likely intermediate practices to be adopted are undersown crops, minimal soil-disturbing mulch systems, and biostimulants and biofertilizers, as they offer the clearest economic benefits and the greatest likelihood of quickly redeeming any upfront investments required. Adoption rates for the use of legumes as the main crop in a rotation program will likely be lower because the practice's economic viability depends heavily on regional circumstances and overall market and regulatory conditions.

Advanced Implementation. Adoption rates at the most advanced stage are likely to be significantly lower—around 15% to 25% across farm archetypes—because these practices are quite specific, and their viability depends largely on each farm's unique circumstances. Adoption rates of such practices as agroforestry will vary considerably by farm type and the local agro-ecosystem. We excluded the advanced implementation stage when quantifying the impact of regenerative agriculture on German farmers and the country's ecology and broader food value chain. This is because available research has not yet covered the farming practices at this stage in depth, and because the feasibility of each practice depends to a great extent on regional circumstances and individual farm setup.

Exhibit 6 - Cropland Implementation Potential by Regenerative Agriculture Stage and Farm Archetype, Through 2035

Average adoption rate over all practices per implementation stage (%)

Farm archetypes	1 Basic implementation	2 Intermediate implementation	3 Advanced implementation
Small farms • ~1.3 million hectares of cropland • ~1.3 million hectares of grassland	80–90	50–60	15–25
Mixed farms • ~4.0 million hectares of cropland • ~2.0 million hectares of grassland	85–95	60–70	15–25
Crop farms • ~4.7 million hectares of cropland • No grassland	90–100	65–75	15–25

Source: BCG analysis.
Note: Excludes optional practices.

Exhibit 7 - Grassland Implementation Potential by Regenerative Agriculture Stage and Farm Archetype, Through 2035

Implementation potential (%)

Farm archetypes	1 Basic implementation	2 Intermediate implementation	3 Advanced implementation
Small farms • ~1.3 million hectares of cropland • ~1.3 million hectares of grassland	65–75	35–45	15–25
Mixed farms • ~4.0 million hectares of cropland • ~2.0 million hectares of grassland	65–75	45–55	5–10
Crop farms • ~4.7 million hectares of cropland • No grassland	Not available, as crop farms are assumed not to operate grassland		

Source: BCG analysis.
Note: Excluding optional practices.

Economic and Socioecological Assessment of Regenerative Agriculture

This chapter assesses the impact of regenerative agriculture on farmer economics, the broader food value chain, and society and the environment as a whole.

Regenerative Agriculture's Impact on Farm Economics

According to conventional wisdom, regenerative agriculture inevitably leads to shrinking profits for farmers. Looking at the economics of German farms on a per-hectare basis, however, we found that the medium- to long-term benefits of regenerative agriculture outweigh the additional costs, boosting farmers' profits. Overall, when a farm's Stage 1 and Stage 2 practices reach a steady state after six to ten years, the farmer's profits can increase by 60% or more as a result.

We used a three-step process to calculate the economic benefits of regenerative agriculture:

- **Step 1:** Determine the current economic baseline. Establish baseline per-hectare profit and loss figures for conventional farms that plant a conventional mix of crops, as well as baseline costs and revenues for four common crop types—cereal and oil seeds, corn, legumes, and grass.
- **Step 2:** Quantify Stage 1 and Stage 2 practices. After reviewing relevant literature and interviewing farmers, assess the per-hectare impact of each Stage 1 and Stage 2 practice on costs and revenues, including revenue obtained through the sale of carbon credits. (See the sidebar "What Are Carbon Credits Worth?") We did not quantify Stage 3 practices such as agroforestry, because their effects take a long time to mature, and research on their economic impact is limited.
- **Step 3:** Identify the financial impact on each farm archetype. Model the financial impact that the various practices would have on each farm archetype to derive the total economic impact at the farm level.

Our analysis excludes consideration of any state or federal subsidies that may apply to farms, and it assumes that purely conventional farms do not apply any regenerative agriculture practices. As a result, farmers can see the full impact on profits of specific regenerative practices that they may be considering.

We also exclude labor costs from our quantification of regenerative practices, for two reasons. First, we assume that the type of farmwork required for regenerative agriculture will shift away from on-field execution and toward planning, which will likely offset some of the savings in on-field labor. Second, most of the labor cost savings are theoretical, as only a small portion of labor hours will be saved in a typical farming scenario. For the status quo baseline in Step 1, however, we include labor costs to provide a more realistic picture.

Finally, we exclude water costs from this on-farm economic analysis because German farmers currently pay negligible fees for their groundwater use and because the need for irrigation depends largely on region and soil type.

What Are Carbon Credits Worth?

To quantify the impact of regenerative agriculture on Germany's farms, its ecology, and the broader food value chain, it is necessary to assess how well regenerative agriculture can reduce the country's overall carbon footprint—either by lowering direct carbon emissions from farm machinery, synthetic inputs, and the soil itself or by sequestering significantly more carbon. Both approaches offer implicit or explicit monetary value to farmers, to society, and to players in the country's broader food value chain.

To assess the economic value of regenerative agriculture in reducing carbon emissions, we used three different prices per ton of CO_2e, projected for 2035:

- External climate costs, showcasing the total societal costs of carbon, at around €223 per ton.[1]
- The price of carbon certificates in mandatory markets, based on the forward price on the European Trading System (ETS) at around €157 per ton.[2]
- The price of carbon certificates in voluntary markets, based on consensus estimates and expert judgments, at around €55 per ton.[3]

Although our earlier studies documented the costs to society of agriculture-related carbon emissions, and forward prices of CO_2 certificates provide clear documentation of mandatory costs, voluntary markets for carbon certificates are still at an early stage of development and require deeper investigation.

Overall, we expect global demand for carbon offset certificates to grow from 0.1 gigaton (Gt) of CO_2e per year in 2020 to around 1.1 Gt of CO_2e in 2030. (See the first exhibit.) And although the supply of certificates currently exceeds demand, the market will reach a tipping point around 2024, after which the market supply of carbon offsets will be unable to meet the growing demand.

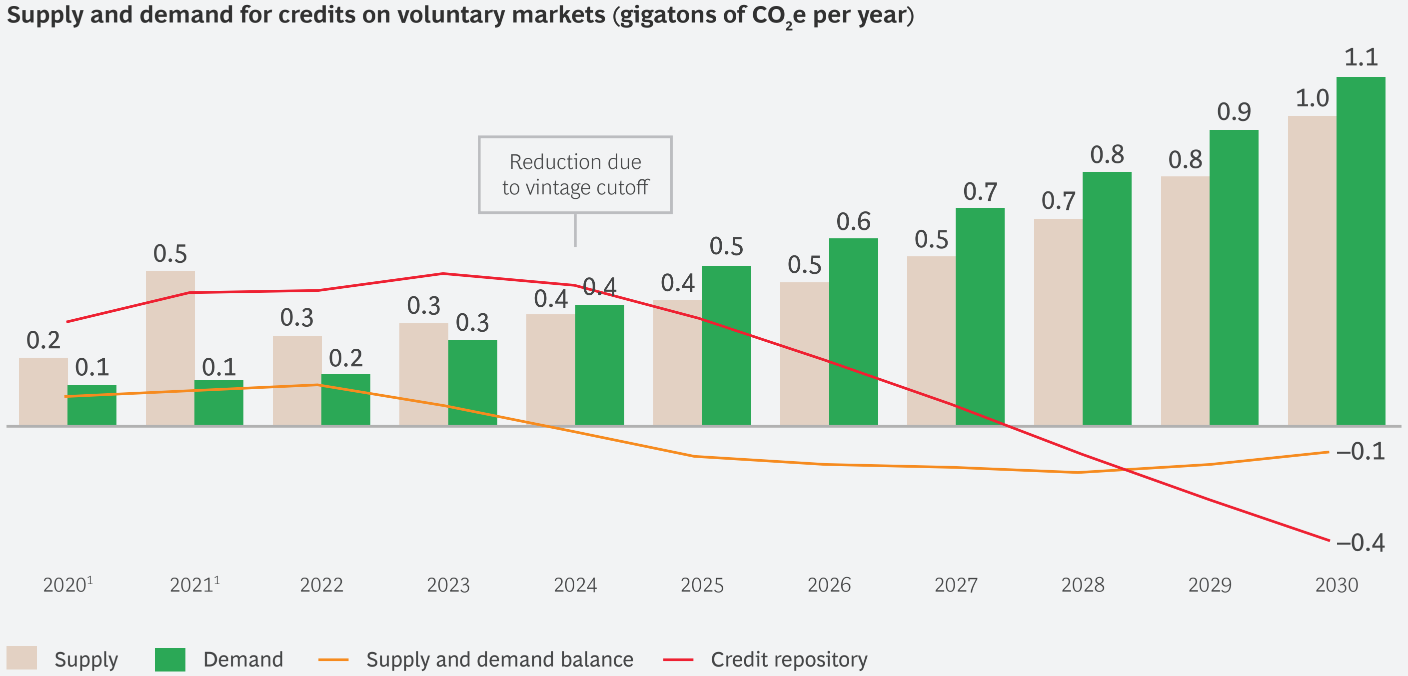
In 2030, the global demand for CO_2 offsets of about 1.1 Gt is expected to exceed carbon credit supply, leading to significant price increases of voluntary carbon credits.

As a result, prices for carbon certificates in voluntary markets will likely rise significantly from 2024 onward, when the commitments that many companies made to meet Science-Based Target Initiative (SBTi) targets come into effect. Predicting prices for voluntary carbon credits remains difficult, as many factors will play a role in pricing and demand. Still, a consensus among experts on future carbon prices is emerging, and this, together with our own experience, leads to a forecasted voluntary carbon credit price in 2035 of around €55 per ton. (See the second exhibit.)

In our analysis, carbon credit prices are relevant to farmers as a potential source of profit and to the country as a whole because of their socioecological impact. In quantifying farm economics, we used the voluntary price as the base price since farmers will probably participate in the voluntary offset market in the future. We based our assessment of the socioecological effects on external carbon costs, which the broader society ultimately carries.

The Value of Carbon Credits Will Increase Substantially as the Supply Begins to Lag Behind the Growth in Demand

Supply and demand for credits on voluntary markets (gigatons of CO_2e per year)

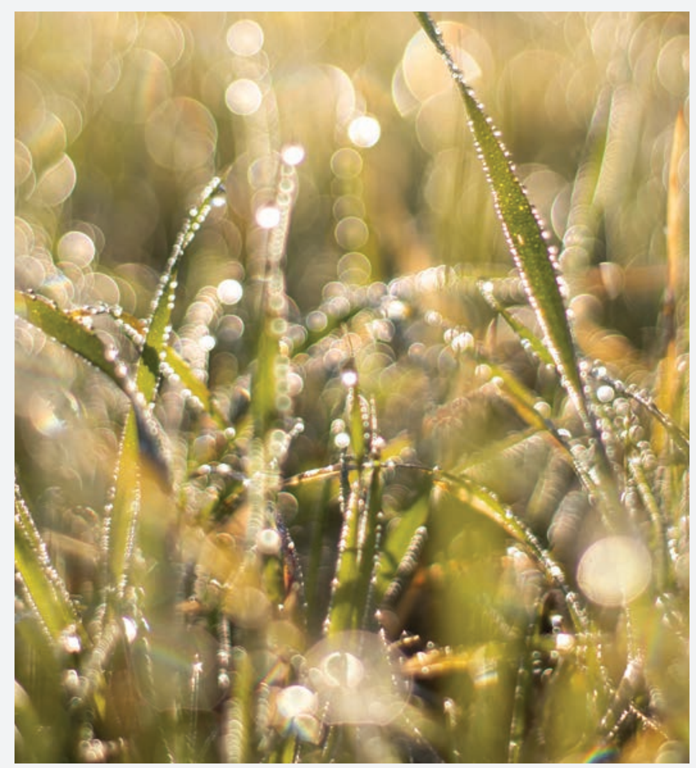


Sources: Forest Trends; Verra, Gold Standard; ACR; CAR; UN IPCC; industry interviews; BCG analysis.
Note: Includes only voluntary emission reductions. Products certified for compliance markets (e.g., Gold Standard CERs, ACR and CAR offsets with ARB approval) are excluded. Refreshed values are based on updated data releases from the World Bank, Global Carbon Project.
[1] Actual; figures for all other years are estimated.

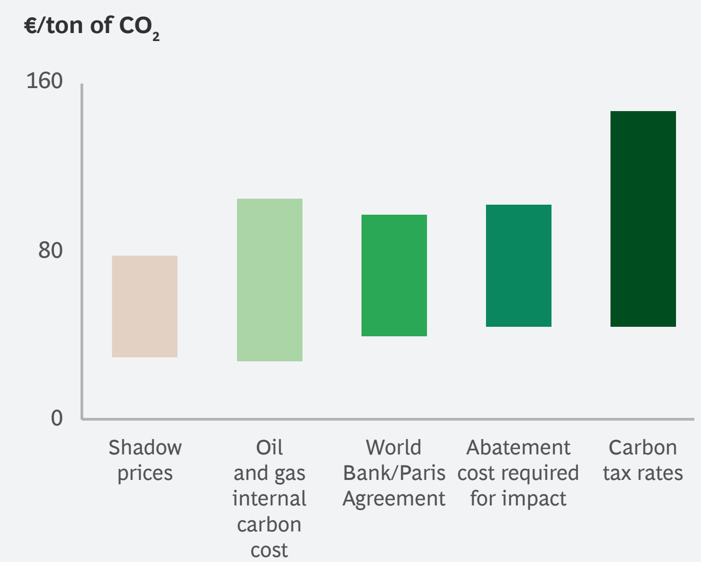
[1] Predicted external climate costs for carbon emissions until 2030; 2035e based on cost rates from the German federal environment agency 2020.

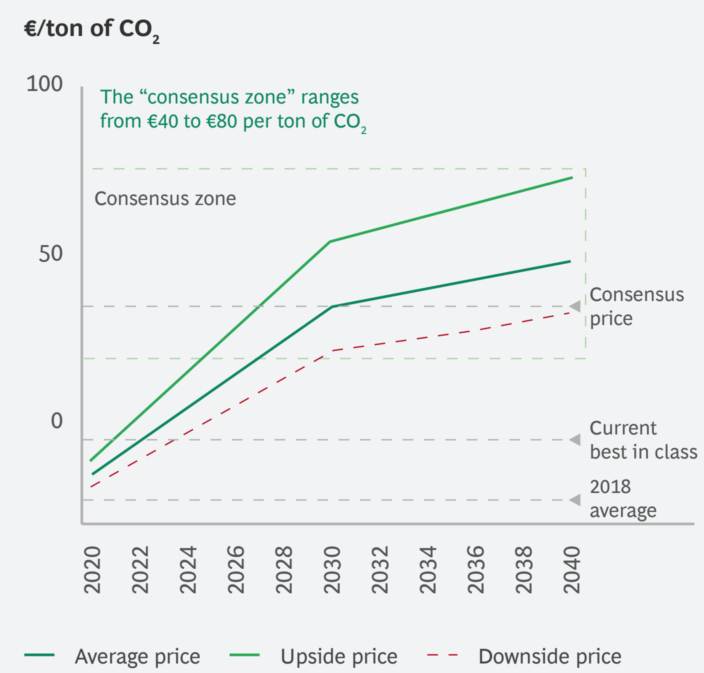
[2] Predicted average until 2029; 2035e based on CAGR (2018–2019); Intercontinental Exchange ENDEX European Union Allowance (EUA); Month Electronic Energy Future ENDEX.

[3] Predicted average until 2040; Ecosystems Marketplace report 2019; Bloomberg; Princeton; World Bank Group – Climate Change 2015; CDP report 2015; Expert interviews; BCG analysis.



Voluntary Agriculture-Based Carbon Prices Are Expected to Rise to an Average of €55 per Ton of CO_2e in 2035





Sources: Ecosystems Marketplace report 2019; Bloomberg; Princeton; World Bank Group, Climate Change 2015; CDP report 2015; expert interviews; BCG analysis.
Note: Assuming a 1:1 conversion factor of euros to US dollars.

Step 1: Determine the Current Economic Baseline
Our analysis of current profit and loss in Germany's conventional farms considers revenues and five cost categories: machine costs, input costs, labor costs, leases, and other costs such as cleaning, drying the harvest, and insurance. Our analysis uses 2021 figures as the basis for all calculations of prices and costs.

We use the following definitions for crop categories and associated revenue:

- **Cereal and Oil Seeds.** This category consists of a mix of 50% wheat, 30% barley, and 20% rapeseed, representing the relative share of each crop at farms in Germany.11 These are the most popular crops grown in Germany, and they yield the highest relative profit, at around €355 per hectare per year, before subsidies.12

- **Corn.** This grain is typically used as feed for livestock and as a feedstock for biofuel. When used for silage, it yields a profit of around €250 per hectare per year.

- **Legumes.** For this category we assume a mix of 50% peas and 50% beans. Legumes are not part of the main crop cycle at most conventional German farms because they don't typically yield any direct profit as cash crops. Nevertheless, they offer considerable nutritional benefits to the soil when included a part of a regenerative crop rotation program. (See the sidebar "Living with Legumes", page 18) We assess the value of their ability to fix nitrogen in soil—an estimated average of 110 kilograms of nitrogen per hectare per year—for use by the next cash crop at around €115 per hectare. This value is not competitive with 2021 prices of chemical fertilizer, but it may become so if fertilizer prices rise.

- **Grass.** Meadows for growing hay to be sold as circular bales yield a profit of around €125 per hectare.

We derived these revenue estimates from guidance provided by chambers of agriculture in several German states.[13] For every crop type, the inputs used—including seeds, fertilizers, and crop protection—are the largest cost.

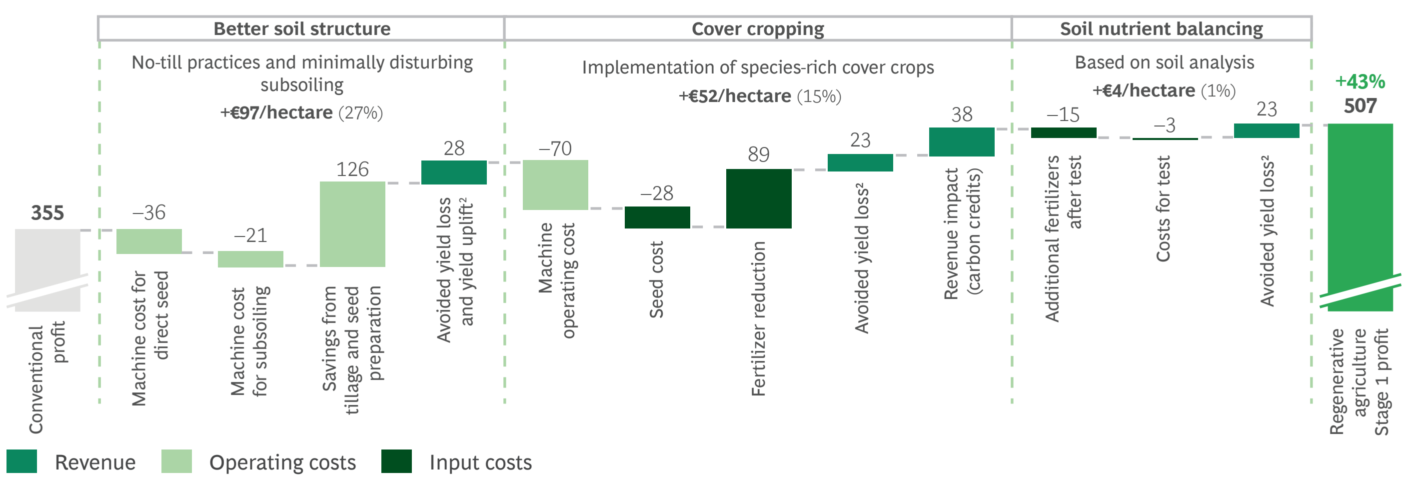
Step 2: Quantify Stage 1 and Stage 2 Practices
This step quantifies the benefits, revenues, and costs of Stage 1 and Stage 2 regenerative practices. We report results for cereals and oilseeds, the most important crops in Germany, measuring revenue and costs for farms that have achieved a steady state of implementation, which typically takes six to ten years.

Stage 1. Exhibit 8 shows the expected profit following Stage 1 basic implementation of regenerative practices in fields that grow cereals and rapeseed. No-till practices, for example, increase profits by an estimated 25%, largely by reducing the cost of tillage and seed preparation, and increasing average yields by improving the crops' resilience to extreme weather events. Taken together, Stage 1 practices should increase farmer profits by 40% or more, a quarter of that increase coming from the sale of carbon credits.

Table 1 details the positive and negative impacts of Stage 1 regenerative practices.

Exhibit 8 - Stage 1 Processes Offer Considerable Upside for Farmers

Stage 1 (steady state after 6 to 10 years)
Cereal and oil seeds[1] (€/hectare)



Sources: Bavarian State Institute for Agriculture; FAO; German ministry for agriculture; DLG; BayWa; KTBL; farmer interviews; BCG analysis.
Note: Conventional and regenerative profits do not include any potential government subsidies.
[1] Average of winter wheat, barley, and rapeseed. [2] Due to better soil structure, which increases drought resistance, based on 2018 drought yield impact.

[11] https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Feldfruechte-Gruenland/Tabellen/ackerland-hauptnutzungsarten-kulturarten.html

[12] Ibid.

[13] Landwirtschaftskammer Schleswig Holstein: https://www.lksh.de/fileadmin/PDFs/Landwirtschaft/Markt/Kalkpl21_22.pdf
Bayerische Landesanstalt für Landwirtschaft: https://www.stmelf.bayern.de/idb
Chamber of Agriculture Brandenburg: https://lelf.brandenburg.de/sixcms/media.php/9/Datensammlung-2021-web.pdf

Table 1 - Stage 1 Practices and Their Impact

Table 1 details the positive and negative impacts of Stage 1 regenerative practices

Practices	Positive impacts	Negative impacts
Better soil structure (no-till practices and minimal disturbance of the subsoil)	• Substantial savings from tillage and seed preparation, as traditional plowing requires high-powered machinery and consumes large amounts of fuel • Small increase in average cereal yield (less than 0.5%, or about €6 per hectare per year).	• Additional machine costs for direct seeding (may be bought and depreciated, or rented) • Machine cost for subsoiler operation, if required; this operation is important to loosen machinery lanes when practicing no-till in combination with controlled traffic farming
Cover cropping (implementation of species-rich cover crops)	• Species-rich cover crops considerably reduce fertilizer needs by binding relevant nutrients in the soil for the next cash crop—up to 35kg of nitrogen, 15kg of phosphate, and 100kg of potassium per hectare per year—and improving nitrogen use efficiency (NUE) • Carbon credits due to soil carbon capture—on average, about 1.7 tons of CO_2e per hectare per year (see Appendix Table 2); although carbon prices are not very transparent, BCG estimates that this value will be around €55 per ton by 2035 for the voluntary market, driven by a supply shortage from 2024 onward; our figure of €38 per hectare per year in farmer profit reflects a conservative 40% profit share of the €55 certificate price, after testing and certification costs and market maker transaction fees (net profit: around €22/ton of CO_2e)	• Machine operating cost for cover crop seeding after cash crop harvest, as well as for simple mulching before the start of the next cash crop cycle • Seed costs for cover crops, which may vary significantly depending on the species mix; for best results, multiple species should be used
Soil analysis and balancing	• Better nutrient balancing in the soil, not quantified separately	• Costs for Haney/Kinsey test—one test, with multiple probes, per 5 hectares every five years (€85 per test) • Fertilizers in addition to nitrogen, phosphorus, and potassium—typically calcium, magnesium and silica—may be needed for advanced soil balancing after testing
Additional impact of Stage 1 practices on cropland	• Avoided yield loss, due to increased drought resistance; four of the past five years were drought years in Germany, and climate change is likely to produce even worse droughts in the next five to ten years); the 2018 drought reduced wheat yields in Germany by an average of 16% • Stage 1 practices, which help bind water in soil and limit evaporation through better soil coverage, should mitigate yield loss in drought years by an estimated 30% • All practices contribute to water absorption, water holding capacity, and groundwater recovery, so we attribute the quantified yield-resilient impacts to all practices equally (€23 per hectare per year, per practice)	
Grassland: Interseeding	• A 20% share of legume seeding can yield about 60kg of nitrogen fixing per hectare per year, reducing the need for synthetic inputs	• Seed costs for advanced interseeding mixes, including legumes

[1] Food and Agriculture Organization of the United Nations, 2020: Advances in Conservation Agriculture Volume 2: Practice and Benefits, Burleigh Dodds Series in Agricultural Science.

[2] https://www.schleswig-holstein.de/DE/fachinhalte/G/grundwasser/Downloads/Bauernblatt_2017_Zwischenfruechte.pdf?__blob=publicationFile&v=1#:~:text=Durch%20Zwischenfr%C3%BCchte%20k%C3%B6nnen%20nur%20dann,N%C3%A4hrstoffbilanzen%20des%20Betrie%2D%20bes%20verbessern

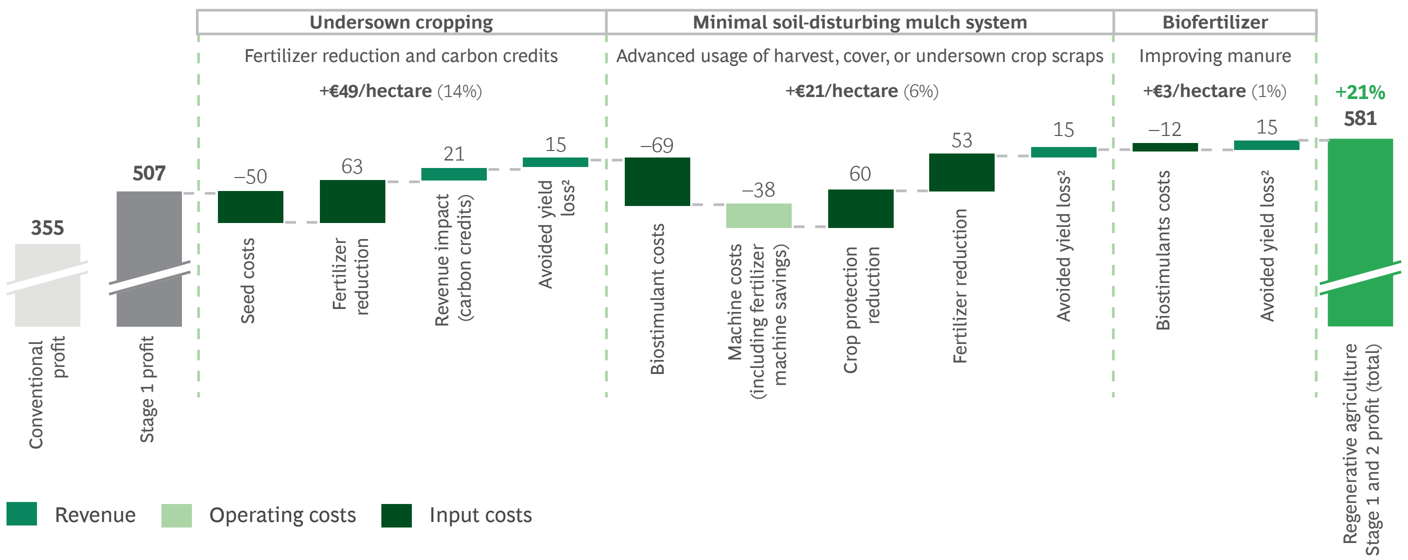
[3] https://www.bmel.de/DE/themen/landwirtschaft/klimaschutz/duerre-2018.html

Stage 2. Exhibit 9 shows the expected profit from implementing Stage 2 intermediate regenerative practices in fields that grow cereals and rapeseed. At this stage, increased profits primarily reflect lower input costs and increased yield resilience. Undersown cropping, for example, increases profits by nearly 15% per hectare per year, primarily by reducing fertilizer costs. Altogether, Stage 2 practices should increase farmer profits by 20% or more, with just under a third of that coming from sales of carbon credits.

Table 2 describes in detail the positive and negative impacts of Stage 2 practices.

Exhibit 9 - Stage 2 Processes Can Boost Profits by an Additional 21%

Stage 2 (steady state after 6 to 10 years)
Cereal and oil seeds[1] (€/hectare)



Sources: Bavarian State Institute for Agriculture; FAO; German ministry for agriculture; DLG; BayWa; KTBL; farmer interviews; BCG analysis.
Note: Conventional and regenerative profits do not include any potential government subsidies.
[1]Average of winter wheat, barley, and rapeseed. [2]Due to better soil structure, which increases drought resistance, based on 2018 drought yield impact.

Table 2 - Stage 2 Practices and Their Impact

Table 2 describes in detail the positive and negative impacts of Stage 2 practices

Practices	Positive impacts	Negative impacts
Undersown cropping (simultaneous growth of a secondary crop alongside the main crop for enhanced soil cover)	• Reduced need for fertilizer by fixing 30kg per hectare of nitrogen and 40kg per hectare of potassium in the soil [1] • Carbon credits from average soil carbon capture of 0.97 ton of CO_2e per hectare per year, assuming net income of about €22 per ton of CO_2e (see Appendix Table 2)	• Seed costs for undersown crops at around €50 per hectare; there are no additional machine costs, however, because seeding occurs alongside main crop seeding runs
Minimal soil disturbing mulch system (advanced use of harvest and cover crop scraps)	• Drastically reduced crop protection costs—especially for herbicides—by adopting the mulch system[2] • Savings of 50kg to 90kg of nitrogen fertilizer per hectare (thus meeting the Green Deal 2030 fertilizer reduction target of 20%); we assume a conservative estimate of 50kg[3] • Avoidance of two herbicide and two fertilizer machine runs, reducing overall machine costs	• Machine costs for mulching and for a cultivator to work the mulched cover crops into the first centimeters of the soil, depending on local context • Costs for biostimulants needed to maximize the impact of the mulch system by triggering microorganism processes[4]
Biofertilizer (improving manure)	• Synthetic fertilizer substitution or volume reduction—not quantified here because costs are highly situation-specific	• Biostimulants costs to be mixed into manure • Biological seed coating costs and compost extract costs, including micronutrient foliar spraying—excluded from calculations here because costs are highly situation-specific
Additional impact of Stage 2 practices on cropland	• Avoided yield loss through drought resistance • As in Stage 1, we assume that Stage 2 practices, which help bind water in soil and limit evaporation through better soil coverage, will mitigate yield loss in drought years by an additional 20%	
Grassland adjusted for grazing or mowing	• Improved drought resistance • Prevention of yield losses of approximately 30% on average for grazing land and hay production • For grazing, reduction in quantity of grass trampled by livestock • For hay production, enablement of an additional cut during drought years as a result of adaptive mowing	• Operating cost for one additional mowing cut every four years • Applies only to meadows, which make up just 40% share of grassland

[1] https://www.schleswig-holstein.de/DE/fachinhalte/W/wasserrahmenrichtlinie/Downloads/untersaaten.pdf?__blob=publicationFile&v=1
[2] https://protect-us.mimecast.com/s/ZWhKCzpn0VSR2VzjMSgW4jk
[3] https://chiemgau-agrar.de/2021/10/27/steigende-duengemittel-preise/
[4] https://shop.em-chiemgau.de/produkt/bodenverjuenger/

Stage 3. Our analysis does not quantify the benefits of Stage 3 regenerative practices, owing to a lack of available research and because the benefits depend greatly on regional circumstances and how particular farms are operated. Nevertheless, farmers are likely to see the following benefits at this stage:

- **Improved Soil Structure.** Biologically activated biochar boosts carbon capture and water holding capacity while reducing nitrate leaching.
- **Reduced Water Evaporation and Heat.** Agroforests and hedges provide shade and act as windbreaks to limit evaporation and improve dew deposition, which helps cool the soil surface.14
- **Reduced Erosion.** Keyline subsoiling helps mitigate the risk of soil erosion during heavy rainfall.
- **Improved Leverage of Biodiversity and Ecosystem Services.** The benefits of using improved ecosystem services include better pollination and natural pest control.

Some Stage 3 practices may entail additional costs related to the structural changes needed to implement agroforestry, intercropping, and smaller fields. In particular, implementing smaller fields may be challenging in the medium term, as most current farm machinery is designed for large working widths. With the advent of more flexible, autonomous farm machinery, however, this is less likely to be an issue.

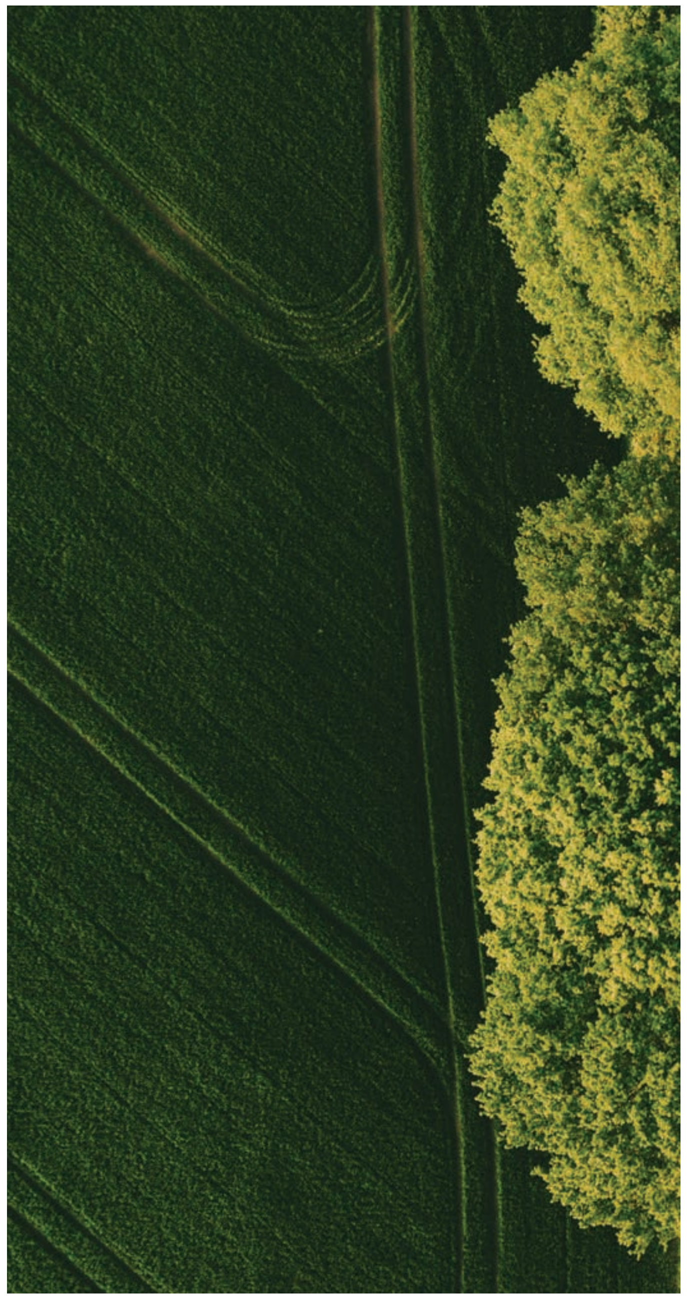
Step 3: Identify the Financial Impact on Each Farm Archetype

What do the economics of Stage 1 and Stage 2 regenerative agriculture practices mean for the typical German farm? How do regenerative practices affect farmers' choice of which crops to grow—and farmers' financial bottom line? And most crucially, should German farmers switch to regenerative agriculture?

Each of the three archetypes defined in the sidebar "How Germany Uses Its Land"—small farm, medium mixed farm, and large crop farm—has a different profit profile:

- **Small Farms.** Although our definition of these farms assumes that they use approximately half of their land for crops and the other half for grassland, two-thirds of the profits come from the cropland. Total profits for these farms would rise from about €11,000 a year for a typical conventional farm to €17,000 a year after Stage 2, excluding subsidies, following a shift from a 50/50 ratio of cereal and corn to a 50/40/10 ratio of cereal, corn, and legumes.
- **Mixed Farms.** Here, total profits would rise from about €80,000 a year to more than €120,000 a year, before subsidies. Cereals and rapeseed would contribute more than 60% of the gross profit, while regenerative practices on grassland would yield the lowest profit per hectare. (See Exhibit 10.)
- **Crop Farms.** The archetypal conventional crop farm—growing cereal on most of the land, complemented by rapeseed and corn—generates about €350,000 in total profits. We assume that a regenerative agriculture farm at Stage 2 will include a 10% share of legumes complementing the crop rotation regime. Total profits would rise to €525,000 at steady state once all regenerative agriculture measures were implemented.

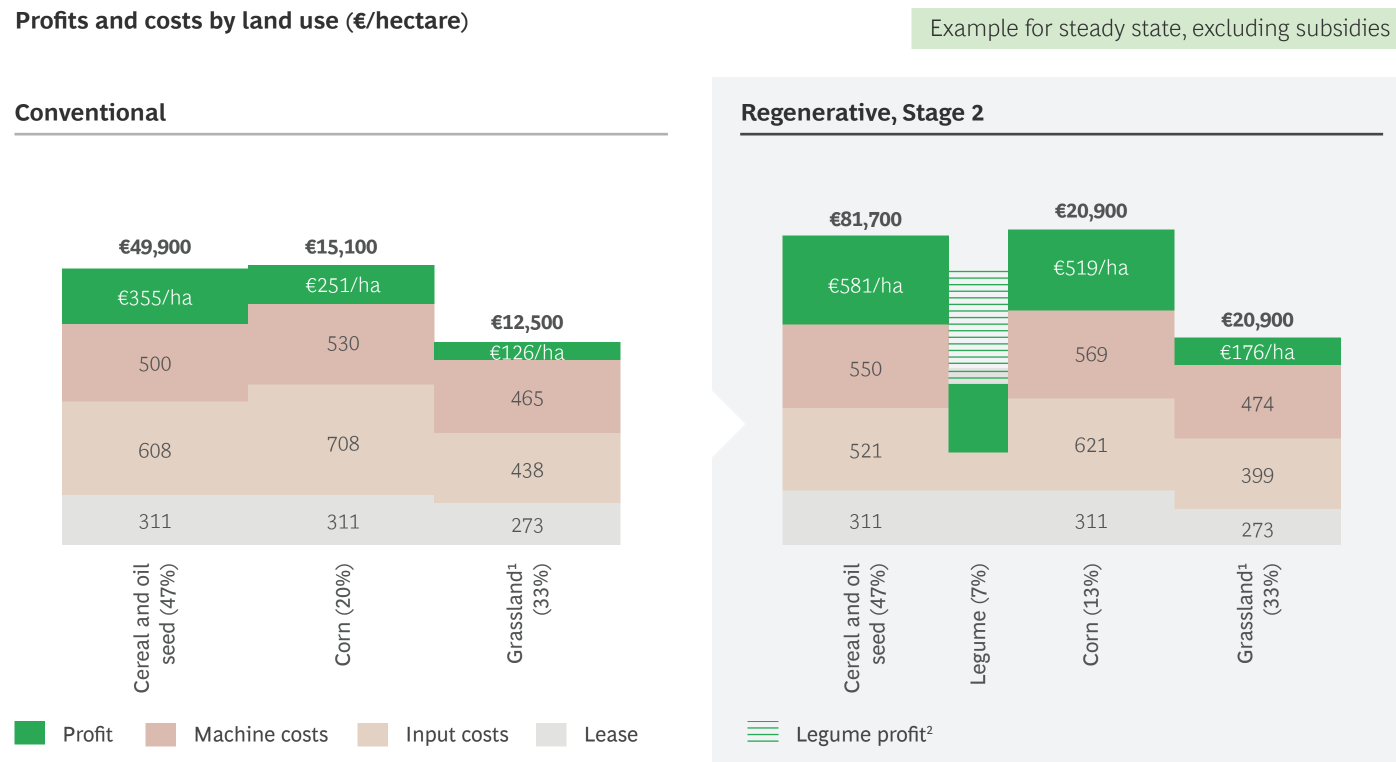
Calculating the added profit from growing legumes is difficult, as it depends largely on the price of nitrogen fertilizer and local legume subsidy programs.



[14] UN Environment Program, 2021: Working with plants, soils and water to cool the climate and rehydrate Earth's landscapes.

Exhibit 10 - Profits for Mixed Farms Could Rise Considerably

Archetype 2: Mixed farm	300 ha Average size	200 ha Cropland	100 ha Grassland	40% of all farmland Total share of archetype



Sources: FAO; German ministry for agriculture; DLG; BayWa; KTBL; farmer interviews; BCG analysis.
Note: Conventional and regenerative profits for cereal, oil seed, corn, and grassland do not include any potential government subsidies.
[1] Calculations assume the same profit level for meadows and for pastures.
[2] Legume profit depends in part on local subsidies and on savings from not having to buy nitrogen fertilizer.

Making Regenerative Agriculture the Accepted Standard

> **"Typically, when shifting to basic regenerative practices, there is already a positive impact on yield and farmer economics in the first year, if no major mistakes in planning and execution are made."**
>
> — Dr. Theodor Friedrich, former FAO expert for conservation agriculture

Viewed across the entire Stage 1 and Stage 2 program, all farm types would profit financially by switching to regenerative agriculture. And under the most favorable conditions, farmers might increase their profits by nearly 65%. What factors make regenerative agriculture so attractive now and in the future? We expect three key factors to drive adoption:

- **Necessity.** Climate change has increased the frequency and severity of extreme weather events, especially droughts and heavy rains. At the same time, biodiversity losses have reduced the contributions of ecosystem services and lowered agriculture's resilience. Under these conditions, regenerative practices can help mitigate yield losses.
- **Viability.** Research and development have yielded new technologies for optimizing agronomic practices, including biostimulants, crop rotation, and cover cropping schemes, thereby clarifying regenerative agriculture's considerable potential.
- **Impact.** Voluntary carbon credit marketplaces offer farmers the opportunity to boost profits by selling carbon credits obtained through the considerable ecological benefits of regenerative agriculture.

The Farmer's Path to Regenerative Agriculture

What does the transition to regenerative agriculture look like from the farmer's perspective? Although every farm is different, the timeline for implementing certain general principles of regenerative agriculture applies to all farms. The following summary outlines the real-life experiences of farmers in Germany and other mature agricultural production systems around the world. (See the exhibit.)

Prepare the Transition (Year 1)
The first step in the transition, before a single seed is planted, involves planning for the coming years. The farmer must decide what share of land to dedicate to regenerative practices. Depending on the size of the farm, farmers typically implement regenerative practices on 10% to 40% of the land at Stage 1, with the goal of learning about the process before attempting any further expansion, while also diminishing the risks of implementation and measuring early results.

The farmer should also plan a crop rotation schedule for coming years, including cover crops and new main crops, to increase diversity and reduce pressure from weeds and pathogens. Farmers must also select crop varieties with strong tolerance to insects and fungi, good nitrogen use efficiency, and high suitability for no-till conditions.

The farmer should conduct a detailed analysis of the soil on the land to be converted, to understand its current condition, and should apply herbicides, if necessary, to remove any weeds. Another crucial step at this stage is to prepare the soil for the transition to no-till farming, in light of the results of the soil analysis. This will ensure adequate aeration, drainage, and surface smoothing.

The biggest investment at this stage is for direct seeding equipment, which may cost from €60,000 to €130,000, depending on size and quality. Options include purchasing a machine outright, renting from a local cooperative machinery pool, or hiring a contractor to do the work. The most appropriate decision depends in part on the replacement cycle for the farm's machinery and on the availability of no-till seeders in the area. The required tractor capacity (horsepower per hectare) is generally lower in regenerative agriculture than in conventional agriculture, as it doesn't call for horsepower-heavy tillage.

This stage also demands significant initial consultation and education, as well as development of a long-term strategy for the farm.

Execute the Initial Transition (Years 2–4)
The next two to four years are a transition phase dedicated to implementing Stage 1 practices and measuring the results. It is important during this phase to adhere to strict no-till practices in combination with direct seeding and cover crops, because implementing them in stages will not yield the best results. The key is to keep the field surface covered continuously. Prior to the first year of planting, the farmer should leave some residue from the previous year's harvest on the field. Subsequently, cover crops, undersown crops between main crops, or mulched crop residues will prevent weeds from reaching sunlight.

Typically, farmers see positive economic results and no reduction in yield during the first year, mainly as a result of improved soil structure and reduced costs for labor, fuel, and machine-hours for soil preparation.

During the transition phase, pressure from weeds between main crops will be at its highest, as residual weeds in the soil try to grow, especially during the spring and summer. Farmers can mitigate this problem in several ways. They can suppress "seed weeds" by continuous mulching and by cutting and rolling cover crops. They can fight "root weeds" by leaving sufficient harvest residues and planting cover crops to maintain a thick layer of vegetation on the field. In this phase, however, farmers will also have to resort to carefully targeted herbicides to manage weeds. As crop rotation widens and becomes more diverse, multiyear and specified herbicide use may be necessary.

To avoid soil compaction on large farms that use very heavy machinery, farmers should consider using fixed driving lanes, also known as controlled traffic systems. Although the tracks will be compacted, they will be used solely for traffic. And because no traffic will occur between the tracks, there will be no compaction on the rest of the field, even under adverse soil conditions. For smaller farms, compaction can be managed with tire pressure control systems and wide, low-pressure tires or rubber tracks. Farmers should monitor compaction regularly and manage it with deep rooting cover crops or, in extreme cases, with low-disturbance subsoiling.

As the economic benefits grow more favorable and farmers gain confidence, they can begin rolling out regenerative practices across the entire farm.

Expand Regenerative Practices (Years 3–5)
Once the Stage 1 implementation is complete, the farmer can begin introducing selected Stage 2 practices, depending on the farm, soil type, and climate and field conditions.

In addition to planting permanent undersown crops, farmers can apply minimally soil-disturbing mulch systems between main crops. This requires an investment of about €30,000 to €40,000 in equipment such as knife rollers for working plant residues into the soil in a minimally invasive fashion. With legumes incorporated in the crop rotation and as cover crops, the soil will require ever less nitrogen fertilizer; to determine the new optimum, farmers should monitor the soil's nitrogen level. They can also gradually reduce inputs of other fertilizers. If possible, they should use organic fertilizer to recycle nutrients from animal husbandry. More biological types of fertilizer, including organic acids and other biostimulants, can improve nitrogen use efficiency.

Farmers should experiment with ways to optimize the cropping system, including adopting further measures for grassland, where adaptive grazing can raise yield potentials—an underestimated factor in Germany.

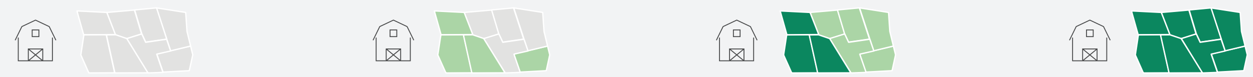
Once the pathogen pressure from the transition phase has abated and greater biodiversity exists above and below the soil, farmer can significantly reduce their use of crop protection chemicals. In applying such chemicals, farmers should strictly follow the results of an analysis of pests and diseases actually present.

Harvest the Benefits (Years 6 and Beyond)
By this stage, the farm will have reached a steady state. Crop rotation will be much wider, production will stabilize, and yields will gradually increase, while use of fertilizer and pesticides will decline significantly. The farmer may need to resort to nonselective herbicides such as glyphosate only in years with extraordinary weed growth, and even then at much lower dosages.

The farm's biodiversity will be much greater, both in the soil and above it. And the soil's health will be far better, with more humus content, higher moisture, increased water infiltration and water holding capacity, and better nutrient balance.

How to Implement Regenerative Agriculture

1 **year prior to introduction**	2-4 **years after introduction**	3-5 **years after introduction**	6+ **years after introduction**
Prepare the transition: Set the foundation one crop season in advance	Execute the first season: Start the regenerative agriculture transition phase	Expand practices: Fully apply Stage 1 practices, and expand in Stage 2	Harvest benefits: Reap the full benefits of introducing regenerative agriculture
Decision on share of area to be transformed Detailed and more diverse crop rotation planning for future years Detailed soil analysis to understand conditions and starting point Preparation of soil Decision on direct seeding equipment (owning, leasing, or contracting) Significant initial consultation and education (reduced along transition)	Start after final soil preparation (focus on subsoiling and flat surface) with some harvest residues Full application of Stage 1 with three key principles: no-till, direct seeding, and constant covering Mitigation of increased weed pressure: • Continuous mulching, cutting, and rolling of cover crops • Sufficient harvest residues and use of most applicable cover crops • Targeted application of herbicides with multiyear planning	Introduction of selected Stage 2 practices after rollout of Stage 1 Introduction of permanent undersown crops Selective application of minimal soil-disturbing mulch systems Monitoring of yields under gradual reduction of fertilizers Shift of fertilizer to more biological types including biostimulants Plant protection with close pest and disease scouting, anticipated reduction, and eventual elimination	Widened system diversity in crop rotation Much less machine-intensive production through no-till Diminishing use of synthetic fertilizers and pesticides Improved soil health and biodiversity below and above soil Improved area hydrology with recovery of groundwater levels and water flows by improved water infiltration, holding, and conduction capacity of the soil



Conventional   Stage 1   Stage 2

Sources: NABU; BCG analysis.

In addition to increasing farmers' income, regenerative agriculture can enhance the value of the land itself. This is primarily the result of upgrading the soil. As soil structure and biodiversity improve, yields will become more resilient to the effects of climate change. Renewed efforts to capture carbon in soil can improve soil metabolism, increase the level of organic matter, and thus increase the soil's nutrient levels. These long-term improvements in soil fertility can significantly increase the financial value of Germany's agricultural land.

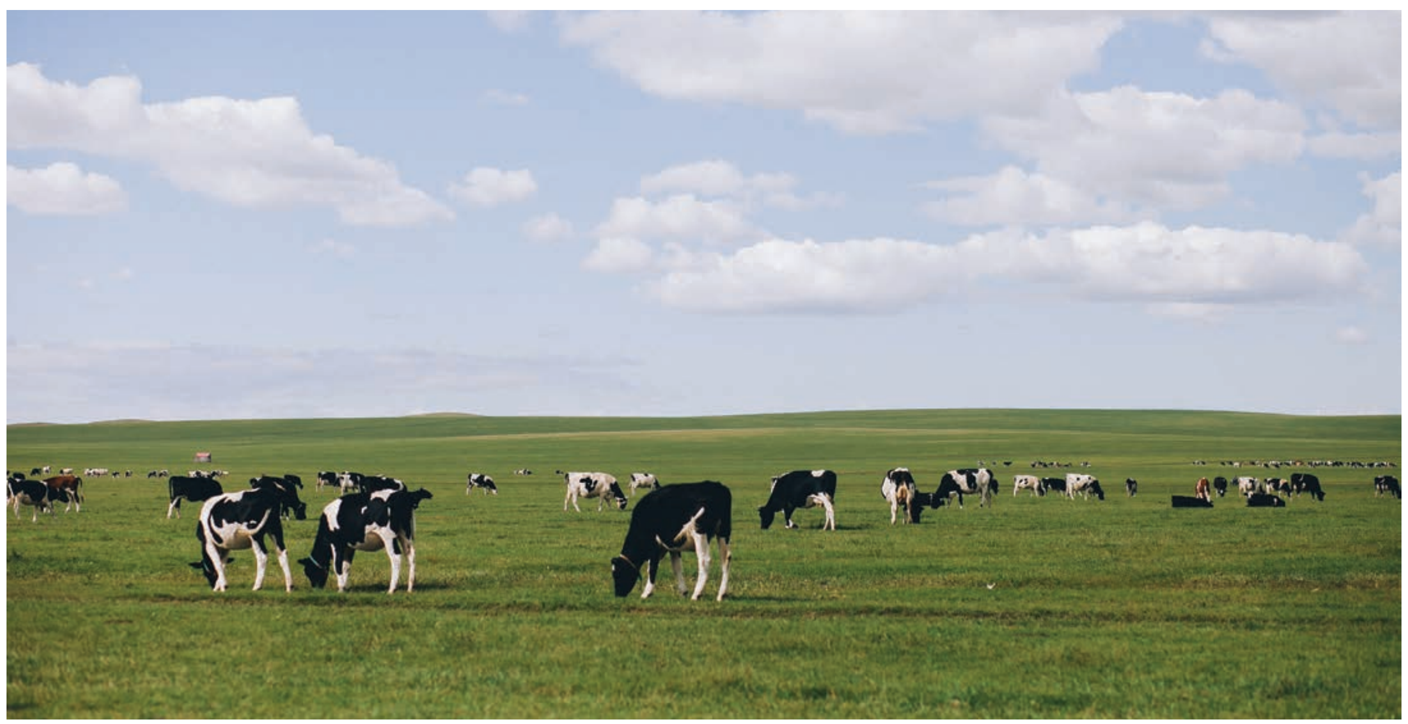
One remaining barrier is the perceived cost of transformation. Some farmers may lack the capital necessary to adopt certain regenerative practices, or they may see too much risk in altering their tried-and-true approach to farming. To overcome such fears, farmers must be convinced that regenerative agriculture will likely increase their profits in the short term by 10% or more.

The Socioecological Impacts of Regenerative Agriculture

Shifting to regenerative agriculture would benefit not only farmers but also German society as a whole, since the farming practices involved can improve the quality of the country's environment on several fronts and enhance the nutritional value of the country's food.[15] This section of the report will attempt to explain and quantify the extent of regenerative agriculture's contribution.

According to our analysis, the total economic value of regenerative agriculture's socioecological benefits would come to approximately €8.5 billion a year from 2035 onward—€7.9 billion in carbon removal and €0.6 billion in water quality improvements. (In this analysis, we use the term carbon synonymously with GHGs, especially nitrogen compounds.) This computation assumes that Stage 1 and Stage 2 regenerative farming practices have reached a steady state, with adoption rates achieving the levels described on page 21. If adoption rates through Stage 2 were 25% higher, the benefit would total €9.8 billion a year. If Stage 1 practices were 25% lower and Stage 2 practices were 50% lower, the benefit would still total €5.7 billion a year.

One way to put these figures into perspective is to consider that the shift to regenerative agriculture would remove around 35 million tons of CO_2e annually. That's equivalent to the amount of CO_2e that would be released if every inhabitant of Frankfurt flew to New York City and back once a week for a year or to one-third of the annual emissions from all cars in Germany.[16] (See Exhibit 11.) In the same vein, the reductions in the need for irrigation that would result from widespread adoption of regenerative agriculture practices, estimated at about 20 million cubic meters of water annually, is equivalent to the annual water use of 430,000 Germans, or enough drinking water to meet the needs of the entire population of Poland for a year.[17]



[15] Montgomery, Biklé, Archuleta, Brown & Jordan, 2022: Soil health and nutrient density: preliminary comparison of regenerative and conventional farming. PeerJ, 10, e12848.

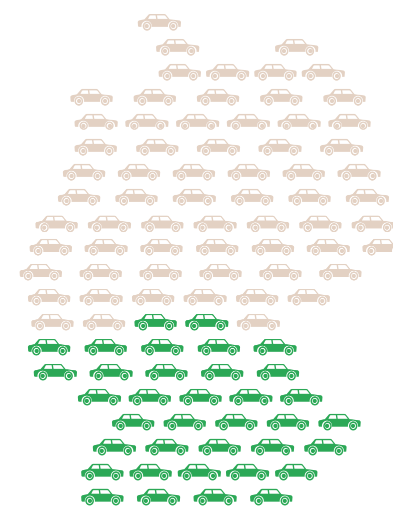
[16] International Civil Aviation Organization Carbon Emissions Calculator, 12.2022. Dereal Statistical Office (Destatis), 2022: Environmental Economic Accounts: Traffic and Environment.

[17] German Federal Environment Agency, 14.10.2022: Water use by private households. Consumer Center, 07.11.2022: How much should one drink per day?

Exhibit 11 - Implementing Regenerative Agriculture in Germany Could Significantly Improve the Country's GHG Balance

Without regenerative agriculture
~100 million tons of total car emissions in Germany in 2019

After implementation of regenerative agriculture
Germany's GHG balance would improve by an amount equivalent to one-third of all German car emissions



1 million tons of CO_2e emission savings

1 million tons of CO_2e emissions

Sources: Statista/Destatis; Destatis and Eurostat.

The value of increased biodiversity and the benefits of improved green water management are more difficult to quantify, but they can be described in qualitative terms.[18]

More than 80% of the quantified socioecological benefit of regenerative agriculture—approximately €6.5 billion annually—come from the use of regenerative practices in Germany's 10 million hectares of cropland. The remaining 20%, or around €2 billion a year, come from the use of regenerative practices in the country's 3.3 million hectares of grassland. By far the greatest impact—more than 90%—involves the increased ability of agricultural land to capture and store carbon and through reduced carbon emissions. Once the expected adoption levels through Stage 2 are reached, the value of carbon reductions alone would total around €5 billion annually for cropland and €1.8 billion for grassland. (See Exhibit 12.)

The results of our analysis of the value of regenerative agriculture on carbon and water depend on a range of economic values for each factor. We discuss in greater detail the sensitivity analysis of the impact of the range of values on carbon removal because of the wide range of likely future carbon price scenarios. (See Appendix Tables 6 and 7 for details on the sensitivity analysis regarding water.)

In the sections that follow, we consider the effects of regenerative agriculture on carbon, water, and biodiversity, and we analyze their quantitative and qualitative impact on Germany's society and environment.

Carbon

Regenerative agriculture can have a twofold impact on Germany's carbon footprint. First, agricultural soil has the potential to function as a major carbon sink because the process of growing crops captures carbon and allows it to be stored in the soil. In Germany, however, humus-depleting cultivation has significantly degraded the agricultural soil, leading to the loss of up to 2 million tons of carbon annually.[19] Our analysis shows that regenerative practices can help build up soil organic matter (SOM) and thus increase the amount of carbon that the soil can store. (See Appendix Table 5.)

Second, regenerative agriculture can reduce the level of direct carbon emissions caused by agricultural activity—primarily in the form of N_2O from nitrogen fertilizer. Although Germany has significantly reduced its total N_2O emissions over the past three decades, the share of such emissions attributable to the agricultural sector has increased, and the sector has achieved only minor reductions.[20] As of 2021, agriculture is estimated to be responsible for nearly 77% of the N_2O released into the atmosphere in Germany.

When farmers apply nitrogen fertilizer to crops, the plants do not absorb it entirely. In fact, nitrogen use efficiency (NUE) in Germany is estimated at about 45% to 50%, meaning that crops absorb less than half of the applied nitrogen.[21] The remaining nitrogen ends up fertilizing weeds, leaching into the ground or into surface water, or being transformed into nitrogen compounds through nitrification processes in the soil and through evaporation in the form of N_2O and escaping into the atmosphere. Regenerative practices can significantly lower the amount of nitrogen fertilizer that farmer need to use, which reduces the nitrogen surplus discharged into the air. Regenerative agriculture also increases the soil nutrients available for plants by promoting better soil biology.

Quantification Approach. In quantifying the amount of carbon captured in the soil, our analysis adopts a bottom-up approach, taking into account how much carbon each regenerative practice captures in the soil, according to the most applicable and available scientific estimates. We estimate the amount of CO_2e emissions avoided through reduced use of nitrogen fertilizer by aggregating the average reduction generated by each practice. (See Table 3.) Our analysis does not account for the wide range of soil types and conditions across Germany, as they are outside the scope of the baseline per hectare we adopted. It also excludes methane emissions caused by livestock production, as this, too, is outside the scope of the report. More than 65% of Germany's methane emissions are caused by agriculture, however, and the most efficient way to reduce those emissions would be changes in diet and reductions in livestock production.

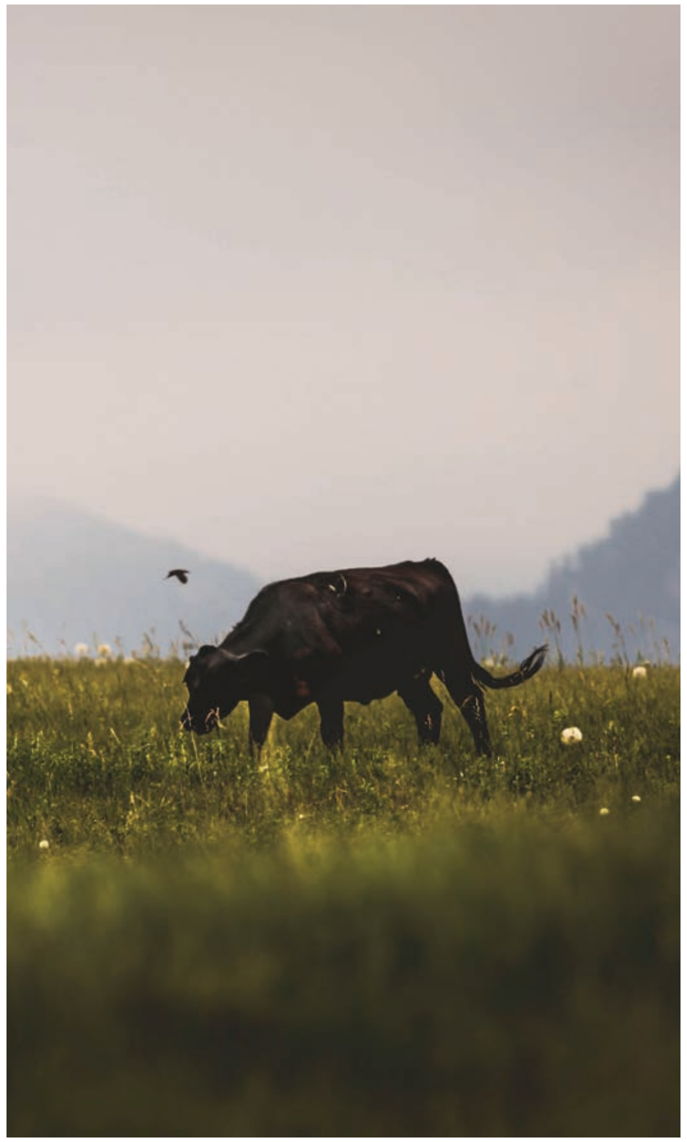
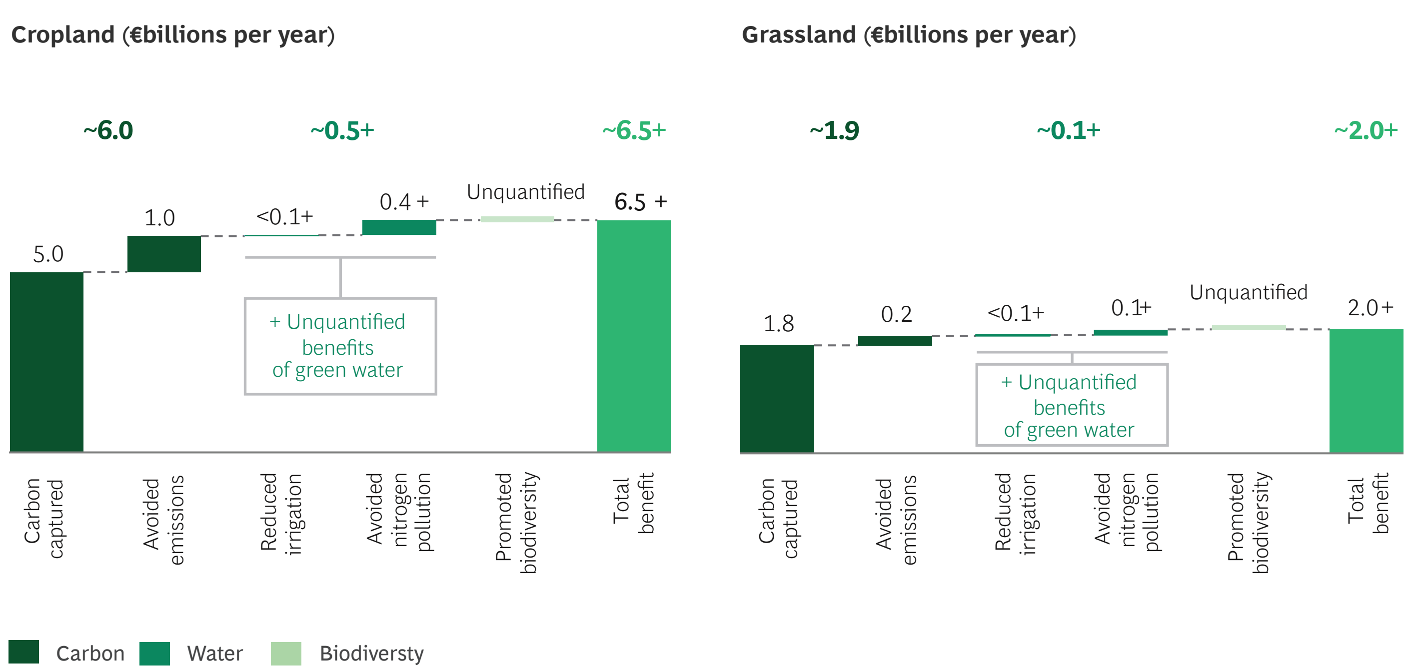


Exhibit 12 - Regenerative Agriculture Offers Benefits Across Three Ecological Dimensions



Sources: NABU; BCG analysis.

Table 3 - Expected Impact, Methodology and Assumptions for Carbon

Ecological dimension	Expected impact	Methodology	Assumptions
Carbon captured in soil	€6.8 billion annually	**Bottom-up:** aggregated average amount of carbon captured in soil by each practice	Carbon price reflects external climate costs at around €223 per ton of CO_2e in 2035[1] Nitrogen use efficiency of fertilizer is about 45% to 50%; increase of NUE is not estimated
Avoided CO_2e emissions through reduced nitrogen fertilizer use	€1.1 billion annually	**Bottom-up:** aggregated average reduction of nitrogen fertilizer use generated by each practice	

[1] Predicted external climate costs for carbon emissions 2035e, based on cost rates for 2030e and 2050e from the German federal environment agency 2020.

[18] Wang-Erlandsson et al., 2022: A planetary boundary for green water. Nature Reviews Earth and Environment.

[19] German Federal Environment Agency, 2013: Global land and biomass – sustainable and resource-conserving use. German Ministry of Food and Agriculture & Johan Heirich von Thünen Federal Research Institute for Climate-Smart Agriculture, 2019: Humus in agricultural soils in Germany (thuenen.de).

[20] German Federal Environment Agency, (2021): Greenhouse gas emissions in Germany.

[21] Expert judgment; Withers et al., 2014: Agriculture and Eutrophication: Where Do We Go from Here?

Sensitivity Analysis. The total monetary benefit derived from carbon reduction—€7.9 billion annually—depends largely on the amount of carbon captured in soil and on the price of carbon. The level of avoided CO_2e emissions due to reduced use of nitrogen fertilizer accounts for only about 15% of the total. (See Exhibit 13.)

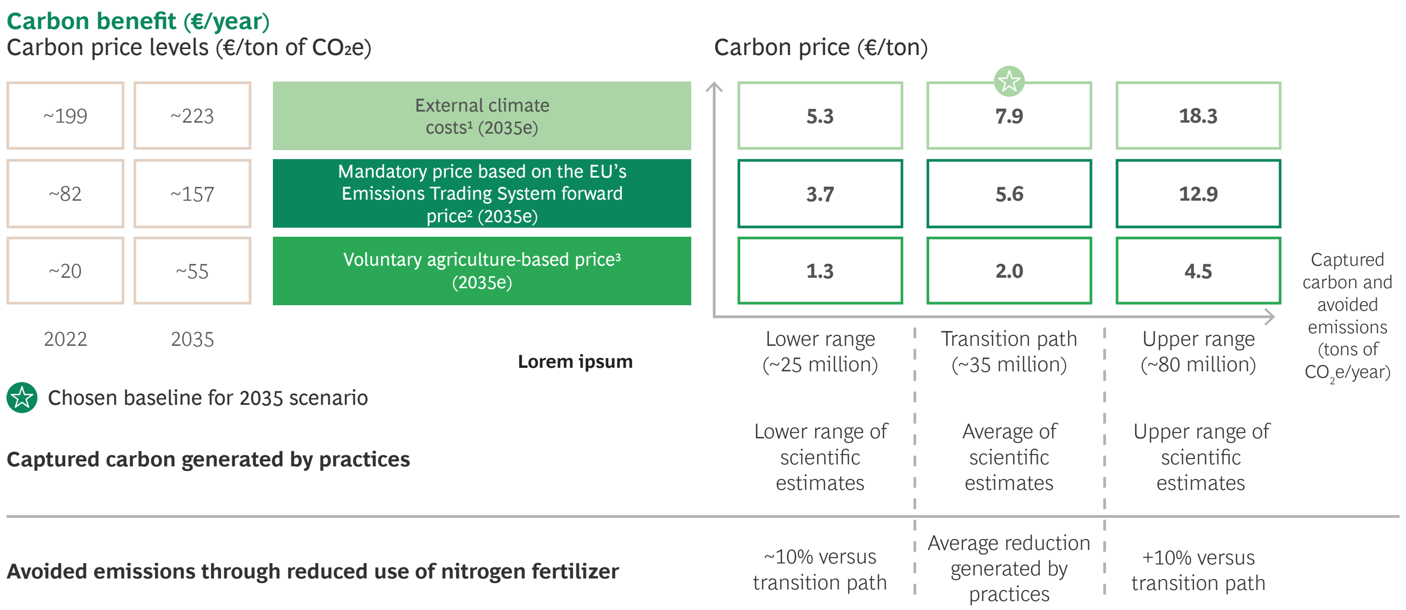
As discussed in the sidebar "What Are Carbon Credits Worth?" on page 25. the carbon price varies by type of carbon credit market. To quantify the socioecological effects, we used a carbon price that reflects external climate costs (around €223 per ton of CO_2e in 2035), rather than the voluntary price levels that we used earlier to gauge the effects on farmers' profits.[22] Scientific estimates of the level of carbon captured in soil that each regenerative practice achieves vary depending on farm context and on how intensively the practice is applied. For our analysis, we selected the averages of the different applicable scientific estimates.

Water

Regenerative agriculture can reduce the harmful effects of conventional agricultural practices on water in three ways: by increasing the capacity of soils to hold and conduct water, and thereby reducing the need for irrigation; by avoiding nitrate pollution; and by regenerating small water cycles that cool ecosystems and surface temperatures. This last benefit supports the dynamics of green water available to plants in the soil—a natural process that is fundamental to maintaining the planet's climate.[23] We do not further detail or quantify this last effect as part of this report, because as yet the role of green water in relation to agricultural practices has not been adequately explored.

Significant periods of drought already affect the production of most crops in Germany, and crops that have long been fed primarily by rainwater will likely require mechanical irrigation for at least temporary periods in the summer season, owing in part to climate change.[24] As a result, the amount of irrigated cropland in the country is expected to quadruple over the next 12 years.[25]

Exhibit 13 - The Carbon-Reduction Benefits Depend Largely on the Price of Carbon and How Much Carbon Is Captured in the Soil



Sources: Ecosystems Marketplace report 2019; Bloomberg; Princeton; World Bank, Climate Change 2015; CDP report 2015; expert interviews; BCG analysis.
Note: Differences in values are possible due to rounding. Calculations assume 2035 adoption rates of regenerative practices at implementation Stage 2.
¹ Predicted external climate costs for carbon emissions in 2035; 2022 figures are based on cost rates for 2020 and 2030e; 2035e figures are based on cost rates for 2030e and 2050e from the German federal environment agency, 2020.
² 2022 price is the Q3 2022 EU ETS price; 2035e price is the predicted average until 2029; 2035e is based on CAGR (2018–2019); Intercontinental Exchange ENDEX European Union Allowance; Month Electronic Energy Future ENDEX.
³ Predicted average until 2040.

[22] Predicted external climate costs for carbon emissions 2035e, based on cost rates for 2030e and 2050e from the German federal environment agency 2020.

[23] Wang-Erlandsson et al., 2022: A planetary boundary for green water. Nature Reviews Earth and Environment.

[24] OECD (2019): Agriculture and water policies, Germany.

[25] Rosa et al., 2020: Potential for sustainable irrigation expansion in a 3°C warmer climate. PNAS.

At the same time, some areas in Germany report decreasing groundwater levels, a situation that experts say has become problematic.[26] In 2015, for example, nearly 80% of the water used for irrigation was drawn from groundwater and spring water sources.[27] Regenerative practices increase the soil's capacity to hold water and improve its infiltration capabilities so that it can more efficiently route excess rain to the groundwater. Consequently, they not only mitigate the effects of temporary drought, reduce the need for mechanical irrigation, and by extension reduce the amount of water used, but also support the replenishing of groundwater aquifers.[28] And by covering the ground year-round, they also reduce the amount of water lost to evaporation.

The cost of excessive nitrate use in German waters now totals more than €1 billion annually. This includes an estimated €670 million a year spent on filtering nitrates from drinking water.[29] In addition, more than €300 million a year is lost in expected penalties from the EU for violating laws governing nitrate thresholds in groundwater.[30] The anticipated expense of nitrate filtration alone costs a German family of four up to €134 in annual drinking water bills.[31]

Although agriculture is not solely responsible for the nitrate pollution in Germany's water, nitrate levels in areas with considerable agricultural activity—especially those with intense livestock cultivation and large shares of specialized crops such as fruit and hops—often exceed permissible water nitrate levels.[32]

Regenerative agriculture can significantly lower the amount of soil-disturbing cultivation and nitrogen fertilizer needed for farming, thus reducing the amount of surplus nitrogen discharged into the water.

Quantification Approach. As with our analysis of carbon, our analysis of water benefits assumes that all Stage 1 and Stage 2 regenerative practices have achieved a steady state following the transition phase. We estimate the overall value of the benefits of regenerative agriculture on water quality in Germany by 2035 at about €560 million per year. Cropland practices generate about 80% of this amount, and grassland practices about 20%.

Table 4 provides an overview of the estimated expected impact, methodology, and assumptions used in the analysis.

This analysis depends in part on future water prices, which remain uncertain due to several factors, including mismatches between water demand and water availability at seasonal peaks in periods with low precipitation, and the

Table 4 - Expected Impact, Methodology and Assumptions for Water

Ecological dimension	Expected impact	Methodology	Assumptions
Reduced irrigation	€50 million annually	**Bottom-up:** aggregated average avoided irrigation resulting from each practice based on correlation with increase in SOM	Water is priced at €2.30 per cubic meter in 2035 2 million hectares of cropland are irrigated in 2035¹ 5% of grassland is irrigated in 2035
Avoided nitrogen pollution through reduced nitrogen fertilizer use	€510 million annually	**Top-down:** aggregated average reduction of nitrogen fertilizer use generated by each practice	Annual nitrate removal costs are €730 million, of which 75% are attributed to agriculture² A cost reduction of 70% is possible, with 30% of excess farm fertilizer not distributed

¹ Rosa et al., 2020: Potential for sustainable irrigation expansion in a 3°C warmer climate. PNAS.
² German Federal Environment Agency 2017; Federal Ministry of Food and Agriculture, 2022.

[26] Science Media Center Germany, 2022: Groundwater in Germany is sinking – how do we adapt?

[27] German Federal Statistical Office, 2016: Irrigation in Agriculture / Agricultural Structure Survey.

[28] Langford and Orr, 2022: Exploring the Critical Role of Water in Regenerative Agriculture; Building Promises and Avoiding Pitfalls, Frontiers in Sustainable Food Systems.

[29] German Federal Environment Agency, 2017: Factsheet Nitrate Costs.

[30] German Ministry of Food and Agriculture, press release 2022: Factsheet Nitratkosten (umweltbundesamt.de).

[31] German Federal Environment Agency, 2017: Quantification of agriculturally induced costs to secure drinking water supply.

[32] German Federal Environment Agency, 2017: Factsheet Nitrate Costs.

sometimes opaque and arbitrary pricing of water when used.[33] Although some experts expect a sharp increase in the prices farmers must pay for water in the future, our analysis assumes that water prices will continue to increase at a more conservative rate, in line with increases in past recent years.

> **Considering the currently decreasing groundwater levels in Germany, a sharp increase in water prices above previous growth rates is expected to hit the agricultural sector in the upcoming years.**
>
> — Markus Pflugfelder, University of Hohenheim

Sensitivity Analyses. The calculated water-related monetary benefits of regenerative agriculture—about €560 million per year—depend on two factors that we considered in separate sensitivity analyses. The first is the effect of regenerative agriculture on the need for and cost of irrigation, which in turn depends on the price of water and the soil's capacity to hold water. Our analysis assumes a water price of €2.30 per cubic meter in 2035. The increased water-holding capacity of soil in Germany that would result from the deployment of regenerative agriculture practices is about 20 million cubic meters per year in our scenario, based on an average of scientific estimates. (See Exhibit 14.) These figure represent the average of the range of scientific estimates.

The second factor is the benefit of nitrate pollution avoided, which depends on the average annual costs of removing nitrates caused by agriculture—around €730 million per year—and the reduction in those costs that regenerative agriculture can achieve.[34] Our analysis assumes a 70% reduction in costs, given our assumed adoption rates by farmers of regenerative practices through Stage 2. (See Exhibit 15.) As above, these figure represent the average of the range of scientific estimates.

Biodiversity

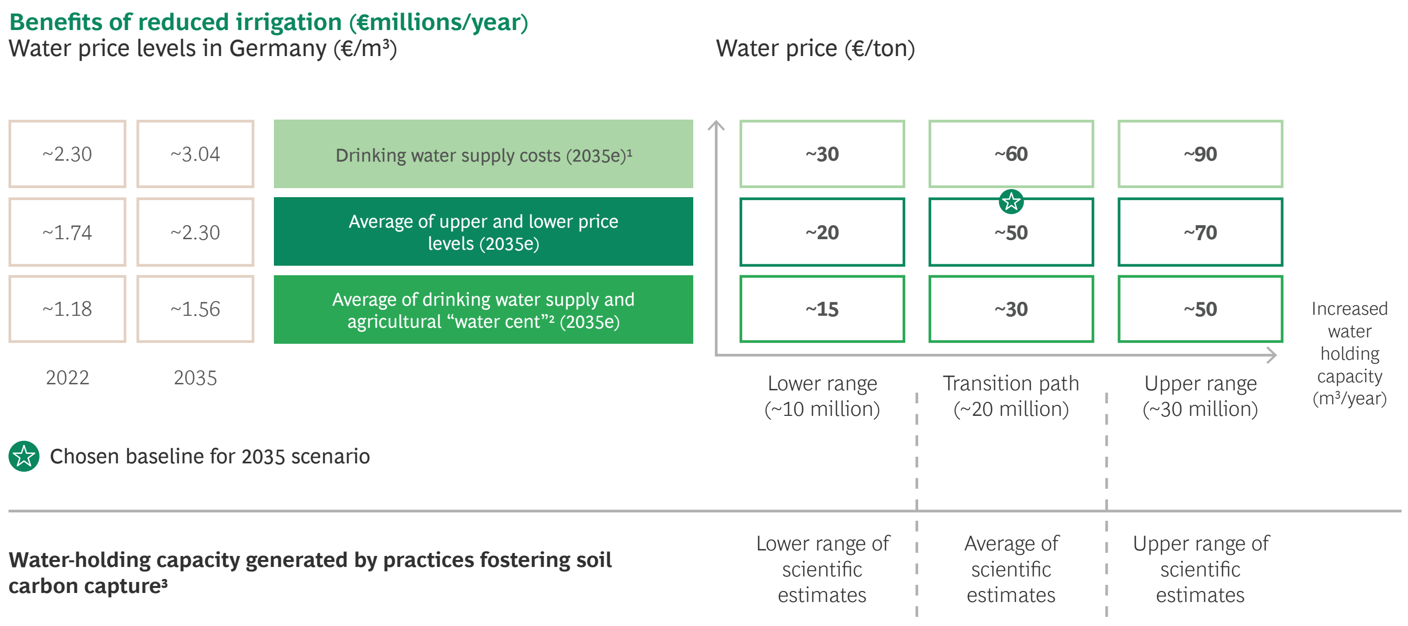
As defined in "The Biodiversity Imperative for Business: Preserving the Foundations of Our Well-Being," biodiversity is multidimensional.[35] It entails the presence and interplay of three levels of diversity: genes, species, and ecosystems. Fully understanding the degree of biodiversity in a particular area requires an analysis not just of visible above-ground species, such as mammal or plant populations, but also of the genetic diversity among species and microbiomes (including all microorganisms in both plants and soil) and the complex interactions within and across ecosystems—for example, soil biodiversity of croplands as well as of neighboring river and forest ecosystems.

The world's croplands contribute around €7 trillion in ecosystem services annually—not just in the obvious form of the food grown, but also through soil formation, climate regulation, habitat provision, waste treatment, and the many other services that nature provides. At the same time, of all forms of economic activity, farming exerts the greatest pressure on biodiversity, primarily through changes in land use, as more and more land is converted to agricultural purposes, and through soil, water, and air pollution. According to one estimate, agricultural activities create more than 25% of the total pressure leading to biodiversity loss around the world, even though the global agri-food sector relies heavily on biodiversity above and below the ground to provide the food we need.[36]

A key goal of regenerative agriculture is to protect biodiversity by reducing the negative impacts of conventional agriculture and to increase the overall biodiversity of cropland and grassland, and thus enhance its contribution to ecosystem services.

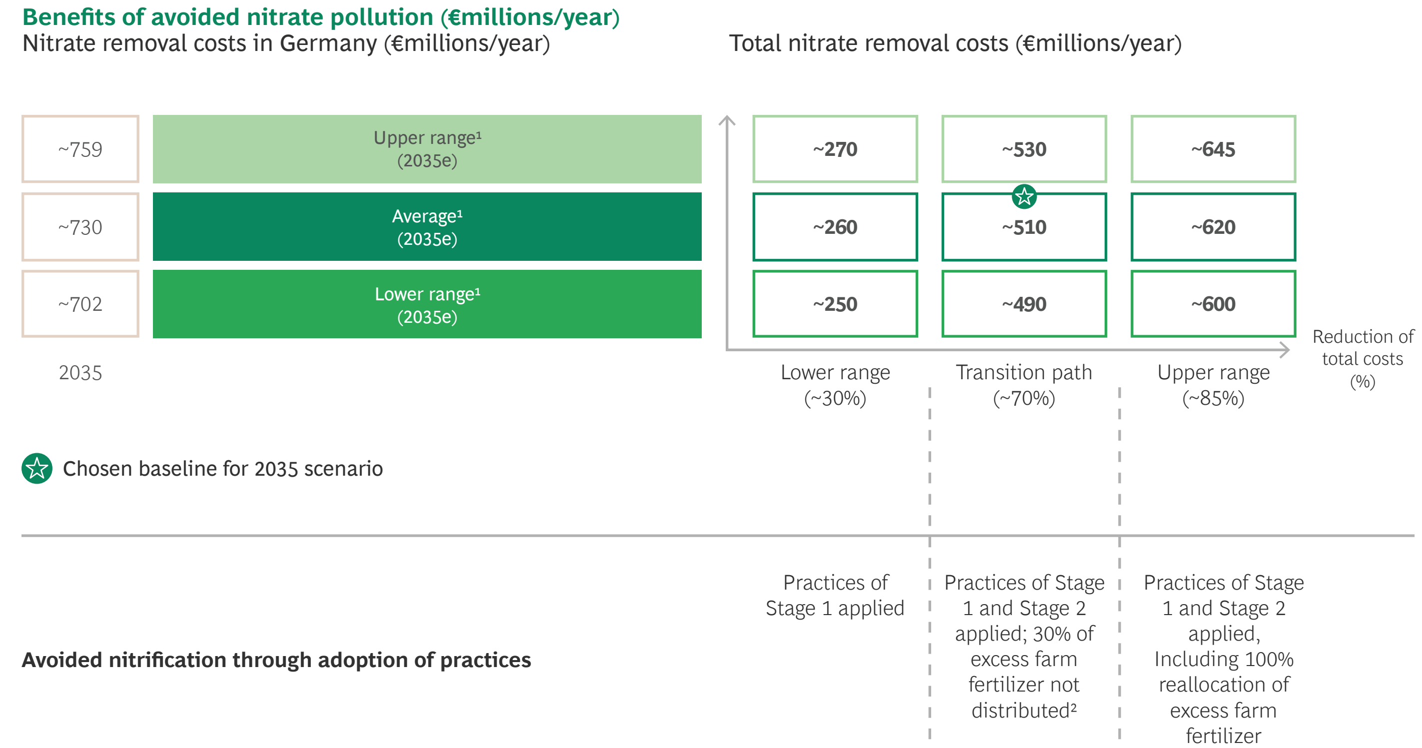
Qualitative Assessment Approach. It is very difficult to quantify the value of biodiversity in economic terms. In part this is because no commonly accepted metric for measuring its value exists beyond the value of the ecosystem services it provides—an aspect that the analysis of regenerative agriculture's positive impact on carbon and water already captures.

Exhibit 14 - Sensitivity Analysis of Benefits from Reduced Irrigation, Depending on Water Price and the Water-Holding Capacity of Soil



Source: BCG analysis.
Note: Green water as in terrestrial precipitation, evaporation and soil moisture—e.g., impact of increased soil moisture on buffering of extreme weather events/regeneration of small water cycles—is not further quantified. Differences in values are possible due to rounding. Calculations assume that all farmers must pay for water withdrawal and that farmers have achieved the expected Stage 2 adoption rates.
[1] Charges for drinking water supply 2019 (m³ charge only); Federal Statistical Office, Germany (destatis.de); 2035 estimate is based on 2.2% CAGR (2017–2019).
[2] Average of agricultural groundwater withdrawal "water cent" costs (2019: ~0.01–0.12 €/m³, excluding city states and federal states with free withdrawal) and drinking water supply costs; 2035 estimate is based on 2.2% CAGR (2017–2019).
[3] Assuming a correlation between water holding capacity and soil carbon capture at a rate of ~2,586 liters/ton of organic carbon); Natural Resources Defense Council, 2015.

Exhibit 15 - Sensitivity Analysis of Benefit from Avoided Nitrate Pollution, Depending on Nitrate Removal Costs and Level of Cost Reduction



Source: BCG analysis.
Note: Differences in values are possible due to rounding. Calculations assume 2035 adoption rates of regenerative practices and assume 40%–45% leaching of nitrate fertilizer in soil/water based on nitrogen use efficiency (55–60%).
[1] 75% of total yearly nitrate removal costs in water (assuming that 75% are caused by agriculture) driven by filtration costs and expected EU penalties for exceeded nitrate levels; German federal environment agency 2017; Federal Ministry of Food and Agriculture, 2022.
[2] Excess farm fertilizer cannot be 100% reallocated and thus remains to be used where not needed.

[33] European Environment Agency, 2017: Water management in Europe: price and non-price approaches to water conservation. German Institute for Economic Research Berlin, Weekly Report 49/2022: Valuable resource water increasingly polluted and regionally overused in Germany.

[34] German federal environment agency 2017, Federal Ministry of Food and Agriculture, 2022.

[35] NABU & BCG, 2020: The Biodiversity Imperative for Business—Preserving the Foundations of Our Well-Being.

[36] Ibid.

Our analysis focuses on the qualitative impacts of specific regenerative agriculture practices on biodiversity in terms of species richness above the ground and enhanced soil biodiversity. (See Exhibit 16.) In general, there are three primary drivers of these benefits: avoidance of interference in the structure of soil; linked reduction in the use of synthetic crop protection and fertilizer inputs; and associated improvements in biodiversity. Two particularly beneficial practices illustrate the impact of regenerative farming:

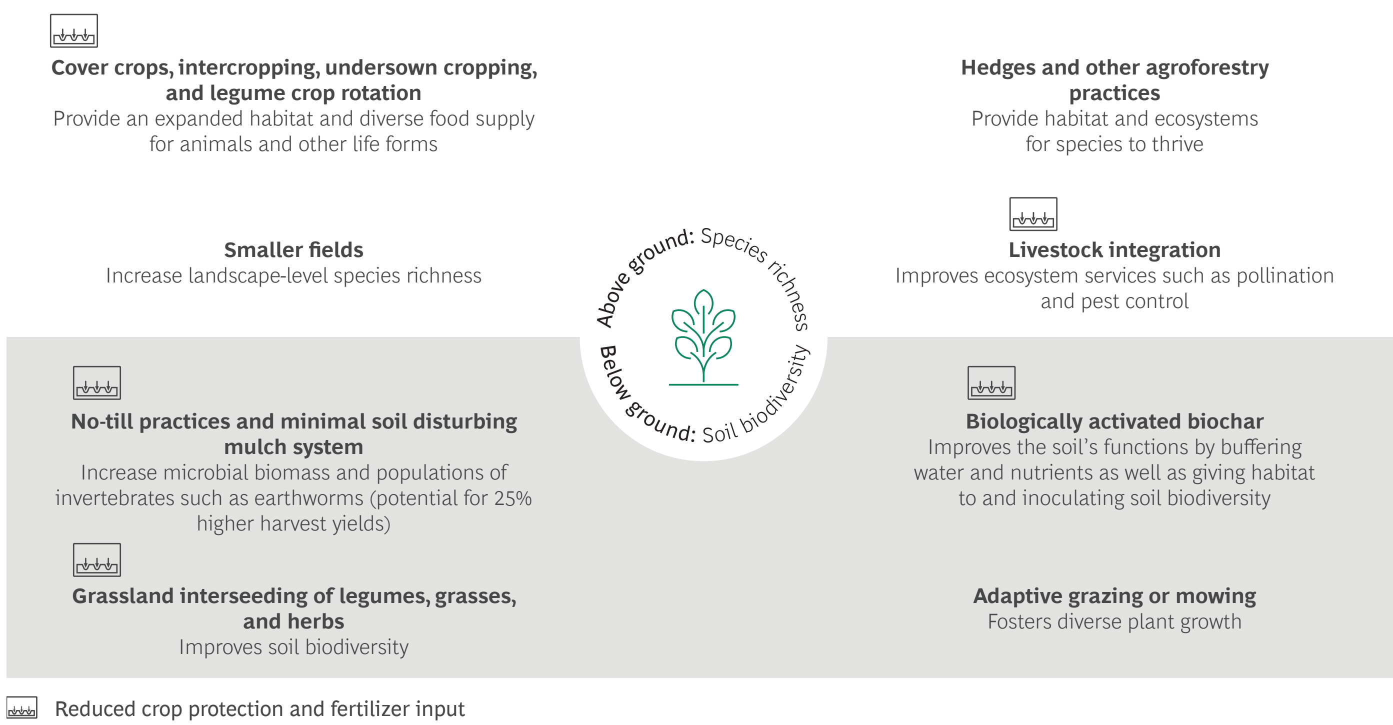
- **No or Minimum Tillage.** Strong evidence indicates that no-till or minimum-till practices that disturb the soil as little as possible increase microbial biomass and invertebrate populations such as earthworms by up to 150%.[37] The presence of earthworms can contribute to a 23% increase in below-ground biomass and a 25% increase in harvest yields.[38] Earthworm burrows increase the soil's water infiltration and conductivity.

- **Smaller Fields.** Research conducted in eastern and western Germany has shown that reduced field size positively correlates with greater landscape-level species richness.[39] In landscapes with smaller mean field sizes, more species thrive and build habitats, which in turn strengthens local ecosystem services, including increased numbers of wild bees to pollinate crops and boost yields. More diverse landscapes, commingling cultivated land with forest and range, also have positive effects on biodiversity.[40]

The positive impact of regenerative practices on biodiversity offers further pragmatic benefits to farmers, including the reduction of entry hurdles to environmental subsidies and greater protection from regulatory penalties during the transition to regenerative agriculture. Depending on the conservation needs and aims of specific regions, some environmental regulations even offer financial subsidies to farmers willing to adopt these practices.

More than half of all the habitable land in the world—and almost half of Germany's land—is devoted to agriculture.[41] Just as we are responsible for ensuring that our food system can feed the planet's growing population fairly and affordably, we must also strive toward an agri-

Exhibit 16 - Regenerative Practices Can Have a Significant Impact on Biodiversity



Sources: Tscharntke et al., 2021; Kremen and Merenlender, 2018; Ma et al., 2022; expert interviews; FAO report, "Advances in Conservation Agriculture Volume 2"; BCG analysis.

[37] Food and Agriculture Organization of the United Nations, 2020: Advances in Conservation Agriculture: Volume 2: Practice and Benefits, Burleigh Dodds Science Publishing. Wittwer et al., 2021: Organic and conservation agriculture promote ecosystem multifunctionality. Science Advances.

[38] Van Groenigen et al., 2014: Earthworms increase plant production: a meta-analysis. Scientific Reports.

[39] Tscharntke et al., 2021: Beyond organic farming—harnessing biodiversity-friendly landscapes. Trends in Ecology & Evolution.

[40] Kremen and Merenlender, 2018: Landscapes that work for biodiversity and people. Science.

[41] Destatis, German Federal Statistical Office.

food system that improves the quality of our water, promotes biodiversity, and helps combat global warming.

Our analysis captures in as much detail as possible the socioecological benefits of regenerative agriculture in removing carbon from the atmosphere, reducing CO_2e emissions, maintaining clean water, and promoting biodiversity. Even so, we believe that our estimated benefit of €8.5 billion annually does not fully capture the value of regenerative agriculture or the extent to which the transition to these practices can contribute to the health and well-being of Germany and the entire planet.

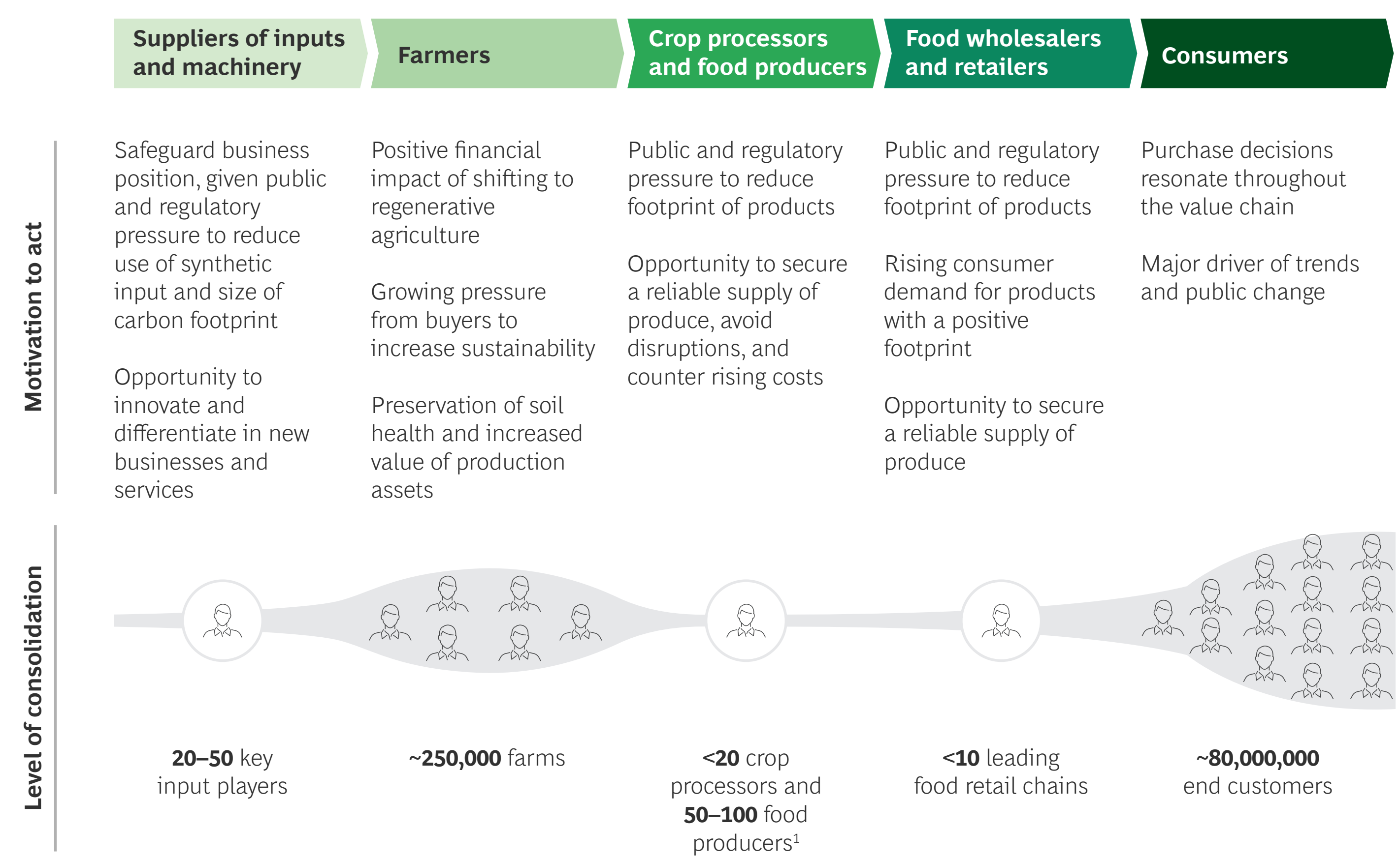
Regenerative Agriculture's Impact on the German Agri-Food System

We have shown that regenerative agriculture can increase German farmers' revenues and profits and provide real socioecological benefits. Now we will consider how to extend these benefits to the country's broader agri-food system.

Germany's agri-food system is highly concentrated, with each step in the chain, aside from the farming step, largely controlled by a few leading players. (See Exhibit 17.) Food producers and retailers, in particular, have considerable bargaining power in their dealings with farmers, and hence are critical to the effort to extend the benefits of regenerative agriculture throughout the country. By supporting the regenerative goals of their farmer-suppliers—working with them as they make the transition to regenerative practices and buying their harvests—these companies will play an essential role.

Their willingness to promote the transition to regenerative agriculture, however, will depend on their understanding of the extent to which they will benefit from regenerative agriculture. In this section, we examine the impact of regenerative agriculture on the downstream value chain, including food producers, wholesalers, distributors, and retailers. Two key benefits to these players emerge: safeguarding their current and future supplies of food and food inputs, and ensuring their reputation and social license to operate.

Exhibit 17 - Stakeholders in the German Agri-Food System Have Many Reasons to Shift to Regenerative Agriculture



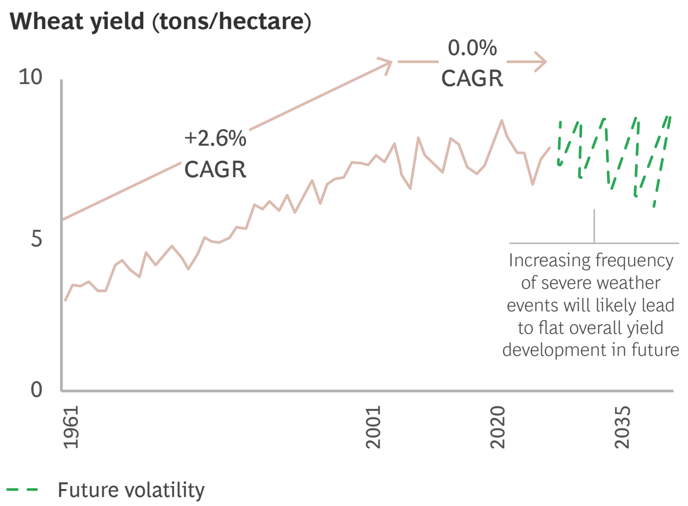
Source: BCG analysis.
[1] Not including another 4,000 or so small and medium-size enterprises in the German food industry.

Safeguarding Future Food Supplies Through Yield Resilience

Thanks to the "green revolution," crop yields rose enormously in the second half of the 20th century. In Germany, for example, annual wheat yields tripled from an average of 2.8 tons to per hectare in 1961 to an average of 7.9 tons per hectare in 2001—a compound annual growth rate of 2.6%, driven by improvements in fertilizer and crop protection, more powerful and efficient machinery, and significant progress in crop breeding.[42] (See Exhibit 18.)

Since the early 2000s, however, the effects of climate change have meaningfully slowed this progress, leading to greater fluctuations in annual yields. In several years, hot and dry periods in spring and summer have resulted in significant declines in yield; for example, in 2018, a drought year in Germany saw yields plummet by 16%.[43] As the deleterious effects of climate change increase, more intense drought years are expected, placing additional stress on yields.

Exhibit 18 - Wheat Yields in Germany Are Becoming More Volatile as Severe Weather Events Grow More Frequent



Source: FAO;BCG analysis.

These changes are likely to have a twofold impact on food companies. First, lower crop yields could reduce companies' access to the crops they need as input ingredients for the food they produce, putting their operations and production volumes at risk. Second, the price that food companies must pay for these crops will increase, especially in years marked by low yields.

By improving crop resilience in the face of severe weather conditions, regenerative agriculture can contribute greatly to securing stable sources of crop supplies, thus mitigating price peaks in challenging years. Increasing the resilience of German food production also helps increase global food security and access by reducing pressure on global food commodity markets in years of climate disruptions. Our analysis shows that regenerative practices—especially no-till and cover cropping—can reduce yield losses by up to 50% in years with severe weather conditions. In 2018, when yields fell by 16%, food companies faced cost increases of around 20%. Regenerative agriculture practices can limit such increases to around 10%. (See the sidebar "How Crop Prices Correlate with Yields and the Impact of Droughts.")

Ensuring Reputation and License to Operate

Pressure from investors, regulators, and consumers on companies in every industry to lower GHG emissions and implement more environmentally friendly practices throughout their operations is growing rapidly. Companies in the downstream food value chain have a special obligation to set and meet ambitious green goals, given the size of their carbon and environmental footprints and their role in supplying food to Germany. By supporting the goals of regenerative agriculture—and the farmers who practice regenerative agriculture—they can enhance their reputations as environmentally friendly companies and ensure that they stay in front of current and future environmental and climate regulations.

Companies in Germany's food value chain can aspire to achieve three levels of alignment with regenerative agriculture, each of which brings added reputational benefits, competitiveness, and license to operate:

- **Comply.** Adhere to existing and upcoming regulations; work with key upstream suppliers and downstream customers to meet Scope 3 emissions targets.
- **Compete.** Set voluntary targets that go beyond current regulatory requirements to maintain social license to operate and improve competitive position.
- **Lead.** Become first movers in regenerative agriculture, reinforcing competitive advantage and boosting shareholder returns.

Comply and Compete. The first two stages of alignment with regenerative goals are becoming table stakes for food producers as the SBTi's findings become the de facto standard and all players commit to them in their efforts to reduce their carbon footprint. Regenerative agriculture can make a substantial contribution to helping these companies achieve their Scope 3 GHG emissions targets, which make up an estimated 85% of the emissions attributable

[42] FAOSTAT wheat yield data for Germany; BCG analysis.

[43] https://www.bmel.de/DE/themen/landwirtschaft/klimaschutz/duerre-2018.html#:~:text=Trockenheit%202018%20war%20Ereignis%20von%20nationalem%20Ausma%C3%9F&text=Hektarertr%C3%A4ge%20bei%20Getreide%20(ohne%20K%C3%B6rnermais,%25)%20waren%20am%20st%C3%A4rksten%20betroffen

How Crop Prices Correlate with Yields and the Impact of Droughts

We analyzed year-over-year changes in wheat and corn yields—and corresponding price changes—in Germany over the past ten years. We found that both wheat and corn show a negative correlation between yield and price growth. In other words, reduced yields lead to short-term price shocks on the market.

Weather-pattern-induced yield shocks for wheat, such as in drought years, have a regression coefficient of –1.3 with prices, meaning that a 16% yield reduction in German wheat production, as in the drought year of 2018, leads to a price increase of around 20%. (See the first exhibit.)

The correlation coefficient is lower for corn, which is mainly used for animal feed and biofuel and biogas production: a 16% yield reduction of corn leads to a price increase for corn of around 8%. (See the second exhibit.)

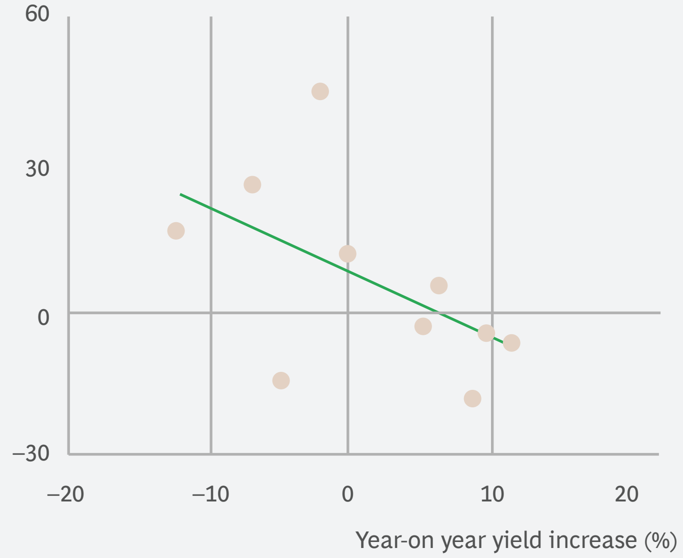
Wheat is a global crop grown on every continent, and wheat prices are set on public markets like the Chicago Board of Trade. Nevertheless, the correlation between average yields and prices in Germany seems valid, as droughts are usually not limited to Germany but instead also affect other wheat-producing EU countries, including France, Poland, and the Nordic and Baltic countries. Therefore, production declines in Germany can serve as a proxy for lower overall production volume across the EU.

Moreover, it is difficult to find substitutes for high-grade wheat, such as bakery-quality wheat, on global markets, given the specific requirements with regard to protein chemical residue content in EU food regulations. Consequently, shortfalls in domestic production cannot be filled easily through global trade. The observed correlation of yields and prices in Germany therefore serve as valid proxies for a comparable correlation throughout the EU.

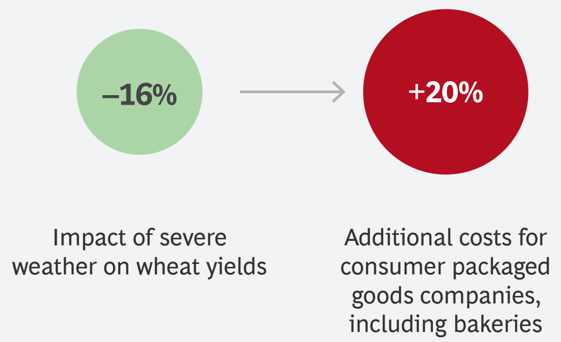
Price increases are relevant for all ingredients purchased on spot markets, and they affect food producers, retailers, and consumers equally in years of severe weather patterns.

Wheat Yields and Price Levels Are Negatively Correlated

Year-on-year wheat price vs. yield increases in Germany (2010-2020)[1]



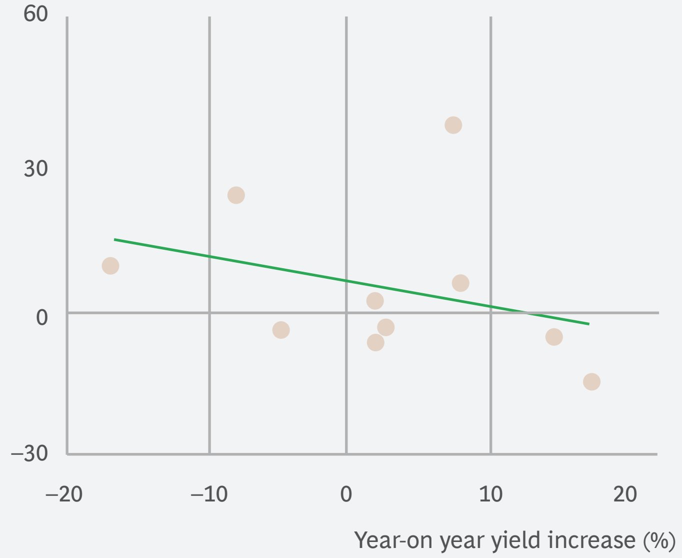
Example analysis of drought year 2018



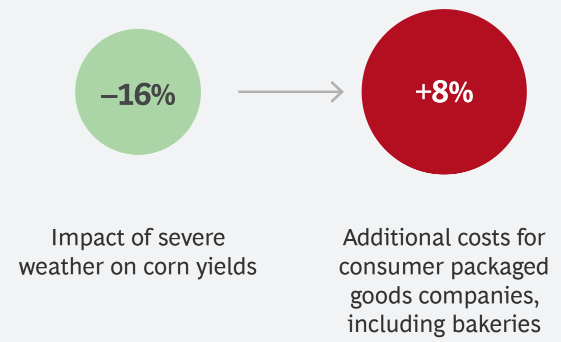
Sources: FAOSTAT data; BCG analysis.
Note: These graphs show the correlation between supply and prices, but other factors (including fertilizer costs, demand, and stocks) affect prices as well. Every 1% dropin yield leads to a 1.3% increase in wheat price.
[1] Excluding 2015, an outlier year.

Corn Yields and Price Levels Are Negatively Correlated

Year-on-year corn price vs. yield increases in Germany (2010-2020)[1]



Example analysis of drought year 2018



Sources: FAOSTAT data; BCG analysis.
Note: Every 1% decrease in yield comes with a 0.5% increase in corn price.
[1] Excluding 2015 as an outlier year.

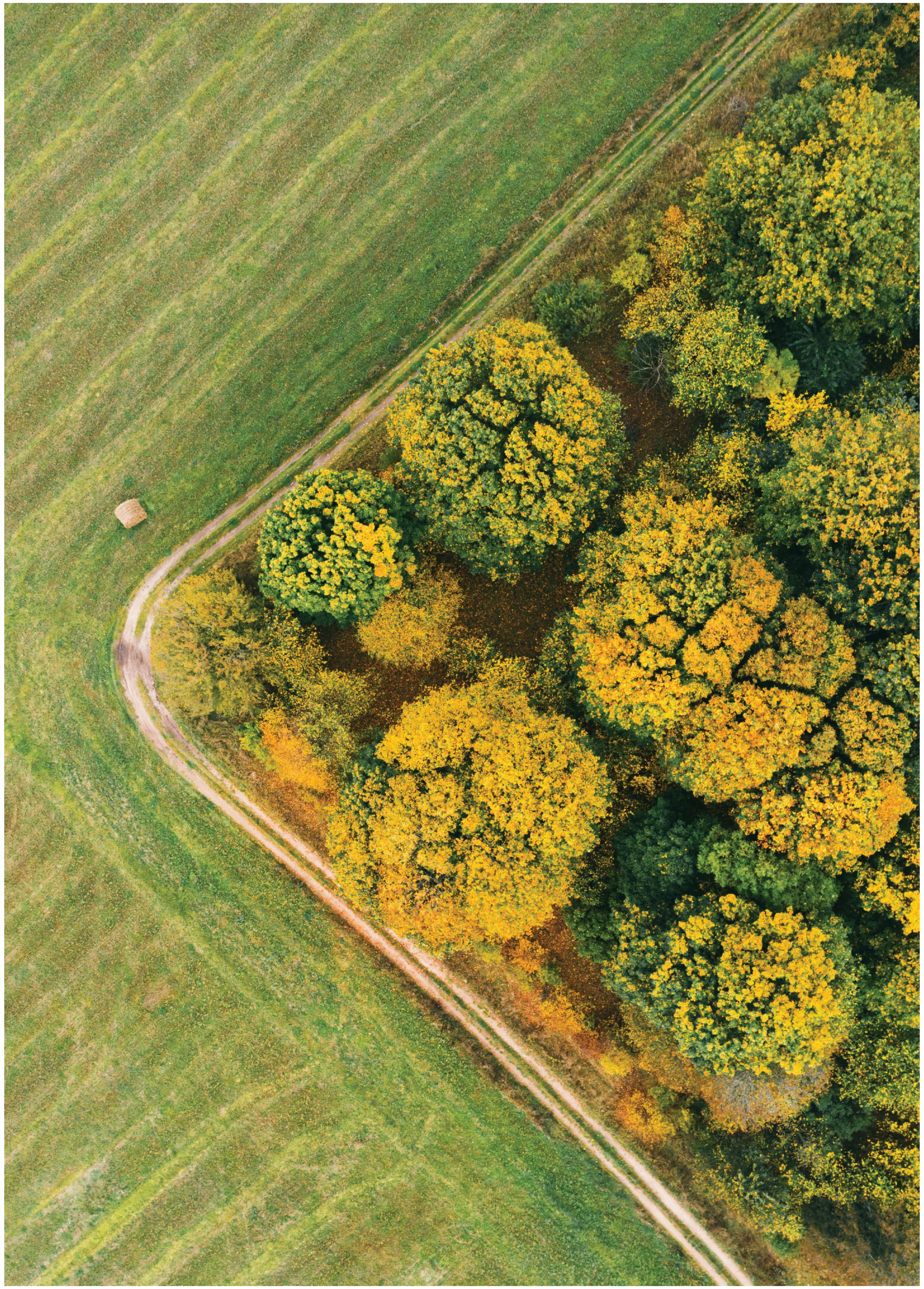
to companies in the downstream food chain. Regenerative agriculture can help address an estimated 35% to 50% of those emissions.[44] Several key players, including Nestlé, Danone, and Kraft Heinz, have already set targets to reduce 50% of their Scope 3 emissions by 2030 and to attain net zero by 2050.[45]

Companies have the opportunity to improve their access to carbon credits that they can use to compensate for unavoidable emissions, by establishing long-term partnerships with farmers whose regenerative practices allow them to create carbon credits. As we noted earlier, the supply of credits on carbon certificate markets is likely to run short in coming years. Food companies can work with farmers to generate these credits—supporting their ongoing soil testing programs, for example, and perhaps even offering their own soil testing capabilities. They could also purchase credits from farmers along with the products they buy.

Food companies have the further opportunity to increase the transparency and sustainability of their supply chains by working with farmers to monitor the regenerative practices they use and by helping them lower their carbon and environmental footprint. By pursuing these efforts, food companies can prepare for the likelihood that regulators will continue to push for greater transparency and sustainability in Germany's food system.

Lead. Companies that have achieved the third stage of alignment with regenerative goals—especially those at the leading edge of the effort—can benefit in several ways.[46] First, they can capture food segments with higher growth potential. Globally, consumers currently spend just $5 billion on green food alternatives, compared with $2 trillion on conventional food. But green alternatives are growing by 22% annually, compared to annual growth of just 6% for conventional food.[47] Leaders can also gain easier access to cheaper capital. Western European leaders in sustainable food borrow money at rates 72 basis points lower, on average, than others do. And they achieve better shareholder returns—an increase of 6 percentage points in four-year total shareholder return.[48]

The positive potential impact of regenerative agriculture on Germany's food chain goes beyond the food companies that make, distribute, and sell the country's food. Farther downstream, end consumers and the broader society benefit in several ways. Having a more secure food supply, grown locally, makes the country less dependent on food sources and energy imports from other countries. Greater price stability means less financial pressure on consumers, especially in times of high inflation. And Germany may be able to export more of the food it grows, offering benefits that extend far beyond the country's borders in times of need.



[44] World Economic Forum & BCG report, 2021: Net Zero Challenge: The Supply Chain Opportunity; Poore et al., 2018: Reducing food's environmental impacts through producers and consumers.

[45] Company publications; BCG analysis.

[46] Refinitiv data (29/11/2021) for listed companies with >$500 million market cap (>$5 billion for automotive due to consolidated nature of industry), CapitalIQ dividend-adjusted share prices (30/11/2021) for listed companies with >$500M market cap; BCG ValueScience; WEF—Winning the Race to Net Zero, BCG analysis.

[47] Statista, Plant Based Food Association, Plant-based meat vs. animal meat sales (three-year average 2017–2020); BCG analysis.

[48] Simple average WACC % (leaders – laggards), outliers removed from sample per interquartile range rule; Sustainability leaders (laggards) defined as top (bottom) quartile Refinitiv Environmental Pillar score. Source: Refinitiv data (29/11/2021) for listed companies with >$500 million market cap (>$5 billion for automotive due to consolidated nature of industry), CapitalIQ dividend-adjusted share prices (30/11/2021) for listed companies with >$500M market cap; BCG ValueScience; WEF—Winning the Race to Net Zero; BCG analysis.

Setting Out on the Path to Regenerative Agriculture

As we have shown, regenerative agriculture has the potential to provide a triple-win for Germany, offering significant benefits to the country's farmers, downstream food companies, and the country as a whole, both economically and in terms of health and well-being. Moreover, these advantages can be achieved without burdening consumers with price increases or premiums. Nor does it require the establishment of regulations and certification labels, as organic foods do. Since farmers, the food industry, and society at large all stand to benefit greatly from the transition to regenerative agriculture, making the case for it should be straightforward—at least in theory.

The actual transition, however, won't be easy. In this chapter, we examine the challenges that are most likely to impede progress, and we outline a path forward for farmers and other major stakeholders.

At the center of the transition are the farmers who grow the country's food. Gaining their support will be key to a smooth and timely transition to regenerative agriculture. We see five potentially significant hurdles in this area.

The first is the lack of a rallying point that might create a sense of urgency about the need to change. Farmers who have not suffered from reduced yields due to severe weather or depleted soil are likely to want to continue to use the conventional farming practices that have worked successfully in the past.

The second is a lack of information about and experience with innovative cultivation methods such as undersowing and interseeding, and with new technologies such as biostimulants and bioleaching inhibitors. As a group, farmers tend to be cautious about new methods and their potential implications.

The third is the regulatory environment. As yet, farmers have not reaped sufficient rewards for sequestering carbon either through monetized carbon credits or through governmental aid. However, as payments for ecosystem services evolve—such as through purchases of credits on carbon markets—this is likely to change.

The fourth is concern over a perceived loss of profits from adopting regenerative agriculture. The transition requires immediate upfront costs—for cover crop seeds, biostimulants, soil conditioners, and other things—but the savings come later, as cover crops accumulate nitrogen in the soil and reduce the cost of fertilizer in later years, for example. The possibility of lower yields during the transition stage, even if it is only theoretical, exacerbates this concern, particularly when grain prices are high and farmers are reluctant to risk the short-term loss of revenue.

The fifth hurdle is perhaps the most daunting: the deep-seated belief among many German farmers in the virtues of synthetic inputs, tilling, and the other practices of conventional agriculture. German agricultural strategy has long reenforced this belief. On the one hand, farmers have received subsidies to grow monoculture cash crops and produce dairy products and hogs for global markets at the lowest possible cost, compounding German agriculture's negative external effects. On the other hand, farmers are constantly urged to boost the sustainability of their operations, through greening subsidies and special aid when they shift to organic farming.

This either/or mindset is reinforced by farmer training curriculums, university agronomy programs, the country's many agronomic advisory councils and private advisors, and the federal chambers of agriculture's consultancy service.

Overcoming these hurdles will not be easy. The key to success lies in supporting farmers in their efforts to begin the journey to regenerative agriculture and throughout the transition. At the outset, the focus needs to be on encouraging them to make no-regret moves to achieve early successes while reducing any perceived risks to a minimum.

In the longer term, efforts to support farmers must include three elements: direct farmer support, education, training, and advice; government aid and tailored subsidies; and support from food companies and retailers. (See Exhibit 19.)

Exhibit 19 - A Three-Pronged Approach to Promoting Regenerative Agriculture

Non-exhaustive

A: Direct farmer support, education, training, and advice	B: Government aid and tailored subsidies	C: Support from downstream food industry and retail players
Academic research and data supply		
Increase regenerative agriculture content in education and consultation	Provide long-term regulatory and subsidy schemes	Ensure long-term farmer partnerships
Strengthen agronomic R&D to identify best solutions and quantify impact	Provide targeted regional funding (regional programs, transition funds)	Scale selected pilots (landscape transformation)
Increase availability of required equipment and inputs	Better regulate voluntary carbon certificates and related marketplaces	Continuously enforce regenerative agriculture in supply contracts as secondary standards
Integrate functionality in digital tools for decision support	Provide upsides (such as biodiversity credits) for ecosystem contributions	Support farmers' transformation through advisory services and financial support
Build networks for regenerative change (via NGOs)		Engage in biologically activated biochar production from organic waste

Sources: NABU; BCG analysis.

Direct Farmer Support, Education, Training, and Advice
Regenerative agriculture practices should be included in apprenticeship training and university education, and local chambers of agriculture should increase the amount of regenerative agriculture content in their training and consultation offerings and develop programs to support structured sharing of experience and mentoring. Private agronomic advisory bodies and consultants should boost their support for regenerative agriculture, too, and foster the sharing of best practices among their customers.

Farming media outlets and events, including online and print journals and sponsored field days, need to devote more space to regenerative farming. Content could include tests of direct seeding machines and other equipment, testimonials to the value of such regenerative practices as using biostimulants and cover crops, long-term studies of the impact of regenerative agriculture, and more.

To facilitate education and media attention, experts must conduct additional research into the effects of regenerative farming in central Europe, as most research thus far has been occurred in North America, which differs significantly from Europe in soil, crop cycle programs, and farm size. The need for further research into practices that improve soil health is especially pressing.

The agriculture input industry must broaden its R&D efforts as well. Most of the research that seed, crop protection, and fertilizer companies conduct is geared toward understanding crops and achieving maximum yield under optimal conditions. But the result of this focus is a lack of understanding about crop resilience under less-than-perfect conditions. Future research must also address soil health to determine how to regenerate soils most quickly while maintaining a high level of crop production—how interactions between the soil microbiome and crops lead to maximum nutrient uptake, for example.

Distributors and retailers of agricultural inputs, as well as farmer co-ops, should make suitable inputs and equipment for regenerative agriculture—such as cover crop seeds, biostimulants, and soil conditioners—available to farmers, and should provide technical support on how to use these products. Related services such as holistic soil testing and balancing must also become standard offerings.

Providers of digital support tools for agriculture-related decisions need to expand their offerings to include functions suitable for regenerative agriculture. These tools should increase their support for long-term decision making, taking into account multiyear nutrient accumulation and balancing, for example, rather than focusing on optimizing crop yields and input cost for single seasons. These tools should also support regenerative practices such as intercropping and undersown cropping.

Government Aid and Tailored Subsidies
The German government should revise its strategic plan for implementing the EU's Common Agricultural Plan (CAP) to ensure that agriculture subsidies are available to facilitate the transition to regenerative agriculture. With the next CAP reform due in 2027, planners should introduce more radical changes to make CAP a strong enabler of regenerative agriculture for both conventional farmers and organic farmers. Direct payments should be linked to socioecological outcomes. To enable farmers to plan securely and reduce the implementation costs of regenerative agriculture at the farm level, land use regulations and subsidy schemes should gradually shift toward outcome-based rewards and penalties.

Federal and state-level policymakers and government bodies can also support the transformation by working to change farmers' mindsets through targeted financial support and funding, including regional programs and monetary incentives for farmers to transition to regenerative agriculture. For example, farmers might receive funding to broaden their crop rotation programs and incorporate a certain share of legumes or to use cover crops and no-till practices. Such subsidies can make a significant difference in farmers' adoption of regenerative practices. In states such as Thuringia that have granted subsidies for incorporating legumes into crop rotation regimes, the share of these crops has increased significantly in comparison with states where this has not been done.[49]

Governments could also grant subsidies to support structural measures, including premiums for smaller fields and for agroforestry systems that call for planting a specific proportion or arrangement of hedges around fields.

In addition to offering public subsidies, governments need to develop a clear regulatory framework to support farm-level carbon sequestration and contributions to ecosystem services. This will offer greater security to farmers and allow them to better quantify the benefits of regenerative agriculture. Efforts in this area could include the following:

- Clear and pragmatic regulations to govern the generation of credits for voluntary carbon credit markets, covering such issues as the required frequency and granularity of solid carbon measurement
- Clear regulations on how to account for carbon credits and certificates, including how downstream food producers and retailers should treat farm-generated credits in their Scope 3 accounting
- A clear framework for assessing farm-level contributions to ecosystem services and improved ecological outcomes, including regulations governing compensation to be paid to farmers for converting land to regenerative agriculture, in the same vein as compensation paid to developers when they convert land to renewable energy projects

Support from Food Companies and Retailers
Many players in the downstream food value chain, including consumer packaged goods companies (CPGs) and major retailers, have launched pilot programs to work with farmers to explore regenerative agriculture practices. Several of these pilots are already gaining scale—some CPG companies are leading the way with broader regional transformation programs that go beyond farm-level pilots—but more need to be scaled up. This means entering into and maintaining long-term partnerships with farmers to secure supplies of regeneratively produced ingredients while providing farmers a guaranteed market and prices for their products and ecosystem services. Companies should also collaborate with third parties to offer impartial and innovative agronomic training and advisory services to support farmers as they make the transition to regenerative agriculture.

And just as many current supply contracts govern the use of synthetic crop protection products through defined secondary standards, downstream companies should begin to enforce regenerative practices in their supply contracts.

Ultimately, food producers and retailers could even generate a new revenue stream by converting the organic waste that naturally occurs in the food chain into biologically activated biochar and distributing it to regenerative farmers.

We believe that these measures, taken together, would go far toward creating and sustaining the transition to regenerative agriculture throughout Germany. The return on investment of regenerative practices is high, not just for the country's farmers, but also for the companies that make, distribute, and sell food—and especially for the country's consumers and society at large, which will benefit from a healthier, more sustainable, and more secure food supply.

To encourage the transition to regenerative agriculture, Germany should establish a nationwide task force that brings together all the stakeholders in the country's agrifood system—including farmers, the German Federal Ministry of Food and Agriculture, regional chambers of agriculture, agricultural universities and schools, consumer packaged goods players, and retailers, as well as the major agriculture input providers and distributors, advisory services, and machinery producers and lessors. Their task: to coordinate efforts to put these measures into practice, and to make the transition to regenerative agriculture a reality.

[49] https://umwelt.thueringen.de/themen/natur-artenschutz/foerderung/kulap

Regenerative Agriculture Practices

Stage	Practice	Definition
Stage 1	No-till practices	Methods such as direct seeding that reduce or eliminate the disturbance of soil by tilling machinery
	Subsoiling	Minimally disturbing breakup of soil below the surface to reduce soil compaction
	Cover cropping	Growing diverse plant groups on croplands that conventional methods would leave fallow for certain parts of the year (also referred to as catch cropping)
	Soil analysis and balancing	Avoiding overfertilization and increasing soil health through nutrient checks and balancing (Haney/Kinsey test)
	Interseeding (grassland)	Enhancing existing cover on pastures by seeding grasses, legumes, and herbs
Stage 2	Minimal soil disturbing mulch system	Cutting cover crops to bring the residue in contact with the soil while minimally disturbing the soil and, potentially, using biostimulants
	Undersown cropping	Simultaneous growth of a secondary crop alongside the main crop for enhanced soil cover
	Biofertilizer/biostimulants and biological seed coating	Producing and using biofertilizers from predominantly farm biomass (including compost) to enhance biodiversity and nutrient management
	Bio leaching inhibitors	Biological solutions to reduce nitrate leaching (currently in development)
	Bio crop protection	Nonsynthetic crop protection, such as pest predators and biopesticides
	Legume crop rotation	Integration of legumes into the main crop cycle
	Adaptive grazing or mowing (grassland)	Grazing: Optimizing movement of grazing animals through pastures (e.g., mob grazing) Mowing: Reducing hay cut length to improve grass stability
Stage 3	Intercropping	Simultaneous cultivation of multiple crop species in a single field (also referred to as mixed cropping)
	Biologically activated biochar	Applying biologically activated biochar—a byproduct of biomass burned in the absence of oxygen, activated with microorganisms—to fields
	Smaller aerial structures	Breaking up larger monoculture fields into smaller and more diverse segments
	Livestock integration	Temporary introduction of livestock onto croplands either for grazing cover crops or, in crop rotation, for grazing field fodder
	Keyline subsoiling	Transverse or vertical planting intended to interrupt the flow of water and impede soil erosion. Also referred to as contour farming or bunting.
	Agroforestry	Integration of trees, hedges, and shrubs in cropland and grassland
	Silvopasture (grassland, agroforestry)	Planting trees on grassland
	Alley cropping (cropland, agroforestry)	Planting trees in rows alongside companion crops; assuming a ten-year ramp period for each tree planted to realize full carbon sequestration potential
	Hedges, windbreaks, buffers (grassland, cropland, agroforestry)	Planting hedges in rows or tree windbreaks or riparian forest buffers on field perimeters
	Grassland pasture cropping	Cultivation of arable crops on pastureland

Glossary

Term	Definition
Biodiversity	The variability of genes; the number, distinctiveness, and spatial distribution of species; and the diversity of ecosystems. The interplay of all of these elements—from the molecular level to the macroenvironmental level—enables ecosystem services through nature's regulating, provisioning, habitat providing, and cultural functions. Altering even a single element inside an ecosystem may curtail those functions.
Biological seed coating	Covering the surface of seeds with low amounts of biologically active ingredients to improve seed performance and plant establishment (through the alleviation of biotic and abiotic stresses) while reducing production costs.
Biostimulants	Natural substances that can be applied to seeds, plants, and soil. These substances cause changes in vital and structural processes in order to influence plant growth through improved tolerance to abiotic stresses and increase seed and/or grain yield and quality.
Carbon credits	Financial products expressed in tons of CO_2 equivalent (CO_2e) that are generated by reducing or removing greenhouse gas (GHG) emissions and are traded in the voluntary, industry, and geographic compliance market by individuals, companies, and countries to offset (or neutralize) emissions; one credit equals 1 ton of reduced GHG emissions.
Carbon farming	Sequestering and storing carbon or reducing greenhouse gas emissions at farm level in order to create carbon credits.
Carbon sink	Storing carbon in soil, oceans, and forests to avoid discharging it into surface water and groundwater and the atmosphere; a sink is a process or activity that removes GHGs from the atmosphere.
Cash crop	The main crop cultivated on a farm to be sold and to generate revenue.
Compost solutions	Application of composted organic materials such as crop residues in the form of compost tea or extract to increase the amount and diversity of microbes in the soil and in crops.
Compound annual growth rate (CAGR)	The average year-on-year rate of growth in a given time period (measured as a percentage change).
Conservation agriculture	A farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species.
Controlled traffic farming	A farming system that confines all machinery loads to the least possible area along permanent traffic lanes
Conventional agriculture	Farming techniques that do not fall under the definition of organic or regenerative agriculture.
Cropland	Land on which agricultural crops, including all annual and perennial crops, are grown.
Ecosystem	A system of interacting living organisms and their physical environment. The definition of the boundaries of an ecosystem varies depending on the focus of the study. Therefore, the scale of an ecosystem can range from very small to global.
Ecosystem services	Nature's regulating, provisioning, habitat providing, and cultural functions.
Ecosystem services value (ESV)	The value to humans of nature's processes of regulating, provisioning, providing habitat, and delivering cultural services.
Eutrophication	Oversupply of nutrients in surface waters and terrestrial ecosystems caused by human activities.
Farm fertilizer	Fertilizer exclusively from animal excretions from animal husbandry or from plant substances produced as part of agricultural plant production .
Fast-moving consumer goods (FMCG)	Products that sell quickly at relatively low cost. Also called consumer packaged goods.
Food distributors and retailers	Businesses that typically buy products from food producers and sell them directly to end customers in their stores.
Food producers and wholesalers	Businesses that typically buy raw inputs (such as wheat or sugar) and produce food products, usually with no direct end-customer contact.
Grassland	Land used for livestock grazing.
Greenhouse gas (GHG) emissions	Gaseous constituents of the atmosphere, produced both naturally and anthropogenically, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds.
Green water	Terrestrial precipitation, evaporation, and soil moisture.
Haney/Kinsey test	Test of soil to determine quantity of soil nutrients available to soil microbes.
Humus	Organic compounds that exist along a continuum of progressive decomposition.
Keyline subsoiling	Transverse or vertical planting intended to interrupt the flow of water and impede soil erosion. Also referred to as contour farming or bunting.
Leaching	Washout of surplus nutrients that are not absorbed by plants but instead are discharged into air, soil, and water.
Legume	The fruit or seed of plants of the legume family (such as peas and beans) used for food.
Liebig's law of the minimum	The thesis that a plant's rate of growth, eventual maximum size, and overall health depend on the amount of the scarcest essential nutrient available to it.
Methane	A potent greenhouse gas (CH_4) that is 25 times more harmful to the climate than CO_2).
Microbial biopesticides	Products obtained from microorganisms that are beneficial and can be applied against plant diseases and insect pests.
Nitrate	An ion formed from nitrogen and oxygen (NO_3-) that can leach from animal manure and nitrogen fertilizers into groundwater, polluting water and leading to algae blooms.
Nitrous oxide	A very potent greenhouse gas (N_2O) with more than 250 times the impact of CO_2.
NPK fertilizer	Fertilizer containing nitrogen, phosphorus, and potassium, the three major nutrients required for plant growth.
Nitrogen use efficiency (NUE)	The share of nitrogen recovered by crops (measured as a percentage of the total amount of nitrogen available).
Organic agriculture	A production system that sustains the health of soils, ecosystems, and people by relying on ecological processes, biodiversity, and cycles adapted to local conditions, rather than on the use of inputs that may have adverse effects.

Term	Definition
Perennial crops	Crops that grow for longer than one year.
Plowing	A cultivation method that involves digging deep into the soil and turning it over before seeding.
Regenerative agriculture	An adaptive farming approach that applies practically proven and science-based practices focused on soil and crop health and aimed at yield resilience and a positive impact on carbon, water, and biodiversity.
Regression coefficient	The degree to which a dependent variable changes when an independent variable changes.
Scope 1 emissions	Direct GHG emissions that occur at sources owned or controlled by a company—including, for example, emissions from combustion in owned or controlled boilers, furnaces, and vehicles, or emissions from chemical production in owned or controlled process equipment.
Scope 2 emissions	All GHG emissions that physically occur at a facility where electricity that a company purchases and consumes is generated. Depending on regional circumstances, emissions associated with heat, cooling, or water purchased from third parties may also qualify as Scope 2 emissions.
Scope 3 emissions	Emissions that arise as a consequence of a company's activities but occur at sources that the company neither owns nor controls. Examples include emissions from extracting and producing purchased materials, transporting purchased fuels; or using sold products and services.
Scouting	An agricultural procedure that tracks the health of plants by traveling through a crop field and making observations.
Small water cycle	The closed circulation of water that evaporates from land and then falls as precipitation over the same terrestrial environment.
Soil carbon sequestration	The amount of carbon stored in soil per unit of area, to a given depth of soil, within a specific time frame.
Soil microbiome	The vast array of microorganisms in soil that contribute to such essential ecosystem services as carbon and nitrogen recycling, soil structure protection, and pathogen suppression.
Soil organic matter (SOM)	Plant or animal matter in soil at various stages of decomposition.
Spot market	A market for currencies or commodities that are sold and given to the buyer immediately, rather than being sold forward and delivered at a later date.
Strip cropping	A form of intercropping that creates smaller field structures.
Subsoiling	A minimally soil-disturbing technique for breaking up soil below the surface to reduce soil compaction.
Tillage	Preparing soil for seeding by intensively agitating the upper soil horizons (through cutting, stirring, or digging) for weed control and soil loosening.
Total shareholder return (TSR)	A calculation of the value of a company's shares based on the rise or fall in their price and the dividends paid to shareholders over a particular period.
Weighted average cost of capital (WACC)	A measure of a firm's blended cost of capital across all sources, including common shares, preferred shares, and debt.

Appendix

Appendix Table 1 - Profit and Loss Impact on Farmers: P&L Baseline

Aspect	Description	Assumption / calculation	Source
Overall summary	Average of profitability data across regions and time	• 33% Schleswig Holstein 2021–2022 • 33% Bavaria 2021 • 33% Brandenburg 2020–2021	Landwirtschaftskammer Schleswig Holstein: https://www.lksh.de/fileadmin/PDFs/Landwirtschaft/Markt/Kalkpl21_22.pdf Bayerische Landesanstalt für Landwirtschaft: https://www.stmelf.bayern.de/idb Landwirtschaftskammer Brandenburg: https://lelf.brandenburg.de/sixcms/media.php/9/Datensammlung-2021-web.pdf
Cereal and oil seed	Split of winter wheat, barley, and rapeseed	• 50% winter wheat, 30% barley, 20% rapeseed	
Legumes	Split of peas and beans	• 50% beans, 50% peas (for Brandenburg peas only) • Nitrogen fixing identified as an additional yield (fertilizer savings)	Grains research and development corporation of the Australian government
Corn	Corn for silage	• 100% corn for silage • Price and yield sold wet; price information from Bavaria only	
Grassland	Meadow (circular hay bales)	• 100% meadow for circular hay bales • Same value for pasture assumed	External price for hay bales over time: heupreis.de
Input costs	Costs for required inputs	• Seeds • Fertilizers (nitrogen, phosphate, potassium) • Plant protection (herbicides, fungicides, pesticides)	
Machine costs	Costs to own and operate machines	• Machine costs include investment costs such as interest, repair and maintenance, fuel (diesel at €1.2/liter) and others (insurance, shelter, fees); reduced working hours are not included in calculations • Assumed field size: 5 hectares; 2km away from machine park • Assumed working widths depend on step; typically, 3m, 4.5m, 9m, 21m, and 36m • Tractor power is typically assumed at 138KW, with selected adjustments where applicable	KTBL calculator
Labor and other	Labor and other costs	• Labor costs for operations • Hail insurance, drying, cleaning	
Lease	Land lease	• Monthly lease	

Appendix Table 2 - P&L Impact: Stage 1 Practices

Revenue | Machine | Input

Practice name	Description	P&L levers	Assumption / calculation	Source
Better soil structure: **No-till practices**	Eliminating or reducing soil disturbance from tilling machinery, including direct seeding	• Additional machine cost for direct seeding: –€36/ha • Savings from conventional tillage and seed preparation: +€126/ha • Yield impact and avoided loss: +€6/ha for cereal, +€46/ha for corn, +€23/ha (1/3) for drought resistance	• Standard machine cost • Comparison of studies of yield impact after change to no-till practices	KTBL calculator FAO (Advances in Conservation Agriculture Volume 2)
Better soil structure: **Minimal soil disturbing subsoiling**	Loosening soil below the surface for minimum disturbance	• Subsoiling every two years: –€21/ha	• Standard machine cost, subsoiling is especially important during the transition period	Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V. (KTBL) calculator
Cover cropping	Planting on cropland that would otherwise have been left fallow for certain parts of the year	• Seed cost: –€28/ha • Operating cost: –€70/ha • Fertilizer reduction: +€89/ha • Avoided yield loss: +€23/ha (1/3) for drought resistance • +€38/ha for carbon credits	• Averaged cost for cover crop seeds and required operative machine work • Fertilizer credit towards following year: nitrogen 35kg; phosphorus 15kg; potassium 50kg • Average prices for NPK from 2021 • Farmer's net profit for carbon certificate of €22/ha assumed (gross profit: €55; 40% lost to transaction and trading services; 20% to testing costs), multiplied by 1.7 tons of CO_2e/ha/year	KTBL calculator Bavarian ministry of agriculture – Contribution margin calculator 2030 carbon certificate consensus range (Eco-systems Marketplace; Bloomberg; Princeton; World Bank Group; CDP)
Soil analysis and balancing	Avoiding overfertilization and increasing soil health through nutrient check (Haney/Kinsey test)	• Test cost: –€3/ha • Input cost after test: –€15/ha • Avoided yield loss: +€23€/ha (1/3) for drought resistance	• One test (€85) per 5 ha every five years • Fertilizer (calcium and magnesium): 1.3 tons/ha, costs €3.50 every three years	Bodenbalance GbR agrarheute.com
Grassland: interseeding	Enhancing existing cover on pastures through seeding of grasses, legumes, and herbs	• Seed cost: –€25/ha • Fertilizer saving: +€64/ha	• 10% additional seeding • 20% legume share enables fertilizer savings of 60kg nitrogen/ha	DLG – Deutsche Landwirtschafts-gesellschaft
Overarching (included in other practices)	Effects from the combination of the above practices • Yield impact from drought resistance	• Overarching impact is allocated to the above practices. Drought resistance via no-till practices, cover cropping, and soil balancing (Liebig's law of the minimum)	• 2018 drought caused an average 16% reduction in wheat yield • Four of the past five years were drought years (expected to get worse in the next five to ten years) • Assumption: 30% reduction of yield loss through regenerative agriculture Stage 1	German ministry for agriculture—measure during drought 2018

Appendix Table 3 - P&L Impact: Stage 2 Practices

Revenue | Machine | Input

Practice name	Description	P&L levers	Assumption / calculation	Source
Minimal soil disturbing mulch system	Allowing cover crops to rot in a controlled area, preferably using tiller (rotovator) and biostimulants	• Operating cost: –€38/ha • Biostimulants: –€69/ha • Fertilizer reduction: +€53/ha • Crop protection reduction: +€60/ha • Avoided yield loss: +€15/ha (1/3) for drought resistance	• Additional machine cost for mulching; saving of 2x herbicide and 2x fertilizer runs • 75 liter/ha biostimulants needed at €0.92/l • Fertilizer reduction of 50kg nitrogen per ha • No additional broadband herbicides needed	KTBL calculator Surface rot biostimulant manufacturer humusfarming.de
Undersown cropping	Simultaneous growth of a secondary crop alongside the main crop for enhanced soil cover	• Seed cost: –€50/ha • Fertilizer reduction: +€63/ha • +€21/ha for carbon credits • Avoided yield loss: +€15/ha (1/3) for drought resistance	• Average price of seeds for undersowing • Fixing of nitrogen (30kg/ha) and potassium (40kg/ha) • Farmer net profit for carbon certificate of €22/ha assumed (gross profit: €55; 40% lost to transaction and trading services; 20% to testing costs), multiplied by 1.1 tons of CO_2e/ha/year	Seed producer price average Bavarian ministry of agriculture – Contribution margin calculator 2030 carbon certificate consensus range (cf. Stage 1)
Biofertilizer/ biostimulants	Farm fertilizer manure improvement by applying biostimulants, including biological seed coating	• Biostimulant costs: –€12/ha • Avoided yield loss: +€15/ha (1/3) for drought resistance	• ~ 90kg nitrogen/ha average input from farm sources overall, assumed ~ 50kg thereof manure • 1m³ manure produces 5kg nitrogen • 1l for 1m³ of stimulants with costs of 1.19€/ l	Nitrate report 2020 – German ministry of food and agriculture Chamber of agriculture North Rhine Westphalia chiemgau-agrar.de
Bioleaching inhibitors (optional)	Chemical solutions to reduce nitrate leaching	Optional, not evaluated		
Bio crop protection (optional)	Leveraging natural pest predators to reduce pesticide use	Optional, not evaluated		
Legume crop rotation	Integration of legumes into main crop cycle	For sensitivity analysis: • Nitrogen fertilizer savings: 116kg nitrogen/ha with €1.06/kg nitrogen Typically implemented on 10% of area/crop cycle		Bavarian ministry of agriculture – Contribution margin calculator
Grassland: Adaptive grazing or mowing	Mowing: Reducing length of hay cut to improve grass stability Grazing: Optimizing movement of grazing animals through pasture	• Avoided yield loss through additional mowing: +€20/ha • Machine cost through additional mowing: –€8/ha	• Impact from drought resistance, assumptions: • Four of five years are drought years • 16% loss (similar to wheat losses) due to drought • With these practices, 30% loss prevention is possible (same as for drought resistance Stage 1 for crops) • Applies to 40% of meadowland (share of	KTBL calculator German ministry for agriculture – Measure during drought 2018 German wildlife foundation
Overarching (included in other practices)	Effects from the combination of the above practices: Yield impact from drought resistance Revenue impact from carbon credits	Overarching impact is allocated to the above practices	• 2018 drought 2018 caused average 16% reduction in wheat yield • Four of the past five years were drought years (expected to get worse in the next five to ten years) • Assumption: 20% reduction of yield loss through Stage 2 (on top of 30% from Stage 1)	German ministry for agriculture – Measure during drought 2018

Appendix Table 4 - P&L Impact: Stage 3 Practices

Practice name	Description	P&L levers	Assumption / calculation	Source
Intercropping	Simultaneous cultivation of multiple crop species in a single field	Stage 3 not quantitatively evaluated for farm-level financial impact		
Biologically activated biochar	Applying biologically activated biochar—a byproduct of biomass burned in the absence of oxygen, activated with microorganisms—to fields			
Agroforestry	Integrating trees, hedges, and shrubs in cropland and grassland • Silvopasture (grassland): Planting trees on grassland • Alley cropping (cropland): Planting trees in rows alongside companion crops; assuming a ten-year ramp period for each tree planted to realize full capture potential • Other agroforestry (grassland and cropland): Planting hedges in rows or tree windbreaks or riparian forest buffers on the perimeter of fields			
Livestock integration	Temporary introduction of livestock onto cropland either to graze cover crops or in crop rotation to graze field fodder			
Smaller aerial structures (optional)	Breaking up larger monoculture fields into smaller and more diverse segments			
Keyline subsoiling (optional)	Targeted subsoiling for irrigation management			
Grassland: Pasture cropping (optional)	Cultivation of arable crops on pastureland			

Appendix Table 5 - Quantification of Socioecological Impact

Drive for impact	Sources
General assumptions	
• Agricultural area in scope: 13.3 million hectares ◦ Cropland: 10 million hectares ◦ Grassland: 3.3 million hectares	• Federal Statistical Office 2020, Germany; excluded out of scope areas of total agricultural area in Germany (16.3 million hectares) • Peatland (0.8 million hectare: 0.2 million hectare cropland, 0.6 million hectare grassland) • Organic farmland (1.5 million hectares: 0.7 million hectare cropland, 0.8 million hectare grassland) • Root crops (potatoes and sugar beets) (0.7 million hectare cropland)
Carbon	
• Level of carbon price for transition path (2035): ~€223/ton of CO_2e • Other lower carbon prices (as per sensitivity analysis) ◦ ~€55/ton of CO_2e ◦ ~€157/ton of CO_2e	• Value for transition path: Predicted external climate costs based on cost rates for 2030e and 2050e from the German federal environment agency 2020[1] • Lower alternatives considered in sensitivity analysis ◦ Expected average voluntary agriculture-based carbon credit price in 2035[2] ◦ Projected mandatory carbon price in 2035 based on ETS Forward Price[3]
(1) Soil carbon capture	
• Carbon capture rate per regenerative practice in tons of CO_2e/ha/year (lower range, average, and upper range of available ranges in values)	Literature review (see Appendix Table 6)
(2) Avoided emissions through nitrogen fertilizer	
• Level of reduction of nitrogen fertilizer/ha/year for transition path ◦ Cropland: ~79kg nitrogen/ha/year ◦ Grassland: ~34kg nitrogen/ha/year • Other reduction levels (as per sensitivity analysis) ◦ Lower range: ~71kg/ha/year (cropland), ~ 87kg/ha/year (grassland) ◦ Upper range: ~31kg/ha/year (cropland), ~37kg/ha/year (grassland)	• Value for transition path: reduced nitrogen fertilizer usage/ha/year with expected adoption of practices in 2035 • Lower range: transition path –10% • Upper range: transition path +10%
• CO_2 emissions/kg nitrogen fertilizer input: 5.6 tons of CO_2e/ton of nitrogen	YARA 2015: Average footprint for nitrogen fertilizer use (excluding fertilizer production and transportation)[4]
Water	
(1) Avoided irrigation	
• Water holding capacity correlates with soil carbon capture rate: 2,586 liters/ton of organic carbon	• Libohova et al., 2018[5] ◦ SOM holds up to 1.5 grams of water ◦ 1.5 grams/gram of SOM = ~ 0.002 liter/gram • Conversion to liters/ton of organic carbon assuming that organic carbon = 0.58% of SOM[6]

[1] Determination of environmental costs, methodological convention 3.1.

[2] Assuming conversion a 1:1 conversion rate of euros to US dollars; Ecosystems Marketplace report 2019; Bloomberg; Princeton; World Bank Group – Climate Change 2015; CDP report 2015 Expert interviews; BCG analysis 5. Intercontinental Exchange Endex European Union Allowance (EUA) Month Electronic Energy Future ENDEX European Energy Derivatives Exchange.

[3] It's crops I want, not CO_2 (yara.is).

[4] Determination of environmental costs, methodological convention 3.1; It's crops I want, not CO_2 (yara.is).

[5] Reevaluating the effects of soil organic matter and other properties on available water-holding capacity using the National Cooperative Soil Survey Characterization Database. *Journal of Soil and Water Conservation*.

[6] German Federal Environment Agency (2022).

Drive for impact	Sources
• Water holding capacity per regenerative practice in tons of CO_2e/ha/year (lower range, average, and upper range of available ranges in values)	• Value for transition path: average • Literature review for soil carbon capture (see Appendix Table 6)
• Level of irrigation water costs for transition path (assuming all farmers must pay for water withdrawal): ~ 1.54€/m³ • Other water costs (as per sensitivity analysis) ◦ **Lower range:** ~1.05€/m³ ◦ **Upper range:** €2.03/m³	• Value for transition path: average of lower and upper range ◦ **Lower range:** expected average of agricultural groundwater withdrawal "water cent" costs and drinking water supply costs in 2035, Germany[7] ◦ **Upper range:** Expected drinking water costs in 2035 based on drinking water costs in 2022 (€1.75/m³), Germany[8]
• Irrigated area (in millions of hectares) ◦ **Cropland:** 2 million hectares ◦ **Grassland:** 0.17 million hectare	• **Cropland:** Rosa et al., 2020: Potential for sustainable irrigation expansion in a 3°C warmer climate • **Grassland:** 5% of grassland extension; expert judgment
(2) Avoided nitrate removal costs	
• Excess nitrate levels in drinking water are ~75% caused by agriculture	Assumption based on expert judgment and data proxies • 77% of German N_2O emissions are caused by agriculture[9] • 81% of surplus nitrogen in Germany is caused by land use[10] The approach for total costs is a tendency for the costs of drinking water supply caused by agriculture. Conclusions on costs incurred in less polluted and in heavily polluted areas are not possible due to the very different pollution situations throughout Germany.
• Nitrate levels in drinking water caused by 1 ha cropland are 1.5x higher than those caused by 1 ha grassland	Assumption based on expert judgment
• Level of costs caused by agriculture (driven by two cost drivers) for transition path: ~€731 million/year[11] **1.** Average filtration costs: ~€503 million/year (Minimum: ~€475 million/year; Maximum: ~€532 million/year) **2.** Expected EU penalties for exceeded nitrate levels: ~€227 million/year • Other cost levels (as per sensitivity analysis) based on range given in sources ◦ **Lower range:** ~€702 million/year ◦ **Upper range:** ~€759 million/year	Equals 75% of total yearly costs • Value for transition path based on two additive cost drivers **1.** German federal environment agency 2017[12] **2.** Federal Ministry of Food and Agriculture, June 2022[13] ◦ **Lower range:** Lower range based on range given for filtration costs (refer to 1) ◦ **Upper range:** Upper range based on range given for filtration costs (refer to 2)
• 40-45% leaching of nitrogen fertilizer in soil/water based on NUE (55–60%)	Withers et al., 2014 (NUE of 60%) and expert judgment[14]
• Linear relation of nitrate rate in water and cost of nitrate removal	Expert judgment

[7] BUND study 2019: The water abstraction fees of the federal states; excl. city states and federal states with free withdrawal); 2019: ~0.01–0.12 €/m³; 2035e: development based on drinking water 1.2% CAGR (2018–2019).

[8] Charges for drinking water supply in tariff areas by tariff type, Federal Statistical Office, Germany (destatis.de); 1.2% CAGR 2018–2019.

[9] German Federal Environment Agency, (2021): Greenhouse gas emissions in Germany.

[10] German Federal Environment Agency, 2021: Nitrogen.

[11] Yearly additional compliance expense for industry to fulfill novel fertilizer regulation (2021) is excluded from cost drivers, given the overlap of costs with regenerative practices (regulated soil analyses, switch to farm fertilizer, use of leaching inhibitors etc.).

[12] Factsheet Nitrate Costs.

[13] Press release on EU nitrate regulation.

[14] Agriculture and Eutrophication: Where Do We Go from Here?.

Drive for impact	Sources
• Level of reduction of nitrate removal costs for transition path: 70% • Other reduction levels (per sensitivity analysis) ◦ **Lower range:** 35% ◦ **Upper range:** 85%	Bottom-up calculation: Nitrate removal costs derived from N fertilizer reduction potential of regenerative practices (both crop- and grassland) • **Value:** Practices of Stage 1 and Stage 2 applied, 30% of excess farm (organic) fertilizer not distributed but still used (= not reallocated to other areas to be utilized elsewhere) • **Lower range:** Practices of Stage 1 applied • **Upper range:** Practices of Stage 1 and Stage 2 applied, incl.100% reallocation of excess farm fertilizer
Green water	
• Green water, as in terrestrial precipitation, evaporation, and soil moisture, is not further quantified for ecological impact (unlike with respect to its impact on farmers' P&L, where we have quantified, e.g., the impact of increased soil moisture on buffering of extreme weather events and regeneration of small water cycles)	Wang-Erlandsson et al., 2022: A planetary boundary for green water | Nature Reviews Earth and Environment
Surface waters	
• Surface waters out-of-scope for water dimension: While not quantified in this report, the effect of N compounds from agriculture on surface waters should be noted • Nutrient accumulation resulting in accelerated growth of algae can lead to significant oxygen deficiency, creating hostile conditions for animals and other plants • This effect not in scope, as in most inland waters phosphorus (also derived by agriculture, e.g., fertilizer) can be blamed for excessive plant growth, not nitrogen, given that the ratio of nitrogen to phosphorus is critical to plant growth conditions	German Federal Environment Agency, 2021: Nitrogen

Appendix Table 6 - Carbon/Water Impact: Stage 1 and Stage 2 Practices

Practice name	Description	Carbon	Water	Source
Stage 1 - Basic implementation				
No-till practices	Eliminating or reducing soil disturbance from tilling machinery, including by direct seeding	0.12–1.48 tons of CO_2e/ha/year	0.09–1.05 m³/ha/year	• BCG and Walton Family Foundation, 2022: US Agriculture and the Net-Zero Challenge
Cover cropping	Planting on cropland that would otherwise have been left fallow for certain parts of the year	0.40–1.47 tons of CO_2e/ha/year	0.28–1.03 m³/ha/year	• Poeplau and Don, 2015: Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis. Agriculture, Ecosystems and Environment • BCG and Walton Family Foundation, 2022: US Agriculture and the Net-Zero Challenge
Grassland: Interseeding	Enhancing existing cover on pastures through seeding of grasses, legumes, and herbs	1.33–2.22 tons of CO_2e/ha/year	0.94–2.20 m³/ha/year	• De Deyn et al., 2010: Additional carbon sequestration benefits of grassland diversity restoration. Journal of Applied Ecology • BCG and Walton Family Foundation, 2022: US Agriculture and the Net-Zero Challenge
Stage 2 - Intermediate implementation				
Undersown cropping	Simultaneous growth of a secondary crop alongside the main crop for enhanced soil cover	~0.97 tons of CO_2e/ha/year	~0.68 m³/ha/year	• Poudel et. al, 2022: Italian Ryegrass, Perennial Ryegrass, and Meadow Fescue as Undersown Cover Crops in Spring Wheat and Barley: Results from a Mixed Methods Study in Norway. Sustainability. Special issue: Agrobiodiversity and Sustainable Food Systems
Grassland: Adaptive grazing or mowing	**Mowing:** Reducing the length of hay cut to improve grass stability **Grazing:** Optimizing movement of grazing animals through pasture	Grazing: 0.03–3.78 tons of CO_2e/ha/year	Grazing: 0.02–2.67m³/ha/year	• Rowntree et. al, 2020: Ecosystem Impacts and Productive Capacity of a Multi-Species Pastured Livestock System. Frontiers in Sustainable Food Systems • Kurtz et. al, 2020: The impact of grassland management on physical and chemical properties of a psammaquent in northeastern Argentina. Revista Argentina de Producción Animal • BCG and Walton Family Foundation, 2022: US Agriculture and the Net-Zero Challenge • Other studies excluded due to classification as high outliers
Legume crop rotation	Integration of legumes into the main crop cycle	2.20–3.33 tons of CO_2e/ha/year	1.55–3.15 m³/ha/year	• Austrian Federal Ministry of Agriculture, Forestry, Regions and Water Management, 2015: Soil and climate Impact factors, data, measures and adaption options (aggregated impact of clover grass and alfalfa)

Note: We used a bottom-up approach (aggregated impact per practice) only. Not listed drivers for carbon: avoided emissions caused by nitrogen fertilizer. Not listed drivers for water: avoided nitrate pollution caused by nitrogen fertilizer. We assumed an adoption rate of grazing vs. mowing of 45% vs. 55%.

Appendix Table 7 - Carbon/Water Impact: Stage 3 Practices

Practice name	Description	Carbon	Water	Sources
Stage 3 - Advanced implementation				
Intercropping	Simultaneous cultivation of multiple crop species in a single field	Quantification of Stage 3 is not listed at the level of single practices		
Biologically activated biochar	Applying biologically activated biochar—a byproduct of biomass burned in the absence of oxygen, activated with microorganisms—to fields			
Agroforestry	Integrating trees, hedges, and shrubs in cropland and grassland			
Livestock integration	Temporary introduction of livestock onto cropland either to graze cover crops or in crop rotation to graze field fodder			

Appendix Table 8 - Biodiversity Impact

Practice name	Description	Biodiversity	Source
Stage 1 - Basic implementation			
No-till practices	Eliminating or reducing soil disturbance from tilling machinery, including by direct seeding	Increased microbial biomass and invertebrate populations	• FAO Report "Advances in Conservation Agriculture Volume 2"
Cover cropping	Planting on cropland that would otherwise have been left fallow for certain parts of the year	Expanded habitat and provision of a diverse food supply for various animals and organisms; reduced chemical inputs	• Beillouin et al., 2021: Positive but variable effects of crop diversification on biodiversity and ecosystem services. Global Change Biology • Triquet et al., 2022: Undestroyed winter cover crop strip in corn fields supports ground-dwelling arthropods and predation. Agriculture, Ecosystems and Environment
Grassland: Interseeding	Enhancing existing cover on pastures through seeding of grasses, legumes, and herbs	Diverse roots to improve soil biodiversity; diverse pasture and reduced nitrogen fertilizer use to enhance insect biodiversity	• BCG and NABU expert interviews
Stage 2 - Intermediate implementation			
Minimal soil-disturbing mulch system	Allowing cover crops to rot in a controlled area, preferably using a tiller (rotovator)and biostimulants	See "No-till practices"	• See "No-till practices"
Undersown cropping	Simultaneous growth of a secondary crop alongside the main crop for enhanced soil cover	See "Cover cropping"	• Jones et al., 2021: A global database of diversified farming effects on biodiversity and yield. Scientific data
Legume crop rotation	Integration of legumes into the main crop cycle	See "Cover cropping"	• Jones et al., 2021: A global database of diversified farming effects on biodiversity and yield. Scientific data
Grassland: Adaptive grazing or mowing	**Grazing:** Optimizing movement of grazing animals through pasture **Mowing:** Reducing the length of hay cut to improve grass stability	Fostering diverse plant growth	• Enri et al., 2017: A biodiversity-friendly rotational grazing system enhancing flower-visiting insect assemblages while maintaining animal and grassland productivity. Agriculture Ecosystems and Environment • BCG and NABU expert interviews

Appendix Table 9 - Impact on German Wheat Supply

Assumption	Description
German versus EU price	The spot market prices for wheat are not determined in Germany, but rather at the European and global level; nevertheless, required quality grades are likely to be produced only regionally and therefore it is fair to assume the same effects on yield and prices across regions in Europe
Flexible market making	We simplified the price assumptions by making the entire market-making process flexible; in reality, longer-term agreements between farmers and food players will lower the overall effect on average prices for the entire crop; assumed production volumes in the scenarios are not affected by this assumption, however
Share of avoidable yield reduction through regenerative agriculture	35% to 50%, based on P&L calculations and adoption rates
Yield impact of extreme weather events such as droughts in Germany	–16%; BMEL - Bundesministerium für Ernährung und Landwirtschaft (based on 2018 dry year)
German wheat and corn price sensitivity to yield fluctuations	1.3x for wheat and 0.5x for corn; analysis of FAOSTAT data 2010–2020

About the Authors

Torsten Kurth is a managing director and senior partner in the Berlin office of Boston Consulting Group and leads the firm's work related to agriculture in Europe. You may contact him by email at kurth.torsten@bcg.com.

Benjamin Subei is a partner and associate director in the firm's Duesseldorf office and an expert on agriculture. You may contact him by email at subei.benjamin@bcg.com.

Felicitas Bünger is a consultant in BCG's Berlin office.

Paul Plötner is a project leader in BCG's Berlin office and focuses on agribusiness and greentech. You may contact him by email at ploetner.paul@bcg.com.

Simon Krämer is food system and soil policy advisor at NABU headquarters in Berlin with a focus on regenerative agriculture. You may contact him by email at simon.kraemer@nabu.de.

Max Havermeier is a consultant in the firm's Munich office.

Acknowledgments

The authors would like to thank the following for their contributions to this report:

NABU
Joerg-Andreas Krueger, Konstantin Kreiser, Maximilian Meister, and Marc Süsser

BCG
Special thanks to Mayra Kürten-Buschle and Nikolaus Lorenz for their considerable contributions.

Louise Berrebi, Jack Bugas, Elena Corrales, Chris Grantham, Jan-Frederik Jerratsch, Georg Kappen, Annastacia Kouvela, Dean Muruven, Helena Nannes, Adrien Portafaix, Johanna Puetz, Rachel Ross, Jonas Schroeder and Shalini Unnikrishna

The authors would like to particularly thank the broad panel of growers, agronomic experts, and farming practitioners for their inspiration and constant contribution to this meta-study:

Ivo Degn (co-founder Climate Farmers), Theodor Friedrich (former FAO representative, expert conservation agriculture), Falk Hoffmann (farm manager Lindhorst Gruppe), Lukas Kersten (farm manager Gut Friedersdorf), Georg König (farmer, co-founder of Kiebitz), Hartmut van Lengerich (Head of Strategy & Sustainability CP Asset Management, Bayer AG), Malte Neuhaus (Bioland), Markus Pflugfelder (University Hohenheim, farmer), Ludwig Riedesel (co-founder Kiebitz)

For Further Contact

If you would like to discuss this report, please contact the authors.

Space for your notes

THE CASE FOR REGENERATIVE AGRICULTURE IN GERMANY—AND BEYOND

BOSTON CONSULTING GROUP + NABU