acatech AD HOC IMPULSE

A Resilient and Sustainable Food Supply

The Coronavirus Crisis and Other Challenges

acatech (Ed.)

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NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

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The acatech IMPULSE series

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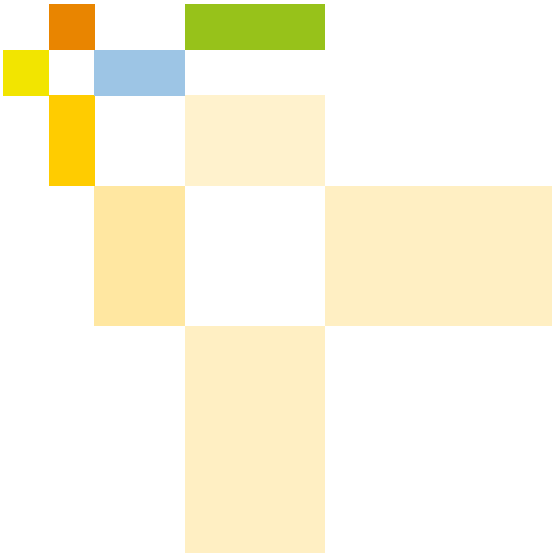

Summary

The term "resilience" denotes the ability to cope with and adapt to crises. In the wake of the coronavirus pandemic, food sovereignty and a resilient food supply have become more important than ever. Formerly often taken for granted, the food supply became a topic of widespread public concern, especially during the first months of the pandemic. Even at the height of the first wave in March/April 2020, the food supply was maintained throughout Germany thanks to the continued functioning of most logistics systems, agricultural production and food production in general. Nevertheless, short-term local shortages of certain products did occur due to higher demand in the food retail sector caused by panic buying. A number of other challenges also became apparent during this period and the months that followed. Huge fluctuations in demand had consequences for entire value chains, there was a shortage of seasonal workers, and fruit and vegetable prices rose. Based on the experience of the crisis so far, a number of **conclusions** can be drawn for future reference:

- Even in times of crisis, **borders** must remain open for the workers and means of production required to provide basic necessities. For example, green lanes have proved to be an effective solution for goods traffic. The logistics industry also requires reliable and easily accessible information on border measures that have been implemented at short notice.
- At the height of the crisis, digital labour **platforms** helped to cope with the sharp rise in demand for food retail workers. Platforms for reallocating logistics space and freight capacity also played an invaluable role in facilitating the transport of higher volumes of goods in the food retail sector.
- The coronavirus pandemic highlighted the need to adapt employment and social standards and ensure their systematic implementation for harvest and meat industry workers. While government responded with a number of ad hoc measures, long-term strategies for change are also necessary in this area.
- Regional and global **value chains** are both integral parts of a resilient structure. The analysis and diversification of value chains and the establishment of redundant solutions in case of emergency can help to reduce cases of over-dependency.

The coronavirus is still spreading, with people in emerging and developing countries especially hard hit by the social and economic impacts of the crisis. The following **developments** can be observed at a global level:

- **High reserves** coupled with international cooperation on **food price monitoring** maintained confidence in the market. As a result, it was largely possible to prevent export restrictions and bidding wars for food imports and thus keep basic food prices stable.
- However, stable prices do not prevent a **loss of purchasing power** in some countries due to the pandemic's economic impacts. Countries where a large proportion of people are employed in the informal sector[1] are particularly vulnerable, with serious implications for access to food.
- If healthy food becomes unaffordable or access to it is limited as a result of the crisis, there is also a danger of high levels of **hidden hunger** around the world, i.e. of insufficient vitamin and mineral content in people's diets.

As well as unforeseen, short-term changes such as those witnessed during the coronavirus crisis, the resilience of the food supply is also influenced by a number of long-term challenges affecting agricultural production. Adaptation to changing cultivation conditions caused by climate change, ensuring the availability of sufficient agricultural land and maintaining soil quality will all be key to productive food production over the longer term. The continuing severe decline in biodiversity and ongoing structural changes pose further major challenges for future agricultural production and thus for our food supply. The key **challenges** are as follows:

- **Climate change**: The extent to which temperatures are rising and precipitation distribution is changing varies from one region to another. The impact on cultivation conditions is thus also variable. Agricultural producers will therefore need to implement different land management practice adaptation strategies. A future increase in extreme weather events could also cause more crop failures.

1 | The informal sector refers to economic activity that is not recorded by the State and is thus not included in the official statistics. Typical characteristics of this type of employment include low qualification requirements, extremely intensive work and a lack of social security protection.

- **Land availability and soil health**: Since agricultural productivity in Germany is already high, it will be difficult to significantly increase crop yields on existing agricultural land. In fact, if the current decline in the land area suitable for agricultural use continues, production volumes can actually be expected to fall. Meanwhile, it will be essential to maintain soil health in order to ensure consistently high yields and guarantee our long-term food security. Extreme weather events and biodiversity loss could have negative implications for soil health and land availability.
- **Biodiversity**: Biodiversity loss changes the processes in ecosystems and upsets their balance. This also has consequences for agricultural production. In addition to the widely cited pollination services provided by insects, a functioning ecosystem includes many soil organisms that are key to nutrient availability and cycling. The interactions within ecosystems are not fully understood and could be affected by phenomena such as climate change. If the severe decline in biodiversity continues, it could lead to the collapse of entire ecosystem functions.
- **Structural changes:** The ongoing decline in the number of agricultural producers in Germany is forecast to continue in years to come. Larger agricultural businesses are better placed to harness economies of scale in order to remain cost competitive and resilient. However, in a highly concentrated market, there is always a danger that the failure of a single company could have major repercussions. Indeed, the closure of individual processing operations such as abattoirs during the coronavirus crisis illustrated the potential impacts that a highly concentrated market can have on resilience. The economic consequences of the coronavirus crisis could exacerbate these structural changes.

In the light of the challenges outlined above, the future resilience of our food supply and the food industry will depend on the sector's ability to operate sustainably in the long run. For this to be possible, it will be necessary to create the appropriate economic, environmental and social conditions. And even if these conditions are created, it will only be possible to partially resolve the numerous land use conflicts that already exist today. In many areas, however, potential solutions are being developed to promote resilience and sustainability and address both long-term challenges and the more immediate challenges thrown up by the current crisis. There is also potential to create value by investing in these areas through the European Green Deal. The solutions in question focus on agricultural management practices based on the principles of the circular economy and sustainable intensification. The aim is to ensure that yields remain high while at the same time significantly reducing agriculture's environmental and climate impacts. The following **priority areas** have been identified as having particularly high potential for meeting these objectives:

- The **sustainable intensification of agriculture** offers various ways of addressing the relevant challenges. Sustainable intensification refers to farming that is sustainable in the long run and makes use of all available methods, concepts and technologies. Research and development and cooperation with practitioners are key to these technologies and their implementation.
- **Adaptation of crop growing and animal husbandry practices** is of fundamental importance in this context. Diversification of cultivation methods and crops can reduce vulnerability in the event of a crisis, although this has to be weighed up against possible efficiency losses.
- Digitalisation and automation can support resilience and sustainability. **Smart farming** provides detailed information about soil and crop condition, enabling targeted application of agricultural inputs. This saves resources and benefits the environment. However, more widespread use of these technologies is hampered by the high investment costs and in some cases also by farmers' data privacy concerns.
- Digitalisation and automation enable **smart logistics** and help to assess and reduce supply chain vulnerability to different types of risk. This allows food production and distribution to respond to supply chain disruption in an agile manner, switching to alternative resources and routes as necessary.
- **Plant breeding techniques** are a key technology for developing resilient, high-performance plants. They can help to adapt plants to changes in climate and enable more efficient nutrient utilisation. Improving plants' ability to cope with drought conditions and other environmental factors makes for a more resilient food supply.
- The **design of new processes and products** that support viable closed-loop recycling also has significant potential. The efficient multiple reuse of naturally produced raw materials reduces negative environmental impacts. Alternative products such as meat substitutes can also contribute to a smaller environmental footprint.
- All of these changes on the production side will not succeed unless they are supported by **consumers and retailers**. Some

measures will result in higher food prices, for example improved animal welfare and processing conditions in the meat industry. People will only accept these price rises if they have confidence in the products and the methods used to produce them. Greater transparency thanks to easily accessible product information and demand-side policy instruments such as nudging all have a part to play. Making information easily accessible and minimising the effort required can facilitate consumer purchase decisions.

The implementation of economically, environmentally and socially sustainable land management practices will also depend on the policy framework. Our society's resilience in the face of short- and long-term changes will depend on the relevant goals being anchored in policy and implemented through socioeconomic and technology strategies. The concept of sustainable agricultural intensification can provide a model for achieving both sustainability and resilience. To this end, the EU member states must come to an agreement on how to proceed in future crises as well as on the development of sustainability standards that ensure a level playing field for competition. Accordingly, the design of State subsidies and regulation, especially at European level, must take into account the entire food industry with all its interdependencies. Measures should meet all the relevant sustainability assessment criteria while also taking resilience into consideration.

The EU's Common Agricultural Policy (CAP) has a key role in the future development of agricultural production. Farms' ecosystem and resilience services benefit society as a whole and deserve financial recognition in the form of appropriate economic incentives. Scientific monitoring of the impacts of regulations and implementation of appropriate adjustments as part of a learning system will be key to the establishment of an appropriate framework. While the concepts and technologies outlined above are already very promising, they should continue to be driven forward through research and development. Close cooperation between research, business and agricultural practitioners will be particularly important in this regard. It will also be important to accelerate the transfer of knowledge into practical applications. This can be supported through training and professional development initiatives and through independent advisory services providing a wide range of information.

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1 Background and aims

In Germany, as in many other countries, the coronavirus pandemic has resulted in drastic measures and restrictions in many areas of public life, some of which were still in place at the time of writing. These measures sought to slow the spread of the virus and prevent healthcare systems from being overwhelmed. As well as protecting public health, the priority for governments in times of crisis is to keep all critical infra-structure up and running and in particular to maintain the food supply for the entire population. What was formerly often taken for granted in Germany has once again become a matter of public concern as a result of the coronavirus crisis. In the latest Nutrition Report published by the Federal Ministry of Food and Agri-culture (BMEL), 39% of those interviewed said that the German farming industry had become more im-portant to them during the coronavirus crisis. This view was especially prevalent among the under-30s.[2] As a result of panic buying, many people in Germany have firsthand experience of short-term local shortages and higher prices for certain products. The importance of ensuring a basic food supply has also featured prominently in media reports.

The first wave of infection had subsided significantly at the time of writing in early August 2020. Many of the measures taken by the government to protect public health – in particular the closure of shops, pubs, restaurants and public places – were lifted in May and June, although some measures to prevent infection remain in place. Due to their systemic importance, food production and distribution businesses including food retailers remained open even during the first phase of the crisis. Despite local shortages of certain products, food production and the food supply were maintained in Germany even when the number of infections was increasing most rapidly in March and April. However, a number of weaknesses have become apparent over the course of the crisis so far. Agricultural production's dependency on seasonal labour and the vulnerability of meat processing plants to localised coronavirus outbreaks are just two examples. The uncertainty created by the crisis and the ongoing restrictions are still having a negative financial impact on farmers and downstream industries. One particular cause of uncertainty is the fact that the hotel, hospitality and catering sector are currently only allowed to operate at reduced capacity, a situation that is expected to continue for some time to come. It is thus likely that demand for food products from these sectors will remain lower than before the crisis for the foreseeable future.

The impacts of the coronavirus crisis require us to reassess the structure of agriculture and the food industry in the light of the pandemic and determine the implications for the **resilience of our food supply**. However, it is also necessary to address long-term challenges such as climate change, land use conflicts, biodiversity loss and structural changes in agriculture. In some cases, the impacts of these problems mutually reinforce each other. The effectiveness of adaptation measures taken as a result of the coronavirus crisis should therefore be judged with reference to these other, pre-existing challenges. In short, it is necessary to find solutions that address all the different challenges simultaneously.

The different characteristics of the challenges described above mean that government and society must address them over different timescales. The full scale of the coronavirus pandemic hit society very suddenly, at a time when little was known about the properties of the virus. This meant that there was very little experience to draw on when designing measures to combat the coronavirus crisis.

In contrast to the acute nature of the coronavirus crisis, the effects of climate change, reduced land availability and biodiversity loss on people and the environment build up more gradually. This calls for a different kind of response from government and the public. Countermeasures must be continuously adapted, while the overall framework must enable the mitigation or prevention of negative and in some cases irreversible impacts.

A resilient food supply must be able to cope with both acute crises and long-term challenges, as well as with the mutually reinforcing effects that are generated when the two coincide. When the different types of challenge come together, the impacts can be particularly serious. The consequences for society can be especially devastating if an acute crisis occurs at a time when long-term challenges have already destabilised the food supply.

2 | See BMEL 2020a.

Resilience

The term "resilience" originates from the field of psychology, where it denotes a person's psychological re-sistance in a crisis, i.e. their ability to cope with and adapt to the situation. The term has subsequently found its way into several other fields. Agricultural systems, supply chains and the food supply system as a whole (including production, logistics, retail, etc.) can and must be resilient in the face of natural disasters, crises and environmental challenges (such as lengthy periods of drought). In this context, the Food and Agriculture Organization of the United Nations (FAO) defines "resilience" as the "ability to prevent disasters and crises as well as to anticipate, absorb, accommodate or recover from them in a timely, efficient and sustainable manner. This includes protecting, restoring and improving livelihoods systems in the face of threats that impact agriculture, nutrition, food security and food safety."[3] In other words, after a disaster or crisis it is not a question of returning to the way things were before, but rather of constructively adapting the system to a new normal that is better equipped to cope with future crises.

Functioning, resilient farms and functioning value and supply chains are key to a secure food supply. Rather than aiming for complete self-sufficiency and full demand coverage, the goal should be to achieve a degree of sovereignty within a globalised economic system characterised by the division of labour. "Sovereignty" refers to the ability to make one's own, independent decisions. It does not mean that we should focus on meeting demand exclusively through domestic resources. Instead, our integration within the international trade system should be seen as part of a resilient structure. Developments in this structure will affect us through global value chains.[4] Sovereignty is key to coping with completely different types of crises, not least when they occur concurrently.

Because its favourable geographical location means that it is able to produce sufficient quantities of good-quality grain and other products, Germany's responsibilities extend beyond its own national borders. Accordingly, this AD HOC IMPULSE publication also considers international developments. Many countries around the world are still in the grip of a serious wave of infection, with many emerging and developing countries being especially hard hit.

This AD HOC IMPULSE begins with an **overview of the food supply situation during the course of the coronavirus crisis up to the time of writing (early August 2020)** (see Chapter 2) and a look at current and possible future trends. Particular attention is devoted to import dependency, product diversity, the domestic market situation and developments on the global market. Secondly, it describes the long-term challenges involved in achieving a secure food supply (see Chapter 3). These point to the ongoing need for a **future-proof and resilient agricultural sector beyond the current crisis**. This section intentionally focuses on agriculture as the first production step in the food industry, since it is here that answers must be found to the future challenges of climate change, land availability, soil quality maintenance, biodiversity loss and structural changes in farming. All of these issues are discussed in Chapter 3. Finally, a number of potential priority areas are identified (see Chapter 4) that can help to **ensure a resilient food supply** while at the same time **improving compatibility with sustainability goals**.

3 | See FAO 2020a.
4 | See acatech 2020a.

2 The food supply during the coronavirus crisis

In response to the initial wave of novel coronavirus infections, in March 2020 the German government introduced a series of far-reaching measures throughout public life and the economy in order to minimise face-to-face contact between members of the public. While businesses involved in the food industry were classified as systemically important and remained open, the government's measures still had volatile impacts on production, logistics and sales in the food sector.

Below, we begin with a review of the food supply situation during the initial acute phase of the coronavirus crisis in Germany (see Chapter 2.1). Even though the first wave has now largely subsided, the pandemic could still affect our food supply going forward. Chapter 2.2 looks at what this means for Germany and at the potential impacts of new local and regional outbreaks or further, more widespread waves of infection. The final part of this chapter discusses the impacts of the coronavirus crisis on the food supply in other parts of the world. The effects are already devastating in many emerging and developing countries and could get even worse, depending on how the pandemic unfolds (see Chapter 2.3).

2.1 Review of the food supply situation during the first wave in Germany

International supply chains and level of self-sufficiency

The food supply is intertwined with globally integrated supply chains and all the different components of the value chain, including logistics. In Germany, too, food production relies on international trade, since even foods for which Germany has a high nominal level of self-sufficiency are produced with imported inputs such as seed, fertiliser and livestock feed. The process chains in the food processing industry also operate transnationally.

In 2018, the self-sufficiency rate in Germany (i.e. the ratio of domestic production to domestic consumption) was over 100% for many foodstuffs (e.g. meat 116%, milk 111%, potatoes 138% and sugar 161%).[5] However, the rate for a number of other key foodstuffs is significantly lower. For instance, it is 91% for grain, just 36% for vegetables and as little as 22% for fruit.[6] This means that imports are key to the availability, price and variety of these foods, especially since some products like bananas cannot be produced in Germany. More than 90% of Germany's fresh vegetable imports come from other EU member states, with Spain and the Netherlands alone accounting for two thirds,[7] while most fresh fruit and citrus imports are from Spain and Italy. These southern European countries were among the worst affected by the coronavirus pandemic. In April 2020, vegetable prices were 26% higher and fruit prices 14% higher than a year ago.[8] Even in June, they were still 5% and 18% higher than in June 2019.[9] This was due to supply shortages caused by logistics issues and supply chain tensions at the beginning of the coronavirus pandemic, coupled with the severity of the crisis and the strict measures introduced to combat it, especially in Italy and Spain.

Experience from the first peak of the Coronavirus crisis has shown that a functioning logistics system for goods and foodstuffs both in the EU single market and in international trade is key to maintaining the food supply. At the beginning of the crisis, border closures had a particularly severe impact on the logistics system. The decisions of various European countries to close their borders were taken at very short notice and introduced individually in the German federal states. The transport of goods and people was severely complicated by the sudden emergence of this patchwork of official regulations coupled with a lack of clear information.

However, these problems were swiftly addressed in consultation with the logistics and food retail industries, ensuring that goods could continue to be transported across borders. Measures included the introduction of green lanes to speed up border crossing checks for heavy goods vehicles (HGVs). The lifting of the bans on driving HGVs at weekends and on public holidays also helped to rapidly ease the initial supply problems.[10] The increased volume of goods needing to be transported in the food

5 | See BZL 2020a, figure for sugar is for 2017.
6 | Ibid.
7 | See BMEL 2020b.
8 | See AMI 2020a.
9 | See AMI 2020b.
10 | See European Commission 2020a.

Food access and health

As well as ensuring that sufficient quantities of food are available at all times, a resilient food production and agriculture system also aims to provide access to food of sufficient quality and diversity for a balanced and healthy diet. In other words, as well as preventing hunger, it also seeks to prevent micronutrient deficiency (lack of vitamins and minerals) caused by a poor diet, often referred to as "hidden hunger".

At a global level, it is apparent that the food crises caused by the coronavirus pandemic are not so much due to problems with food production and logistics as to problems with access to food. Even if the food supply itself is sufficient, there is a danger of collapsing markets and diminishing purchasing power leaving people unable to access enough food.

Even in Germany, the fact that the crisis has caused a hike in fruit and vegetable prices could pose a threat to healthy diets. Higher food prices have a direct impact on consumer behaviour and nutrition. Even before the crisis, surveys revealed that average fruit and vegetable consumption in Germany is far too low. 85% of people in Germany fail to consume the amount of vegetables recommended by the German Nutrition Society, while around 60% fall short of the recommended daily intake of fruit.[11, 12] Fruit and vegetables both form an essential part of a healthy diet and prevent long-term health impacts such as obesity.

The coronavirus crisis has had an especially pronounced impact on children's diets, since the closure of educational establishments meant that children no longer had access to the lunchtime meals provided by day nurseries and schools. However, the current evidence suggests that, for most households, cooking more meals at home and higher prices for some foods have not had a negative impact on eating habits. In fact, two thirds of those surveyed for the Federal Ministry of Food and Agriculture's 2020 Nutrition Report – one of the few studies on this subject – said that the coronavirus crisis had not affected their cooking and eating behaviour at all.[13] Only a small minority of respondents (7%) said they were eating more ready meals, whereas 30% said they had been cooking more of their own food during lockdown. Nevertheless, socioeconomic disparities in diet were also apparent during the coronavirus crisis. For instance, the study found that improvements in cooking and eating behaviour as a result of the crisis were more pronounced among high-income households, while a deterioration in diet quality was more frequent in low-income households.[14] Therefore, it is not only the availability of basic food that plays a key role in socioeconomic dietary habits, but also a balanced and affordable supply of a wide variety of foods.

retail sector was absorbed by logistics company capacity that had been freed up because it was no longer needed for deliveries to the catering sector, for example. Thanks to private digital labour platform initiatives, it was also possible to recruit enough personnel to cover the higher demand in the food retail trade.

The labour supply in the food industry

Extra store and warehouse staff had to be recruited in order to keep food retailers' shelves well stocked when demand spiked at the beginning of the crisis. Eventually, it proved possible to meet these additional manpower requirements. However, the situation of fruit and vegetable growers demonstrated just how important the labour supply is for the entire food production chain.

Unlike production in an industrial enterprise, agricultural production depends on natural factors of production and cannot simply be stopped at short notice and then resumed at a later point in time. Moreover, fresh produce is often perishable and can only be stored for a limited period. Yet it is precisely this perishable produce that is essential for a balanced diet. The labour shortage caused by lockdown thus became a serious issue for agricultural producers. In particular, the supply of seasonal workers from abroad was severely curtailed due to border closures and restrictions on leaving and re-entering their home countries. The cultivation and harvesting of many vegetable, fruit and special crops such as asparagus and strawberries or apples and wine in autumn is extremely labour-intensive, and the same applies to food processing operations in abattoirs and meat processing

11 | See MRI 2008.
12 | See MRI 2014.
13 | See forsa 2020.
14 | See forsa 2020.

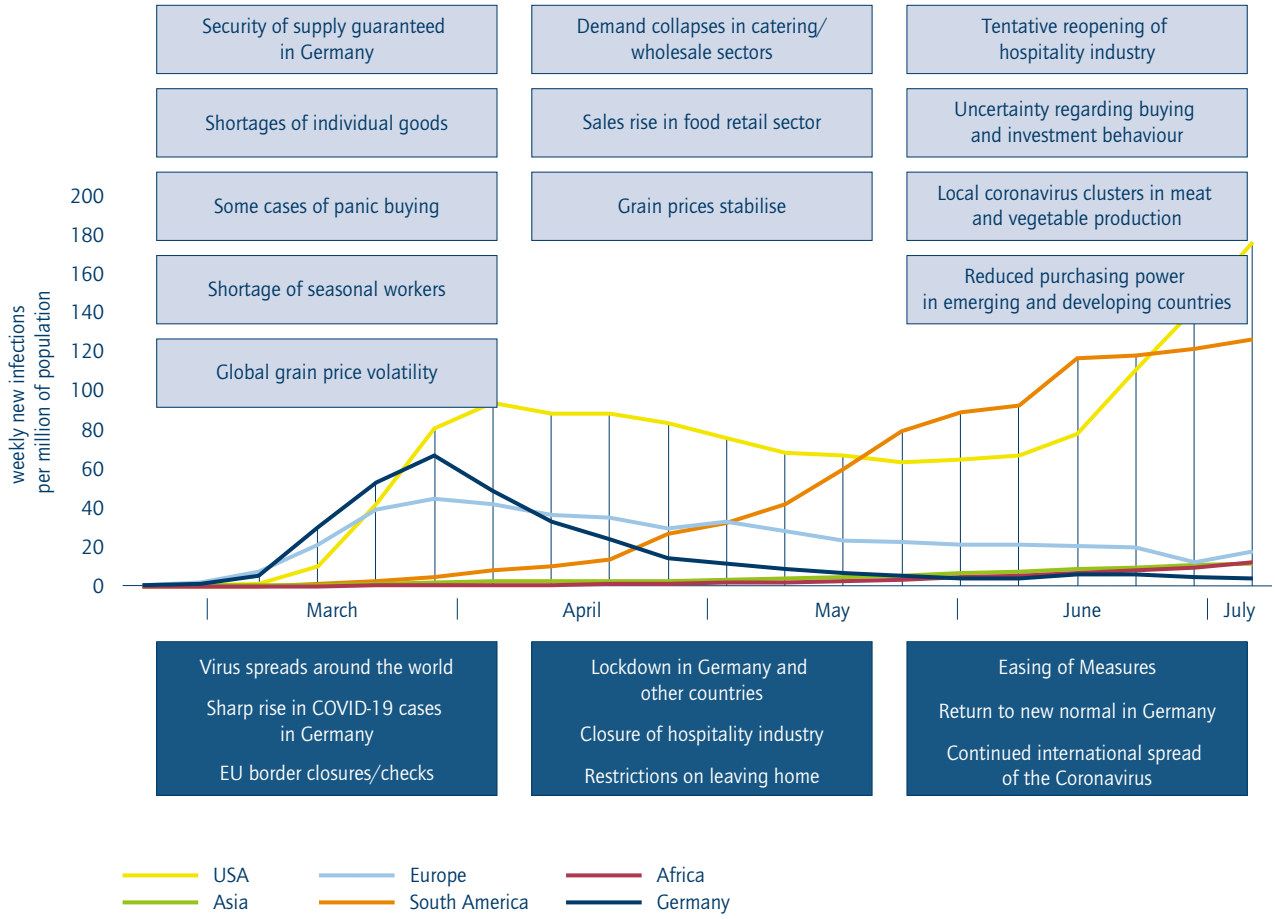

Figure 1: The coronavirus crisis and its impacts on the food and agriculture sectors (Source: authors' own illustration based on data on the coronavirus pandemic taken from OurWorldinData 2020, retrieved 16 July 2020)

plants, for example. On the other hand, even large farms require only small numbers of workers for many of Germany's traditional arable crops such as wheat and sugar beet.

The government allowed German farms to bring in a limited number of up to 80,000 seasonal workers from abroad in April and May, although strict hygiene arrangements had to be in place for their transport to Germany and their accommodation once they arrived.[15] By mid-May, only 41% of this quota had been used. The restrictions on the numbers of seasonal workers entering Germany were extended to the middle of June,[16] and the entry restrictions at Germany's borders were subsequently lifted. However, health and safety requirements relating to the organisation of farm work remain in place.[17] In addition, during March and April efforts were made to mobilise a further 10,000 workers a month from within Germany.[18] While these German volunteers did help to overcome the shortages during the first weeks of the crisis, farms can only rely on them as a supplement to their regular workforce. Moreover, their inexperience means that they are not generally a like-for-like replacement for foreign workers who have spent many years working either in agriculture or in the food processing industry.

The coronavirus pandemic highlighted the need to adapt employment and social standards and ensure their systematic implementation for harvest and meat industry workers. Strict implementation and monitoring of the government's accommodation and work organisation measures is essential in order to

15 | See BMI/BMEL 2020.
16 | See BMEL 2020c.
17 | See BMEL 2020d.
18 | See BMI/BMEL 2020.

protect seasonal workers against infection after they arrive in the country. The cluster of coronavirus cases in German abattoirs led to widespread public debate about working conditions in the meat industry and demonstrated the importance of adapting work practices in order to strengthen resilience.[19] This is especially true of jobs that require people to work in close proximity to each other. The fact that the coronavirus spreads via aerosols poses a new challenge that will now also need to be addressed by work practices. In overall terms, the existing regulations will need to be reviewed and adapted to the latest knowledge. The German government responded to the outbreaks with a variety of ad hoc measures including increased health and safety inspections and, from January 2021, a ban on the formerly widespread meat industry practice of subcontracting foreign workers.[20]

Commercial impacts

Social distancing rules led to dramatic changes in food demand. Consumption in the catering sector collapsed across the country from the end of March 2020 as businesses closed and people were only allowed to leave their homes for a limited number of reasons. On 22 March, the heads of Germany's federal states passed a resolution to completely close all restaurants and bars except for takeaway deliveries. They only began to reopen in May, with the exact date varying from one federal state to another. At the same time, however, food retail sales rose sharply from as early as February on. Between February and June 2020, monthly sales in the food retail industry rose by between 10% and 20% compared to the same month in 2019.[21] The highest rises in sales were recorded between February and May, with a lower increase of 10% recorded in June following the reopening of restaurants and bars. The figures for July and August 2020 were not yet available at the time of going to press.

The dairy and meat markets were (and continue to be) particularly hard hit by the changes in demand caused by the crisis. Both recorded significant falls in sales and prices, with serious consequences for the industry's profitability. Meat producers, especially those in the pig fattening business, were forced to keep feeding their animals for longer than necessary from a meat production perspective. And although dairy farmers were to some extent able to reduce their animals' milk yield by adjusting their feeding regimes, this was by no means enough to compensate for the collapse in demand from the catering sector. Before the crisis, the catering trade accounted for approximately one fifth of all dairy sales, and the increase in demand from the food retail sector only partially made up for this loss of business. A further problem is that the catering sector typically uses different product ranges and pack sizes. As a result, smaller, less flexible dairies whose main customers are in the catering sector have been particularly hard hit.

How has Germany coped with the crisis so far?

Overall, Germany coped well with the changes affecting the food supply during the initial acute phase of the coronavirus crisis. Supply chains could have been disrupted by border closures, but the authorities moved swiftly to overcome this threat and ensure comprehensive food supply.

Nevertheless, the events of the past few months have highlighted weaknesses in our supply system, as illustrated for example by the shorter supply of some fruits and vegetables and the associated increase in prices. One thing that has become abundantly clear is that a resilient food supply – and thus an adequate and balanced diet – is reliant on a functioning logistics system and the availability of experienced (seasonal) foreign workers at harvest time. It is possible to imagine situations in which the availability of the necessary goods transport and labour could no longer be guaranteed. It is thus necessary to develop strategies that address potential worst-case scenarios beyond the current crisis.

2.2 Likely future trends in Germany

There is still a huge amount of uncertainty. Firstly, a number of restrictions remain in place, especially for the catering sector. Secondly, there is still the threat of further waves of the virus that could lead to the reintroduction of tighter restrictions. And thirdly, the uncertainty is severely compounded by the development of the pandemic around the world. Many countries, particularly outside of the EU, are experiencing major waves of infection that hit much later than in Germany.

This means that demand for certain foods is likely to remain lower for some time to come (Trend 1). Moreover, the fall in demand from some parts of the world where the pandemic is still spreading poses commercial problems for the food industry that will require an appropriate response (Trend 2). In view of the

19 | See Günther et al. 2020.
20 | See Deutsche Bundesregierung 2020.
21 | See GfK 2020.

weaknesses in the supply system that became apparent during the first wave and the fact that the pandemic is still in full swing internationally, the possibility of a second wave makes it essential to increase the resilience and sovereignty of our food supply so that we are better equipped to cope with future crises (Trend 3).

Trend 1: Lower demand for certain products

The effects of the ongoing spread of the coronavirus around the globe can be expected to affect the market in Germany for some time to come. For instance, dairy product prices are forecast to remain lower into 2021.[22] Northwest Europe also has a large potato surplus that reached two million tonnes in May 2020. These potatoes are used to make products such as chips, mostly for sale to the catering sector.[23] The gradual reopening of bars and restaurants is only making a relatively small dent in this surplus, and (with the exception of takeaway deliveries) it is unlikely that bars and restaurants will return to business as usual any time soon. Large events are still prohibited and smaller events may only go ahead if hygiene plans are in place and social distancing is observed. This means that consumption will continue to be higher in private households and lower in bars and restaurants – businesses will therefore need to cater to different markets. Foods that were formerly sold to wholesalers or delivered direct to catering businesses will now need to meet the product specifications of the retail trade, requiring entire manufacturing facilities to switch over to different pack sizes. While possible in principle, this will be both complex and initially costly.

Trend 2: Commercial uncertainty

The collapse in demand from the catering sector is compounded by the fact that meat and dairy products are also German agriculture's most important exports.[24] Demand for these products is also collapsing in parts of the world where the pandemic is still spreading. As a result, farmers are being paid lower prices for their dairy and meat products. If this continues, fattening operations and dairy farms in Germany could face financial difficulties. The authorities have intervened in the market by financing the use of private warehousing space for dairy products and beef, sheep and goat meat products.[25] While this has helped to stabilise prices at low levels, it also means that prices will remain at low levels until the stored products have been sold.

The current uncertainties mean that, for the foreseeable future, agricultural producers will not be able to plan ahead with their customary degree of confidence. The situation is compounded by the fact that certain steps in the production process are partially governed by natural timescales. The next crop of potatoes grown for processing was already sown at the end of March 2020. Since farms had already ordered the crop, the area under cultivation for 2020 is actually slightly higher than the previous year, despite the current potato surplus.[26] The pig fattening value chain has also been severely affected. Fattening farms need to sell fattened animals on so that they have room for new animals, whose numbers were already fixed before the onset of the coronavirus pandemic. However, a bottleneck occurred when a number of abattoirs were closed following coronavirus outbreaks on their premises. As a result, it is possible that there will be a large discrepancy between supply and demand for the foreseeable future. In addition to reduced sales and lower incomes, in the worst-case scenario it may be necessary to dispose of surplus pigs, poultry and milk, for example. Even if farmers are able to sell the animals on at a later date, they will fetch a lower price because older animals have a higher proportion of fat, which reduces their market value.

Farms could also face another shortage of seasonal workers in the event of a second, more pronounced wave of the virus. This could significantly limit their ability to harvest their crops. Government aid packages may be necessary if agricultural producers' risk insurance is insufficient to compensate for these lost crops and the decline in sales due to changes in demand.[27] In addition to these emergency government interventions, however, it is also necessary to address structural problems. For instance, overproduction in the dairy market was already causing financial difficulties for some dairy farms before the coronavirus crisis. This and other structural problems must be proactively addressed through appropriate, long-term incentives (see Chapter 4). The current crisis cannot be allowed to overshadow this issue if the agricultural sector is to operate resiliently in the future as well as the present.

Although on the whole there have not been any critical shortages of imported food or agricultural inputs over the past few months, it is not possible to completely discount worst-case scenarios such as a second wave resulting in a shortage of HGV drivers because so many have fallen ill. A further element of uncertainty concerns

22 | See Rabobank 2020.
23 | See NEPG 2020a.
24 | See BMEL 2018a.
25 | See European Commission 2020b.
26 | See NEPG 2020b.
27 | See BMEL 2018b.

the possibility of production or logistics problems in other countries pushing up the price of agricultural inputs or intermediate products, with negative consequences for domestic food production in Germany. Livestock farmers in Germany and the rest of the EU are highly dependent on imported feed from Latin America – 35.47 million tonnes of soybean products were imported in 2018, 24.1 million tonnes of which came from Brazil, Argentina and Paraguay alone.[28] Brazil is one of the countries worst affected by the coronavirus. If its ports were to close for any length of time, the impact on soybean production and logistics could be extremely serious. Various other additives used in today's food industry are also imported from just a handful of countries around the world. These include carrageenan[29] and palm oil, which are mostly produced in the Philippines, Indonesia and Malaysia.

Trend 3: Sovereignty and global trade

As far as food sovereignty is concerned, Germany holds national food reserves that would allow it to be self-sufficient for around six months in the event of a worst-case scenario involving long-term disruption to logistics and value chains. As of April 2020, approximately 950,000 tonnes of food were held for this purpose by Germany's Federal Grain Reserve and Civil Emergency Reserve, primarily wheat (625,974 tonnes), rye (100,382 tonnes), rice (81,570 tonnes), oats (64,335 tonnes), lentils (19,126 tonnes) and condensed milk (4,695 tonnes).[30] In addition, if private households build up sensible stocks of food as recommended by organisations such as the Federal Office of Civil Protection and Disaster Assistance, this should prevent a recurrence of the panic buying and local shortages seen at the start of the first wave, if and when a major second wave occurs.

On the whole, events during the crisis suggest that it is necessary to at least maintain and potentially even increase Germany's food sovereignty ("sovereignty" is defined in Chapter 1). This does not mean that Germany should become completely independent of international trade. Global networks often offer lower production costs and access to products that cannot be produced locally, such as coffee and bananas. Moreover, they supply food to consumers in countries that are net importers of food, where only limited domestic production is possible due to the local environmental conditions. Germany's favourable geographical location for agricultural production means that it has a responsibility towards the global community: only 11-28% of the global population can fulfil their demand for grain and other basic food within a 100-kilometre radius.[31]

In addition, global networks can potentially provide cover if local or regional supply structures are disrupted by extreme weather events or natural disasters, since these are often confined to a particular locality or region. International supply chains allow global enterprises to respond efficiently to risks and create parallel emergency solutions by establishing redundancy (fallback structures). In the case of soybeans, for example, the feed that companies sell on to farmers can be sourced from Eastern Europe as well as Brazil.

On the other hand, local production can be an important factor for supply chains, not least because it reduces transport costs and has a lower environmental footprint. In some cases, however, the number of borders that need to be crossed can also be a key consideration. For instance, soybeans transported by ship from Brazil come to Germany via the Netherlands. This means that they cross fewer borders than soybeans from Eastern Europe, which have to cross several EU countries where problems were encountered at border crossing points in the early stages of the first coronavirus wave. Standard one-size-fits-all solutions are also unsuitable for value and transport chains, since we do not know what type of crises may occur in the future and what their consequences might be.

Local production makes sense with regard to sustainability, provided that the appropriate methods are employed (see Chapter 4.4) and local conditions are taken into account (see Chapter 4.1). Its benefits include shorter transport distances and a stronger connection between consumers and farming. However, consumers' desire for regional products should not be the main driver, since this could result in inefficient resource utilisation. Optimal utilisation of the regionally distinct natural production conditions is key to the efficient and sustainable production of agricultural produce.

2.3 Global trends

The coronavirus pandemic will have global repercussions. Some of these are only beginning to become clear and will depend on how the pandemic evolves. Developing and emerging countries lack the financial instruments to tackle the pandemic in the same way as the industrialised nations. It is also hardly possible to mitigate the economic crisis in these countries. As a result, their populations are hit harder and more directly, and people's purchasing power can dwindle very rapidly. Rising food prices could exacerbate this problem still further.

28 | See OVID 2020.
29 | A plant-based gelling agent and emulsifier.
30 | See Deutscher Bundestag 2020a.
31 | See Kinnunen et al. 2020.

Stable basic food prices

Knee-jerk responses were occasionally observed in the global agricultural market at the beginning of the coronavirus crisis. Turkey, Morocco and Egypt, all of which depend on imports, bought up large quantities of grain to protect against possible price rises. At the same time, some of the world's largest producers announced export restrictions or imposed export bans. These included Romania and Russia for wheat and Vietnam and other Southeast Asian countries for rice. The uncertainty caused a rise in price volatility for products such as wheat. However, in the months that followed, governments relaxed these restrictions and the logistics problems were solved. Consequently, except for rice, there has been no pronounced increase in global market prices for basic food, nor is any such increase expected in the near future. Falling demand in other areas was partly responsible for this trend. For instance, extremely low oil prices and a downturn in economic activity caused a significant drop in energy sector demand for maize used in ethanol production. This resulted in downward pressure on global maize prices.[32] Greater security is also provided by the fact that countries around the world now maintain higher reserves of basic food than they did at the time of the global financial crisis and recession in 2008/2009.[33]

Food access and purchasing power

An analysis of price trends on the global agricultural markets is not enough in itself to describe the impact of the crisis on food access, since local losses of purchasing power can also have a major effect. Although the economic crisis is also causing food insecurity to rise in some industrialised nations such as the US[34], it is people in **emerging and developing countries** who are particularly badly affected by a loss of purchasing power if their country's economic performance declines significantly as a result of lockdown measures taken to tackle the crisis coupled with falling foreign demand. The loss of purchasing power due to the collapse of the labour market – which is dominated by manual jobs – means that parts of the population are no longer able to afford food. Many people in these countries' large informal sectors[35] have few if any savings, making them even more vulnerable to severe economic crises – these people can find themselves in a very precarious situation as soon as they stop earning a daily wage. The economic impacts of the crisis and the associated lack of physical and financial access to food pose a genuine threat to food security in several emerging and developing countries.[36] For instance, a study in Bangladesh found that the coronavirus crisis has caused a 60% increase in extreme poverty.[37]

In the context of food access, the United Nations World Food Programme warns that the coronavirus crisis and its economic impacts could cause the number of people facing starvation to double from 135 million in 2019 to 265 million in 2020.[38] And this figure does not even include cases of micronutrient deficiency (lack of vitamins and minerals), commonly referred to as hidden hunger, caused by a poor diet. Moreover, the World Bank estimates that the coronavirus crisis and its economic impacts are pushing approximately 71-100 million people into extreme poverty, with Sub-Saharan Africa, India and South Asia likely to be the regions hardest hit.[39] The economic crisis will in turn have all manner of social impacts, with many fearing a rise in child labour, for example.

Previous crises, especially the financial crisis and recession of 2008/2009, were characterised by a lack of trust between market players. Export restrictions, stockpiling and the resulting increase in prices for basic food caused supply crises, especially in countries that rely on imports.[40] In some countries, the devaluation of the domestic currency due to the economic crisis and the fact that agricultural commodities are quoted in US dollars combined to push food prices up even further. In emerging and developing countries that are dependent on imports, rising prices for basic food such as wheat, rice and maize can have serious social and societal consequences that are exacerbated by precarious living conditions and less developed healthcare systems. Quite apart from the public health impacts, developing and emerging countries are also more vulnerable to the impending global economic recession. In the worst-case scenario, the combination of these factors could lead to further negative consequences and even political instability. A rise in prices for basic food was one of the many factors that triggered the social and political unrest in the Arab world during the early 2010s that came to be known as the Arab Spring. Crisis regions where a hunger crisis could potentially exacerbate a refugee crisis are of particular concern.

32 | See AMIS 2020a.
33 | See AMIS 2020b.
34 | See The Brookings Institution 2020.
35 | The "informal sector" is defined in footnote 1.
36 | See FAO 2020b.
37 | See BRAC Centre 2020.
38 | See WFP 2020.
39 | See Mahler et al. 2020.
40 | See Sharma 2011.

How can we help?

As long as there continues to be a high degree of uncertainty regarding the future evolution of the coronavirus crisis and the associated economic crisis, Germany should prioritise the monitoring of global developments and the promotion of international cooperation with a view to preventing the kind of effects that occurred after the 2008 financial crisis. One way of doing this would be to increase the support it provides to help existing international institutions monitor the global markets. In the wake of the 2008 crisis, the G20 and other major producing countries established the Agricultural Market Information System in order to carry out comprehensive monitoring of the global markets for the key food crops of maize, wheat, rice and soybeans. The aim of this instrument is to prevent price volatility and improve global food security. A huge expansion of development cooperation in order to achieve the goal of a world without hunger will require investment in agriculture and food programmes. During its presidency of the European Union in the second half of 2020, Germany has the opportunity to use all the available diplomatic channels in pursuit of this goal. Supporting existing institutions such as the FAO is likely to be the most effective way of providing relief in crisis situations. However, it is always important to ensure that aid measures do not undermine functioning local markets.

In its Policy Brief on the Impact of COVID-19 on Food Security and Nutrition, the United Nations proposes three mutually reinforcing sets of priority actions to support crisis countries[41] that in some respects go beyond mere crisis management:

1. "Mobilize to save lives and livelihoods, focusing attention where the risk is most acute".[42] (One of the examples cited by the UN is keeping trade corridors open within and among nations.)

2. "Strengthen social protection systems".[43] (One of the examples cited by the UN is putting food and nutrition assistance at the heart of social protection programmes.)

3. "Invest in a sustainable future".[44] (One of the examples cited by the UN is laying the foundation for a more inclusive, green and resilient recovery by ensuring COVID-19 dedicated resources are used in a "build to transform" approach and are evidence-based.)

41 | See UN 2020.
42 | Ibid., p. 4.
43 | Ibid., p. 4.
44 | Ibid., p. 5.

3 Long-term challenges for a secure food supply

Notwithstanding the need to address the impacts of the coronavirus crisis, it is also necessary to remain focused on wider trends that are set to become increasingly important in years to come and will have a major influence on food supply resilience even when we are not in the middle of an acute crisis. According to the UN policy brief on food security in the coronavirus crisis:

> *"The pandemic came at a time when food security and our food systems were already under strain. Conflict, natural disaster, climate change, and the arrival of pests and plagues on a transcontinental scale preceded COVID-19 and were already undermining food security in many contexts."*[45]

While food processing and logistics are not so strongly affected by environmental factors, agricultural production is highly vulnerable to changes in natural resources or environmental conditions. The extent to which these ongoing challenges are taken into account in the structure of the agricultural sector will decisively contribute in determining the resilience of the food supply. Below, we address the challenges posed by climate change (Chapter 3.1) and land use conflicts (Chapter 3.2). Other equally important challenges include soil protection and soil quality maintenance (Chapter 3.2) – both of which are key to healthy plant growth – and efforts to combat biodiversity loss (Chapter 3.3). The ongoing structural changes in the agricultural sector (Chapter 3.4) will also play an important role in its future.

3.1 Adapting to climate change

Climate change can cause changes in production conditions, production risks and potential yields. Consequently, it is essential for the agricultural sector to adapt to the changing climate conditions in Germany. Despite some differences in the detail, climate projections for Germany forecast a significant rise in temperatures accompanied by wetter winters.[46] The decadal climate prediction of Germany's National Meteorological Service also forecasts drier weather over the coming decade.[47] A modest rise in temperatures could benefit productivity by extending the growing season, for instance. However, yields could be seriously compromised if the forecasts are correct and climate change results in more frequent and severe extreme weather phenomena such as droughts, heavy rain or storms.[48] The extended periods of extremely dry weather in Germany, first and foremost in 2018 but also in 2019, clearly demonstrated that recurrent droughts will have a negative impact on domestic agriculture. As a result of the drought conditions, the German grain harvest in 2018 (excluding grain maize) came to just 34.5 million tonnes. This was 19% lower than the three-year average (2015 to 2017) and the lowest figure since 1994.[49] The German government responded by providing financial support for farmers in the form of emergency drought payments. While the weather in 2020 has so far been less extreme than the two previous years, local conditions mean that the soil water balance remains stressed in many regions. There are several parts of Germany where soil moisture at depths of up to around 1.8 metres is much lower than the long-term average.[50] As a result, it is possible that some regions will once again have poor rapeseed, winter barley and winter wheat harvests this year.[51]

Events in recent years suggest that climate change – in some cases combined with other factors – is likely to cause a bigger and/or more frequent reduction in crop yields in years to come. It has been calculated that, in the worst-case harvest scenario, Germany's self-sufficiency level would fall to just under 100% even for wheat and barley. This already happened in 2018 for the grain crop as a whole (including rye, oats, etc.) (see also Chapter 2.1). Meanwhile, Germany's already low level of self-sufficiency in vegetables would decline still further. Potatoes and sugar beet are the only two crops where German farmers produce significantly more than is required to meet domestic demand, even in years with very poor harvests.[52]

It is essential for agriculture to adapt to a changing climate in order to ensure food security both in Germany and globally (see Chapter 4.1). Adaptation measures must also include the reduction of greenhouse gas emissions from agriculture,

45 | See UN 2020, p. 3.
46 | See UBA 2015.
47 | See DWD 2020.
48 | See UBA 2015.
49 | See BMEL 2018c.
50 | See UFZ 2020.
51 | See European Commission 2020c.
52 | See Industrieverband Agrar e.V. 2020.

primarily nitrous oxide from fertilisers and methane from cattle. Without these adaptations, it will no longer be possible to guarantee farms' productivity and profitability or ecosystem services such as the maintenance of genetic and biological diversity or the reduction of erosion risks. The agricultural system's resilience to disruptive factors such as pests and plant diseases will also be diminished.[53]

3.2 Land use and soil functionality

Land is indispensable for agricultural production and neither the quantity of arable land nor the quality of the soil can be easily increased in the short term. Sustainable land use is thus of central importance: Soil functionality is key to long-term food security and the sustainable production of food and biogenic resources. Protecting arable land and soil quality and integrating them into policy and technology strategies will thus help to maintain the stability of our society in the face of unexpected short- and long-term changes and increase the resilience of the systemically important areas of food production.

Agriculture and other land uses

While the problems associated with soil sealing have been a topic of discussion in this context for many years, land consumption has continued more or less unabated, particularly at the expense of agricultural land.[54] The graph below shows a breakdown of land use in 2019. Persistently high property prices, especially in big cities, have led to widespread calls for the construction of more new housing. This is clearly at odds with a reversal of the soil sealing trend. The development of commercial premises and transport infrastructure also contributes to the soil sealing problem. Between 2000 and 2018, the amount of agricultural land in Germany fell by 7,940 km2 in real terms, while the amount of land used for housing and transport rose by 5,880 km2 over the same period.[55] Approximately 60 hectares of soil are sealed every day. The German government's original target of reducing soil sealing to just 30 hectares a day by 2020 is unlikely to be met.[56] Since agricultural productivity in Germany is already very high, it will be difficult to achieve further efficiency gains by increasing the inputs on existing agricultural land. Total national yields will therefore fall in the long run, with a negative long-term impact on food sovereignty and food supply resilience.

Competition for land within the agricultural sector

The goal of achieving climate neutrality by 2050 will likely result in substantially higher demand for biogenic resources, leading to competition with food production for agricultural land. In a bioeconomy, wood and sugar may be used as replacements for fossil fuels, for example. In 2018, bioenergy was the second most important form of renewable energy after wind power, accounting for 8% of total electricity production in Germany. Moreover, bioenergy accounted for approximately 50% of all primary renewable energy consumption.[57]

In the interests of efficient resource utilisation (see Chapter 4.4), these conflicts can be partly mitigated by the use of secondary biomass (e.g. co-products and by-products). However, sustainable, efficient land use will still be key to maintaining a secure long-term supply of both food and biogenic resources. A number of possible solutions are presented in Chapter 4.

Maintaining soil health

It is not just the available area of farmland that is important for agriculture – soil quality is also key. Maintaining soil health is vital for long-term food security.[58] From a functional perspective, soil resilience encompasses basic soil functions such as biomass production and the storage, filtering and cycling of nutrients, water and other substances. It is through these functions and services that soil provides us with food and other natural products. Closely linked to soil organic matter content and its management, soil resilience is key to optimising food production and securing the food supply. For example, low soil organic matter content in the root zone can reduce wheat protein content and productivity. Soil organic matter content is also negatively affected by accelerated soil erosion, salinisation, overuse of nitrogen fertilisers and other processes that can reduce soil carbon storage. Soil microbial communities controlled by biogeochemical and physical soil structures and processes are key ecosystem engineers of soil resilience. However, they need an adequate, continuous supply of organic matter in order to maintain a healthy soil structure.

53 | See WBAE/WBW 2016.
54 | See UBA 2019.
55 | See UBA 2019.
56 | See UBA 2020a.
57 | See FNR 2019.
58 | See European Commission 2020d.

The frequency of extreme weather events is increasing as a result of climate change. As severe droughts become more common, only areas with a high water storage capacity and adequate soil water reserves will be able to keep yield losses within acceptable parameters. The impact of the changing climate will be greater in certain regions where local conditions are less favourable. Moreover, rising temperatures cause changes in crop nutrient requirements and a reduction in the amount of carbon stored as soil organic matter for a given input. There are pronounced differences in soil – and its quality and health – depending on the climate zone and local conditions. A site-specific approach should therefore be taken to soil protection, the maintenance of soil functionality and land use.

3.3 Biodiversity loss

Numerous studies have shown that biodiversity is declining dramatically both in Germany and in other parts of the world.[59] These studies often focus on regional trends for individual bird or insect species or species groups – there are very few comprehensive long-term studies. The main drivers of biodiversity loss include management practices, changes in climate, land use/development and soil pollution.[60] This illustrates how the trends described in this chapter are linked to each other in multiple different ways.

Biodiversity loss also has implications for agricultural production. The widely cited pollination services provided by bees and other insects are of particular importance to fruit and vegetable farmers.[61] Biodiversity also has a fundamental influence on the stability of the agricultural ecosystem. Biodiversity is vital to soil functionality, since animals, plants, fungi and microorganisms are instrumental in nutrient and humus cycling and soil

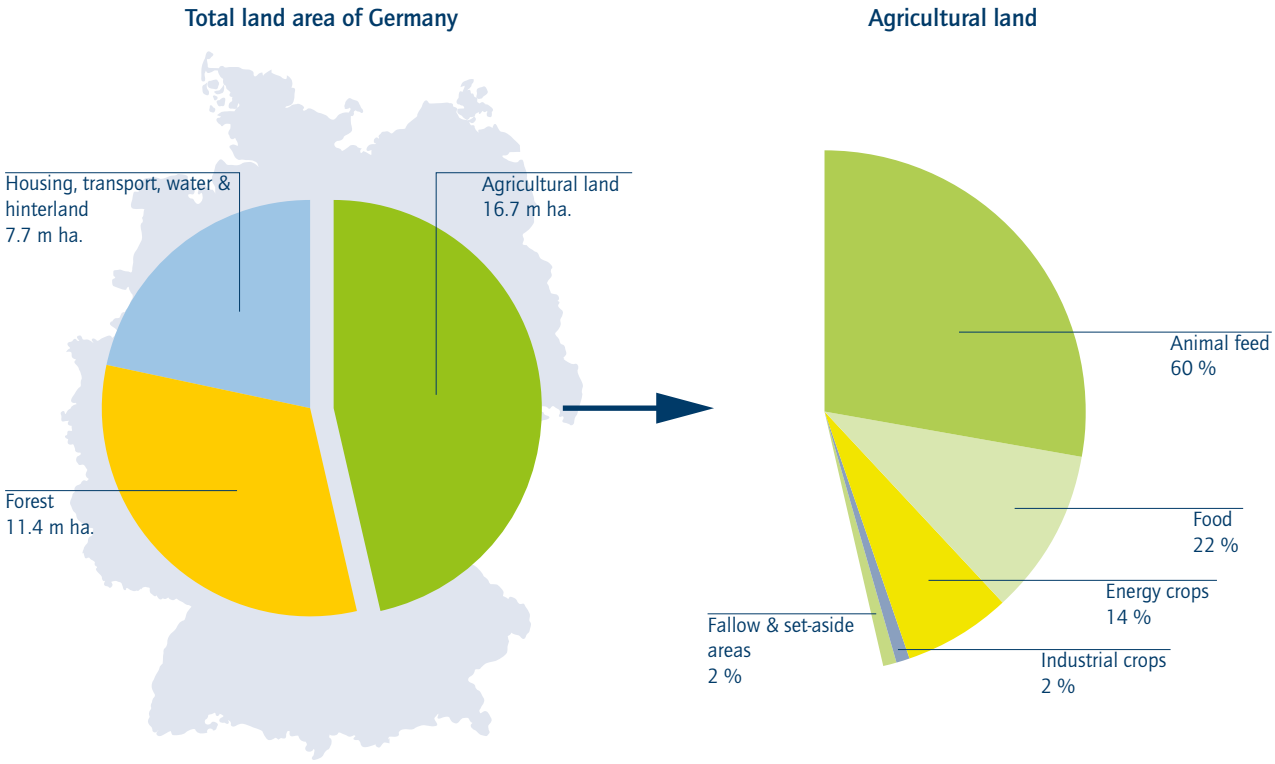

Figure 2: Land use in Germany 2019 (Source: FNR 2020)

59 | See Leopoldina/acatech/Akademienunion 2018.
60 | See UBA 2013.
61 | Grains such as wheat, rye and maize are primarily wind-pollinated.

aeration, for example. This makes biodiversity key to soil functionality and hence to agriculture.[62] Conversely, soil organisms, plants and insects are reliant on healthy soil during some or all of their development stages and are directly affected by changes in soil quality. This mutual dependency of soil functionality and biodiversity can amplify both negative and positive developments. The loss of individual species can be compensated for by surviving organisms from related species. However, every time a species is lost, the ecosystem's flexibility and resilience to external factors are diminished. If the severe decline in biodiversity continues, entire ecosystem functions could be lost, with serious and potentially irreversible consequences for the agricultural ecosystem.

Consequently, the precautionary principle should be applied to biodiversity loss and its impacts in order to increase the urgency of efforts to tackle this challenge. A sustainable, long-term overall strategy for agriculture and its management practices must make it possible to reconcile productivity and sustainability (see also Chapter 4.1). This will involve a lengthy learning process that will require heightened efforts in biodiversity research and practice (see Chapter 4). The resulting data can provide the basis for a nuanced, continuous analysis of the influence of different management types and individual factors such as plant protection products and tillage.

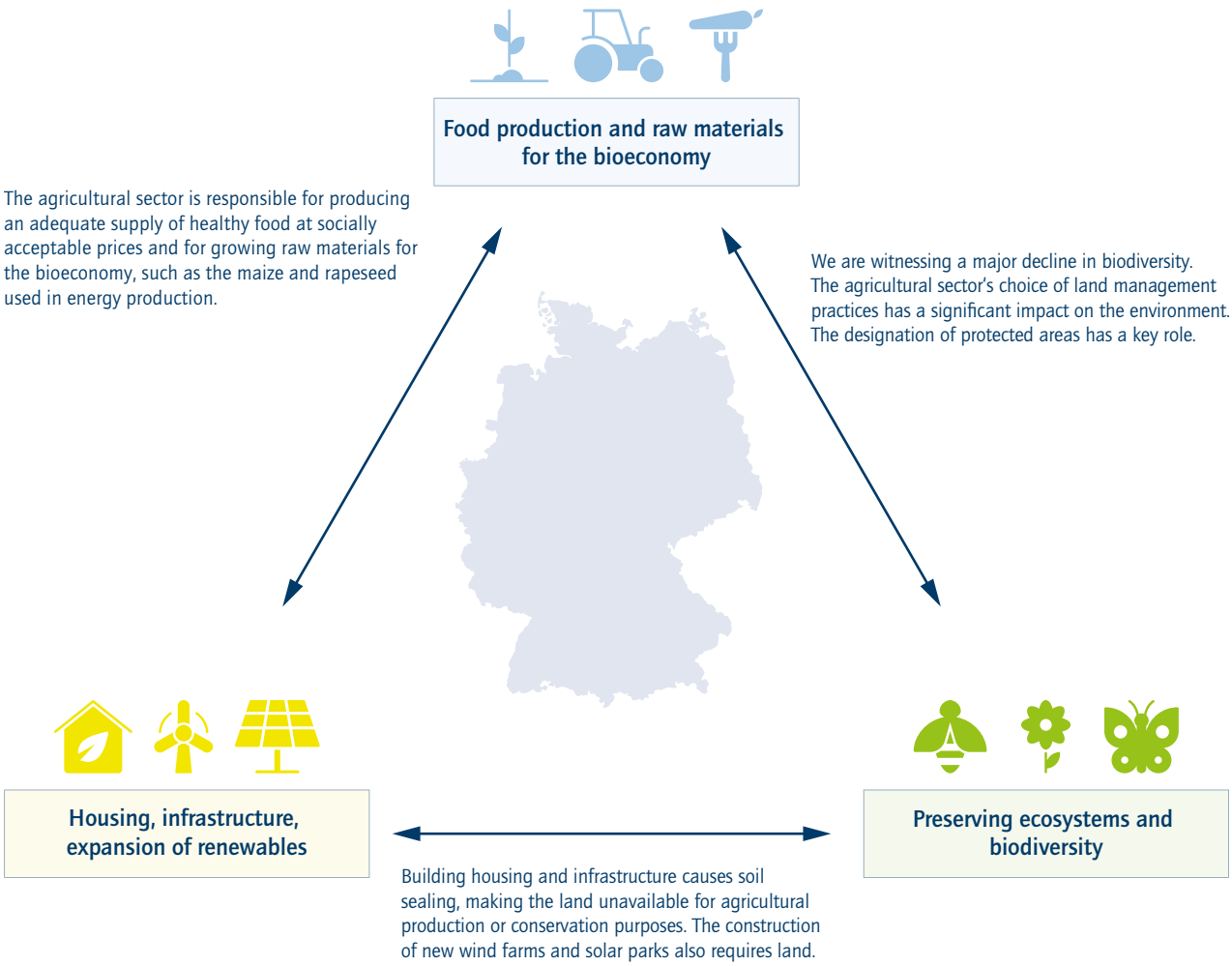

Figure 3: Land use conflicts (Source: authors' own illustration)

62 | See UBA 2013.

3.4 Structural changes

As a topic with wider social repercussions, structural change in agriculture has received a lot of attention in the media. The number of farms in Germany is declining continuously and is forecast to keep falling significantly in years to come.[63] On the one hand this is partly due to problems with farm succession. A little over a third of all farmers in Germany are over the age of 55[64] and will have to hand over the business to the next generation in the next few years. The handover to their successors is a focal point in assessing whether to keep these farms going or give them up. On the other hand, as in other industries, larger businesses are generally able to operate more efficiently and remain competitive thanks to economies of scale. The impending recession means that producer prices will probably remain low for some time to come. This will cause even greater difficulties first and foremost for smaller farms, thereby accelerating structural change.

However, the trend towards larger farms does not have any direct negative repercussions for the resilience or sustainability of agricultural production. In the short term, larger farms are more resilient to lower producer prices, since economies of scale allow them to produce more efficiently and cheaply. Large farms are also better placed to invest. In addition, the fact that the overall number of farms is still relatively high means that, on the whole, the agricultural production market is not highly concentrated. Accordingly, the failure of large individual agricultural operations would not be enough to threaten the overall resilience of the food supply.

In contrast, the meat processing market, for example, is much more concentrated and the size of meat processing businesses can pose a problem for resilience. During the coronavirus crisis, the closure of one major processing operation was enough to cause a bottleneck in the pork production value chain. The size of the businesses in a highly concentrated market with just a handful of producers or processors can have negative implications in the event of a crisis, since the closure of a few large businesses or disruption to their logistics systems can be enough to jeopardise security of supply for specific products. Although regional disruption to the value chain can to some extent be compensated for globally, this is dependent on a functioning logistics system. Consequently, both global food production value chains and decentralised structures adapted to regional conditions both form an important part of a resilient food industry.

63 | See DZ Bank 2020.
64 | See DBV 2019.

4 Priority areas for a resilient and sustainable food supply

"This crisis can serve as a turning point to rebalance and transform our food systems, making them more inclusive, sustainable and resilient."[65]

This sentence from the United Nations policy brief on food security in the coronavirus crisis highlights the fact that, as a result of the COVID-19 pandemic and climate change, resilience and security of supply are once again receiving greater attention as criteria for shaping system-critical sectors, not least agriculture, logistics and the associated value chains. The transformation towards more sustainable agriculture has already begun and is key to creating an agricultural sector that is resilient in the long run and is able to provide sustainably produced food and raw materials, thereby also making an important contribution to a circular economy.

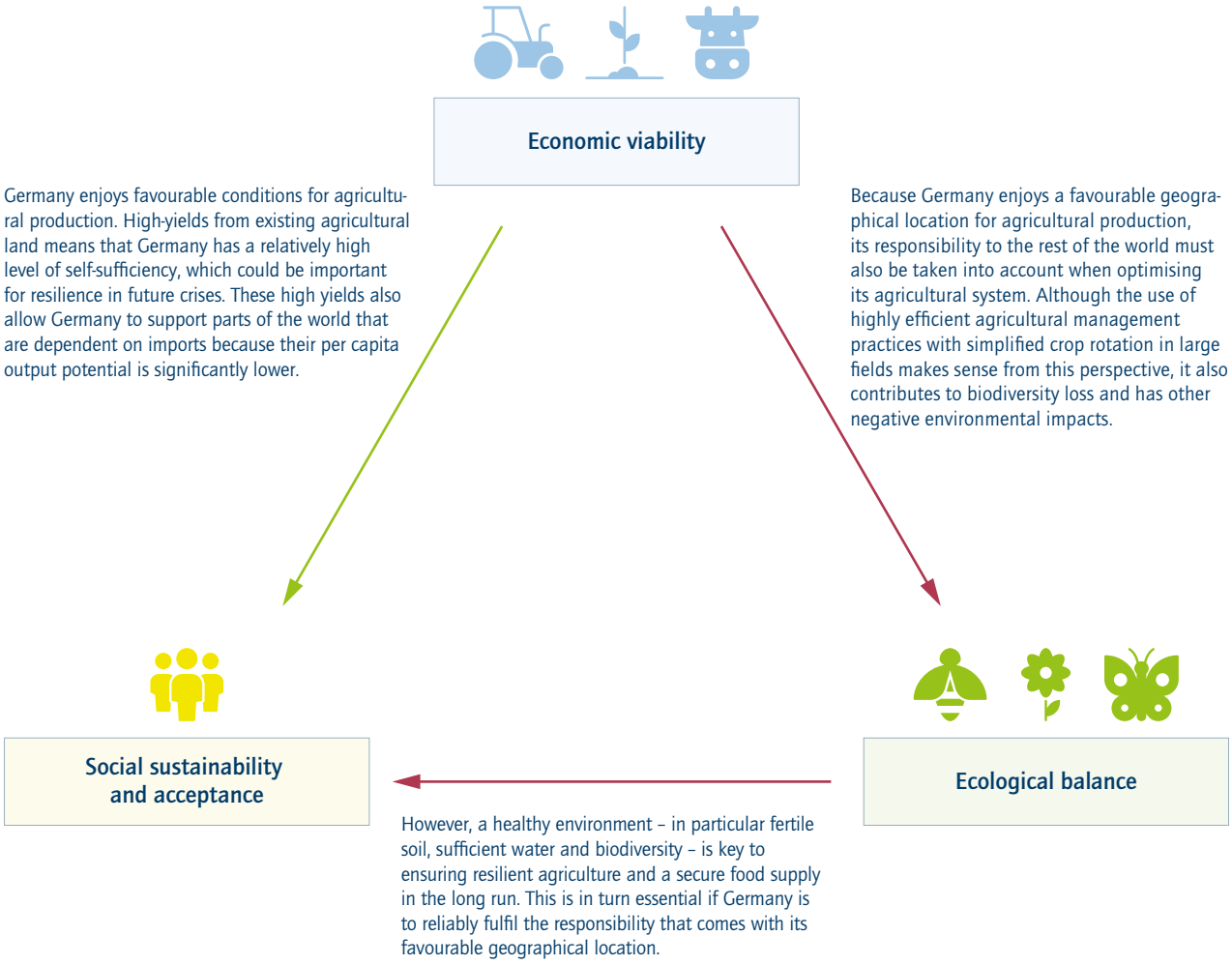

Figure 4: Conflicts in sustainable agriculture (Source: authors' own illustration based on acatech 2019)

65 | See UN 2020, p. 4.

The circular economy is an integrative concept that aims to shape and combine production and consumption patterns in a way that transforms linear process chains into cyclical ones. Producers and consumers both have a key role to play in optimising and – as far as possible and ecologically desirable – closing material and energy cycles.[66] Another key component is the knowledge-based production and use of biological resources known as the bioeconomy, which can provide replacements for fossil fuels and help to deliver processes and services in every sector of the economy.[67]

The European Green Deal and the associated biodiversity[68] and farm-to-fork[69] strategy documents stress that a climate-neutral, bio-based circular economy is key to doing business sustainably. Sustainable agriculture is thus set to become increasingly important, with a focus on both the production and consumption sides. Sustainable agriculture has three equally important dimensions: it must be socially sustainable and accepted, environmentally balanced and economically viable. Ensuring a secure supply of healthy, sustainable food and increasingly also of

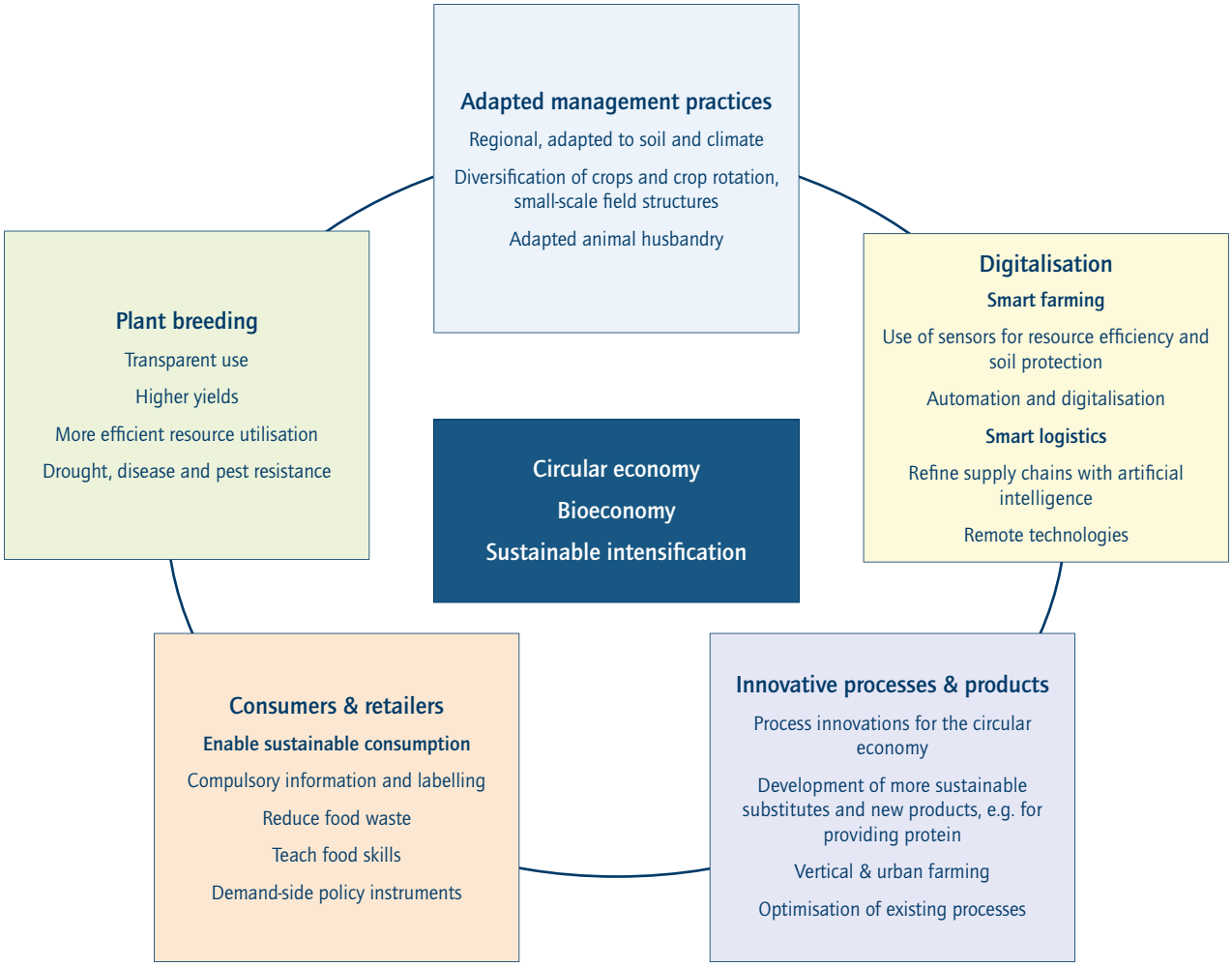

Figure 5: Overview of priority areas with high potential for reconciling resilience and sustainability. (Source: authors' own illustration)

66 | See CEID 2019.
67 | See BMBF/BMEL 2014.
68 | See European Commission 2020e.
69 | See European Commission 2020f.

resources for use in materials and energy production is key to the social acceptance of agriculture. These three dimensions of sustainability are also pillars of resilient agriculture. However, it can be difficult to balance all three of them equally at the same time. This can result in conflicts that also impact on resilience (see Figure 4).

Innovative solutions for reducing conflicts and strengthening resilience

The use of technological solutions, innovative processes, technology platforms and sustainable management practices holds considerable promise for mitigating the current conflicts between sustainability and resilience. These technology-based approaches should also encompass aspects such as education (see box on research and knowledge transfer) and public acceptance. Many innovations are already partly in use or are undergoing intensive trials. The ongoing development of these innovations and the promotion of their more widespread adoption by farmers has become even more important in the light of the coronavirus pandemic. This chapter looks at sustainable agricultural intensification and its management practices (see Chapter 4.1), the potential for digitalisation on farms and in logistics and value chains (see Chapter 4.2), the potential offered by plant breeding (see Chapter 4.3) and the development and establishment of substitutes or completely new products and innovative processes (see Chapter 4.4). Consumer acceptance will be key to more widespread use of existing products and processes and the establishment of new ones, as well as to the deployment of technological solutions. It will therefore be necessary to ensure transparency with regard to product characteristics and production methods (see Chapter 4.5).

The role of policymakers

The methods and instruments in the different priority areas outlined in this AD HOC IMPULSE publication (see Figure 5 and below) can help to promote a sustainable agricultural system that reconciles resilience with climate and environmental protection. The transformation to sustainable agriculture will call for these priority areas to be addressed by decision-makers, especially as part of the forthcoming reform of the European Union's CAP. The substantial subsidies that farmers receive through the CAP have hitherto been largely based on cultivated area. Attaching considerably more weight to ecosystem services could contribute to a sustainable and resilient agricultural system. The reform offers policymakers an excellent opportunity to bring about change in the agricultural sector, complemented by additional legislation such as the Fertiliser Ordinance. However, Germany will need to find and build the necessary majorities within the EU.

In addition to individual incentives, it will be especially important to establish a conducive overall framework that rewards sustainable farming and supports the prompt adoption of research findings and new technologies by agricultural practitioners. Value creation in agriculture is also of fundamental importance, since good long-term economic prospects are vital to maintaining a sustainable agricultural sector. Given the need to find a balance between all the different aspects involved in sustainable agriculture, the principle of learning, evidence-based policymaking is of paramount importance. Incentives should be regularly

Rural areas and new housing developments

In the long term, it is possible that the increased use of digital technology prompted by the coronavirus crisis – including the large rise in the number of people working from home – could lead to an increase in the popularity of rural areas as places to live. If people only need to commute to work occasionally, it becomes less important for them to live near their workplace, provided that they have access to the relevant infrastructure such as broadband and good transport connections. But accommodating new residents and infrastructure also means developing more land. It is thus necessary to strike a balance between our society's many competing demands on land use. The amount of land available for conservation purposes and agricultural production is shrinking continuously as a result of soil sealing (see Chapter 3.2).

Greater use should be made of existing residential areas in order to keep new soil sealing to a minimum. Soil sealing can also be avoided by restoring brownfield sites so that they can be used for other purposes. At a planning level, construction projects' environmental impact assessments evaluate the impacts on people and the environment and establish the measures that must be taken to offset them. At present, the assessment of the different soil and environmental functions (environmental protection, biodiversity, groundwater regeneration) does not carry enough weight in spatial planning. A stronger focus on these factors would help to reduce the damage caused by soil sealing if the land least suited to other purposes was selected for development. In the context of land use, questions also need to be asked about tax incentives for developing new land without restoring disused sites to an equivalent condition.

reviewed to ensure that they are achieving their aims and should be adapted in line with the evaluations' most recent findings.

The overall framework should be carefully shaped to promote efficiency, resilience and sustainability, ensuring that farmers can continue to make a living from farming, that food security continues to be guaranteed for our society and that the environment and rural areas remain in good, liveable condition.

4.1 Sustainable intensification and adaptation of management practices

The adaptation of management practices and more widespread use of new and existing technologies will require individual measures and innovations to be anchored within an overarching, systemic approach. The task facing us is nothing less than to overcome the major challenges of climate change, growing competition for land use, environmental protection and biodiversity loss in order to strengthen the resilience of the food supply against the backdrop of a growing global population. Consequently, agriculture must find a way to become sustainable, efficient, profitable and resource-efficient all at the same time. Sustainable intensification is a concept that has become popular in recent times and can provide a model for achieving these goals in years to come.[70] It denotes an overarching approach that employs an array of framework conditions and technological solutions while also taking economic factors into account. As well as maintaining high yields, it also addresses sustainability goals by promoting the most (resource-)efficient use of agricultural inputs.

In sustainable intensification, the appropriate combination of elements of organic and conventional farming in a sustainable, productive system is key to enabling profitability, adaptability, security of supply and efficient land use. For many crops, switching from conventional farming methods to more environmentally-friendly organic farming in its current form entails an average loss of harvest yields of between 20% and 45%.[71, 72] A widespread switch to organic farming would thus result in a corresponding reduction in domestic production. Assuming that consumer habits remain unchanged, this would either cause export volumes to fall or make it necessary to increase food imports from countries with potentially lower environmental standards. Germany enjoys a favourable geographical location for agriculture, with good soil and high yields. Sustainable intensification in Germany can efficiently combine the benefits of organic and conventional farming. Below, we provide a more detailed description of the key aspects of this approach, which include adapting management practices, innovations in smart farming and plant breeding, and the development of innovative new products and processes. Increased research activity and faster knowledge transfer are key to improving our knowledge in the abovementioned priority areas and fostering implementation in agricultural practice. Consumer behaviour is also an important demand-side instrument for influencing agricultural production and boosting consumption of sustainably produced products.

Adaptation of management practices

The sustainability and resilience of agricultural systems and thus the resilience of the food supply are closely connected to the adaptation of management practices, i.e. of crop rotation, crops, varieties and techniques. Maintaining soil functionality and water storage capacity are key to sustainable harvests. In the future, irrigation and soil water balance management will become more and more important as extreme weather becomes more frequent and evaporation increases during the hotter and drier summer months. In general, intensive irrigation-based farming is not widely practised due to the high costs involved. It is employed to grow potatoes and maize in some parts of northern Germany but is otherwise confined to special crops such as certain vegetables. Even in the face of continued climate change it is unlikely to provide an economically viable solution for field crops. Consequently, other climate change adaptation solutions will have to be found for these crops (see also Chapters 4.2 to 4.5). Nevertheless, in some parts of the country it may still be necessary to resort to efficient field irrigation in order to obtain high field crop yields.[73] However, higher water demand in the agricultural sector could aggravate water use conflicts with other sectors.

Changing climatic conditions will also give rise to new requirements for maintaining soil functionality. These will include taking account of soil acidity and the availability of nutrients (especially nitrogen and phosphorus) and maintaining soil organic matter. Management practices will have to be adapted to the different soil properties and climatic conditions prevalent in different regions. The adaptation of management practices in line with a sustainable intensification model will enable more efficient use of inputs and of the available water and nutrient resources, as well as mitigating the impacts of droughts and reducing the

70 | See SAPEA 2020.
71 | See UBA 2020b.
72 | See WBAE/WBW 2016.
73 | See Spellmann et al. 2017.

risk of low yields. New or rediscovered cultivation strategies can also play their part. Agroforestry, for example, can provide benefits in dry locations by incorporating more varied components such as rows of trees and hedgerows into areas devoted to field crop cultivation. These diverse landscape elements bring about positive changes in the local climate, provide habitat for different animal species and enable increased soil carbon sequestration.

Diversification of management practices and products can be an important means of tackling the challenges of climate change and biodiversity loss and meeting the requirements for resilience in individual farms. Growing a wider variety of crops in smaller fields has various environmental benefits. It supports biodiversity through more staggered growing seasons and by providing a greater range of opportunities for wildlife. A diverse mosaic of crops is less vulnerable overall to plant diseases, while different crops also respond differently to extreme weather conditions. Growing several crops also helps to reduce the risks associated with one particular crop failing. On the other hand, farmers will have to accept lower overall profit margins. Since 2013, farms receiving CAP greening payments have no longer been permitted to grow the most profitable crop on all of their land. Thus, the benefits of diversification have to be weighed up against lower revenue and less efficient management practices. As a result, there is limited appetite for diversification among farmers unless they are offered financial incentives in the form of subsidies.

Adapting animal husbandry systems

Both the animal welfare and the environmental and climate protection dimensions of livestock farming feature prominently in the public debate on sustainability. Meat production adds significant value for agricultural businesses in Germany, particularly medium-sized farms, and will remain a key pillar of a diversified agricultural sector. However, the meat industry will also need to adapt its management practices in order to get better at reconciling the three sustainability dimensions of social acceptance/social sustainability, ecological balance and economic viability. Livestock farming consumes a lot of resources compared to plant-based protein production, since it is significantly less efficient in its use of water, nutrients and land.[74] Large quantities of soybean are imported from Latin America for livestock feed, while approximately 60% of agricultural land in Germany is also used to grow animal feed, half of which is grassland.[75, 76] While this land is largely unsuitable for other forms of food production, it could be used for environmental conservation purposes.

Animal welfare is also an important issue for the German public, although people's ideas about what constitutes good animal welfare vary considerably. Both the Federal Ministry of Food and Agriculture's Borchert commission and the German Ethics Council have called emphatically for changes to animal husbandry practices.[77, 78] Practices vary depending on the species in question. In general, they are distinguished on the basis of floor area per animal and housing type, e.g. whether the animals are kept in tie-stalls, are free-range or have access to pasture. There are several other species-specific aspects to good animal husbandry that are taken into account to varying degrees by different forms of livestock farming. It is also necessary to consider the effects of antibiotic use in animal husbandry. This is especially important because livestock farms are still allowed to use the antibiotics of last resort[79] that are also used to treat multi-drug resistant bacteria in human medicine. While the treatment of sick animals must still be possible on animal welfare grounds, this needs to be weighed up against the long-term effects on the healthcare system's ability to treat bacterial infections.

Another risk that must be considered where large numbers of livestock are kept involves the potential emergence of zoonotic diseases – infectious diseases that can pass from animals to humans and vice versa. It is estimated that somewhere between 152,000 and 575,500 people died as a result of the 2009/2010 swine flu pandemic that was caused by an influenza virus which originated in pigs.[80, 81] Influenza viruses showing similar characteristics to the swine flu pathogen are currently widespread in Chinese pig farms,[82] and scientists warn that a significant proportion of the people who work on these pig farms already have antibodies for these flu viruses. The implication is that these viruses can pass easily between animals and humans. In Europe, too, pig farms are a reservoir of potentially zoonotic influenza viruses.[83] In view of the devastating effects of pandemics that have become all too

74 | See Poore/Nemecek 2018.
75 | See BZL 2020b.
76 | See BZL 2020b.
77 | See BMEL 2020e.
78 | See Deutscher Ethikrat 2020.
79 | See Deutscher Bundestag 2020b.
80 | See Dawood et al. 2012.
81 | See Smith et al. 2009.
82 | See Sun et al. 2020.
83 | See Henritzi et al. 2020.

apparent around the world during the current coronavirus crisis, action must be taken to prevent the risk of zoonotic diseases emerging in the livestock farming sector. Improved risk analysis coupled with increased livestock monitoring would be an important step in this direction. Possible measures based on risk assessments must be publicly debated both in Germany and worldwide.

The issues outlined above illustrate the complex challenges involved in adapting animal husbandry practices. A comprehensive analysis should be carried out of the different impacts of livestock farming on the environment and climate, on the overall resilience of our society and on animal welfare, in order to ensure that any solutions take proper account of all the relevant dimensions. If the right changes are to be made, it will be necessary to involve the widest possible range of actors – sustainable outcomes will only be achieved through a broad, interdisciplinary approach. Economic factors should also be taken into consideration to ensure that farms can remain financially resilient. Ultimately, farms cannot be expected to invest large sums of money in hi-tech equipment and animal housing unless they have a secure basis for their long-term planning. A wide range of instruments are available for adapting animal husbandry practices as part of a sustainable intensification model. They include structural measures such as more sustainable stocking levels, together with a variety of possible individual measures, for example the use of technical devices installed in livestock housing to reduce emissions or changes to feeding regimes. The transformation to sustainable, species-appropriate livestock farming in Germany must also be supported by consumer behaviour. If demand for cheap meat produced to low animal welfare and environmental standards remains at the same level in Germany, imports of these products could promote even less sustainable

Research and knowledge transfer

Farms have to take a large number of different factors into account. In the future, changes in the factors of production (soil, water balance, nutrients, etc.) due to phenomena such as climate change and biodiversity loss will be key fields of research. This applies both to basic research and to applied research into adaptation strategies for reconciling high yields with sustainability goals.

An interdisciplinary approach should be adopted that includes other fields such as community land use planning for biodiversity. It is also essential to draw on practitioners' expertise, since ultimately it is farmers who know the most about farming practices and local conditions on their farms. Farmers should therefore be more closely involved in the research and applied development of new management practices and technologies, for example through usability studies. Moreover, in keeping with the principles of lead user theory, particularly innovative farms could collaborate with researchers on technological solutions by acting as a source of ideas. It is important for researchers to take the everyday needs and practices of farmers into account in order to ensure widespread adoption of innovative processes.

Cooperation between researchers and practitioners should therefore be stepped up as a basis for applied research into management practices and potential adaptation strategies.

The flow of information to farms must also be improved in order to ensure that successfully trialled methods are implemented in practice. To overcome future problems such as those caused by a changing climate, farmers' hands-on knowledge will need to be supplemented by the relevant research findings. This makes comprehensive training and professional development of people working in agriculture even more important so that they can act as multipliers for the transfer of knowledge into practice. A broad training initiative encompassing all the different levels – from universities to agricultural colleges and master craftsman training – would help to promote the use of new technologies (e.g. smart farming, see Chapter 4.2) and management practices.

Agricultural extension (also known as agricultural advisory services) is another key pillar that should be expanded and supported in order to improve its effectiveness. Both the State and private initiatives should be involved in providing wide-ranging, state-of-the-art advice that farmers can access individually. Platforms can be used to facilitate access to knowledge and support the rapid sharing of information. As well as being independent and transparent, advisory services should provide opportunities for cooperation.

and animal-friendly meat production in other countries. Consequently, transparent labelling of animal husbandry and production standards (see Chapter 4.4) should also be required for imported products. At European level, this can be regulated primarily through the CAP.

4.2 Digital solutions for farms and logistics providers: smart farming and smart logistics

Smart Farming

Agriculture already makes extensive use of digital technology, with more and more operations being progressively automated and digitalised. The technology and analytics are constantly advancing and becoming increasingly affordable for widespread deployment. Drones and satellites (remote sensing) are one area with significant potential – by helping to precisely analyse plant and soil condition, they can enable targeted measures to address nutrient deficiencies or local disease outbreaks. The targeted application of nutrients or plant protection products makes it possible to maintain yields while saving resources by only using as much as necessary. This is a very welcome technology, not least because it benefits biodiversity and soil protection (by reducing the impacts of tillage on humus) while also reducing costs in the long run without any detriment to yields. However, it does require significant upfront investment. The application of plant protection products and fertiliser is another area where remote sensing has considerable potential and can make a significant contribution towards sustainable intensification. In general, agriculture already makes extensive use of digital technology. Nevertheless, there are several innovative methods and processes that can currently only be implemented on a small scale or that are not yet widely used. It is therefore necessary to drive the continued development of these technological advances and promote their more widespread use.

While smart farming reduces overall reliance on the availability of labour, increasingly digitalised and automated farming methods do depend on rapid data availability and can only be implemented with full Internet coverage (at least 4G). This is an area where many rural areas still need to catch up. Furthermore, there is some scepticism among farmers concerning data privacy and ownership and also with regard to the lack of compatibility between different manufacturers' equipment, which can make it difficult for them to switch suppliers. Pioneering initiatives have now been launched to enable the exchange of data between equipment made by different manufacturers.[84] It can be challenging for farms to switch over to smart farming systems and other digital technologies due to the high investment costs and additional training requirements. These factors can hold back the adoption of the relevant technologies and can in some cases be an obstacle to resilience where robust, simple and flexible self-organising processes are key. The costs and uncertainty regarding payback are particularly critical in regions with lots of small farms. Organisations such as producer cooperatives and other established forms of cooperation such as machinery syndicates allow farmers to spread the cost of buying the technology. Other alternatives include service providers such as contractors and consultants, or manufacturer hiring and leasing models.

The promotion of digitalisation and automation has huge value-added potential in Germany, which has a strong agricultural engineering industry and is also a major exporter of agricultural machinery. As well as the big agricultural technology manufacturers, the industry is also home to several smaller service providers and software companies. Smart farming adds value, reduces environmental impacts and maintains or even increases yields in an adaptive agricultural system. Despite some obstacles, it will thus be an important field in years to come.

Digital logistics solutions

Besides its impact on farms, the potential of digital solutions in the food industry extends to logistics providers. The operational and logistics constraints at the beginning of the coronavirus crisis resulted in some disruption, particularly to supply chains (see Chapter 2.1). Supply chain bottlenecks can have various causes and occur at different points in the chain. Moreover, individual supply chains can be very different to each other due to differences in product characteristics such as perishability, country of origin or downstream processing. Many companies already make use of artificial intelligence (AI) to support their procurement and distribution processes.[85, 86] Greater use of AI techniques will improve supply chain transparency and make risks easier to identify. These techniques can help businesses to draw up contingency plans and reduce supply chain vulnerability to different types of risks.[87] Remote technologies, especially ones that enable working from home, play an important role in maintaining logistics coordination during a pandemic. By enabling efficient logistics process management during the current crisis,

84 | See PLS 2020.
85 | See acatech 2020b.
86 | See PLS 2020.
87 | See acatech 2016.

these technologies have shown themselves to be a vital part of a resilient system.

It is also important for firms to become aware of supply chain disruption as soon as possible so that they can rapidly switch to alternative resources if necessary. It is particularly important to ensure reliable information on transit regulations and waiting times at border crossings – an area where there was much confusion during the early days of the coronavirus crisis. In the event of similar crises, a central service could provide consolidated, up-to-date information from different authorities and countries so that logistics chains could be adapted accordingly. Digital labour, logistics space and freight capacity platforms have also proved invaluable during the coronavirus crisis, facilitating the redistribution of resources between companies that have been affected more or less seriously by the crisis and between different parts of the logistics industry. The fact that staff could be rapidly redeployed from other industries helped to cope with the sudden spike in demand in the food retail sector. On the basis of this experience, a government-supported platform could be established that would serve as a point of contact offering similar services in future crises.

4.3 Plant breeding

Plant breeding can play a key role in adapting agriculture to a changing climate and enabling more efficient resource utilisation. Plant genomes can be modified using both conventional breeding methods and techniques based on CRISPR-Cas technology, which enables targeted editing of DNA sequences. Both traditional and more recent techniques can be used to combine and permanently alter plant characteristics. Plant breeding is a key technology for simultaneously promoting efficiency, sustainability and resilience. Whatever the changes in environmental conditions and regardless of the techniques used, the overriding goal of plant breeding is to enable high and stable yields per unit of area by making plants more tolerant of biotic (fungi, bacteria, viruses) and abiotic (drought, heat) stresses and by making more efficient use of nutrients and other growth factors.

All crops are susceptible to damage from fungi, bacteria and viruses, which destroy a significant percentage of global harvests every year. Research into these harmful organisms and how to make plants resistant to them can thus contribute significantly to more efficient resource utilisation. The development of resistant varieties can help to reduce the use of plant protection products, thereby also lessening their negative impacts on biodiversity.

The use of breeding techniques to adapt plants to changing climatic conditions is far from straightforward. Complex cascades of processes within cells and biochemical reactions that also interact symbiotically with other organisms make it difficult to precisely modify the plant genome in order to achieve the desired effects. Further research into these mechanisms is thus particularly important. New technologies such as genome editing can play a crucial role both in research and in product development. When evaluating these technologies, it is important to carefully consider their opportunities and risks in order to ensure that they are used responsibly. Innovations in plant breeding will need to be exploited rapidly and to their full potential if we are to overcome the challenges currently facing the world.

The plant breeding techniques outlined above will not succeed unless they are accepted by the public. If the general public is not prepared to buy products that have been produced using these technologies, there is little point in adopting them. The public must therefore be provided with reliable information about their advantages and disadvantages. Transparency in the production and use of these plants is of paramount importance. CRISPR-Cas gene editing involves a targeted modification of the genome. While the use of chemicals and radiation to bring about random modifications of the genome is not classified as genetic modification, in 2018 the European Court of Justice (ECJ) ruled that plants modified using CRISPR-Cas gene editing techniques should be subject to the regulations governing genetically modified organisms (GMOs). This means that the cultivation of such plants and the sale of food and animal feed made from them requires prior approval within the EU. The approval process typically lasts 6 years and costs somewhere between 11 and 16 million euros.

The high cost of the approval process places serious constraints on the technology's potential applications. It means that new plant traits will only be developed if they promise to recoup these costs. In other words, the technology is not financially viable for niche fruits, niche plant characteristics or specialised applications. The costs are also beyond the means of most smaller businesses and public research institutions. This seriously limits the innovative potential of CRISPR-Cas technology by favouring the commercial exploitation of common agricultural crops with simple traits that are generally sold by large enterprises. There has been strong criticism of the underlying legal framework from within the German scientific community, which has proposed the development of alternative regulatory approaches with the necessary transparency and care.[88]

88 | See Leopoldina/DFG/Akademienunion 2019.

4.4 New processes and products

In the food industry, too, there are several innovations in the context of the circular economy and bioeconomy that enable the efficient, multiple reuse of raw materials and contribute to efficient land use (see Chapter 3.2). This can involve a wide range of ideally high-grade end uses, with the aim of supporting viable closed-loop recycling. In addition to the use of environmentally and climate-friendly raw materials, the design of processes and products that enable the efficient, multiple reuse of raw materials is also key.[89] Examples of these new processes include the development of technologies that use bioreactors to process secondary biomass into high-grade products such as the raw materials for biofuels or precursor chemicals.[90, 91] Efficient material recycling saves valuable raw materials and frees up land which can then be used for the production of food or animal feed.

Another example of a process that supports closed-loop recycling is the extraction of nitrogen and phosphorus compounds from the waste air and liquid waste from animal housing. The extracted compounds can subsequently be reused as mineral fertiliser. As well as reducing the nutrient input in ecosystems, the process enables the recovery of resources that can be used as fertiliser, thereby helping to reduce the amount of energy used in fertiliser production. The processing of slurry into mineral fertiliser and organic soil conditioner has a similar goal. The big challenge for this process is the removal of the slurry's high water content. The fact that mineral fertilisers are easier to transport and store facilitates the more sustainable, supra-regional use of these naturally occurring nutrients. A further example involves the use of distillates from dry wood distillation as soil conditioner. The use of products like this reduces the need for mineral fertilisers produced using energy-intensive methods. Nevertheless, it is necessary to compare the practicality and individual environmental footprint of the different processes. The extraction of compounds from slurry and the waste air and liquid waste from animal housing requires expensive equipment that is not only costly to purchase but currently also consumes significant quantities of energy.

Alternatives to traditional agricultural production technologies pursue a similar closed-loop recycling/resource efficiency approach. In hydroponics and vertical and urban farming, nutrient inputs are precisely controlled, thereby preventing emissions and allowing surplus nutrients to be sustainably recycled. This means that food can be produced closer to the consumer, since the production process is less dependent on local environmental conditions. While this can help to lower our food's carbon footprint by reducing the need for packaging and transport, the food's overall sustainability footprint is largely determined by the production method. Since these alternative production technologies are both costly and energy-intensive, their sustainability relies on the availability of renewable energy. These alternative production technologies are thus of particular value as a means of increasing domestic production in countries with limited potential for traditional agricultural production.[92]

More sustainably produced substitutes or new products are already benefiting from changes in demand. Just under half of those surveyed for the 2020 Nutrition Report had tried meat or dairy substitutes.[93] While the majority of these products are currently made with plant-based protein, in the future they could be supplemented by other protein sources such as algae, fungi and insects, provided that these become more widely accepted by the general public. The same applies to lab-grown meat, which already has a niche market and could become increasingly important in the future. However, many of these production methods still require substantial further development, particularly in terms of how to scale them up and address their consumption of resources such as energy. In the long run, these advances could lead to a reduction of livestock numbers in Germany, thereby diminishing the impact of livestock on the environment. As well as alternative protein sources, the optimisation of animal feeding strategies can also help to reduce the environmental footprint of livestock farming. This includes tailoring the composition of animal feed so that the content of various amino acids is no higher than is necessary for the animals' growth. Reducing the amount of surplus protein in the diet of animals such as pigs can improve animal welfare, reduce emissions and save on expensive raw materials for animal feed.[94]

The processes described above illustrate how circular economy principles can contribute to a more sustainable and resilient food industry. However, possible dependencies on material flows in other industries could affect resilience. Disruption to coordinated reuse cascades can cause bottlenecks, limiting the availability of resources for downstream uses. In the long run, the circular

89 | See Bröring et al. 2020.
90 | See Clariant SE 2020.
91 | See Covestro AG 2020.
92 | One example is Singapore's 30 for 30 Strategy, which aims to increase domestic production from 10% to 30% by 2030.
93 | See BMEL 2020a.
94 | See LfL 2020.

economy and global food industry could complement each other, creating a system that is both more sustainable and more resilient to sudden, crisis-induced changes thanks to its diversified production systems and delivery channels.

4.5 Consumers and retailers

The transformation to more sustainable and resilient food production will need to be supported by changes in consumers' purchasing and consumption behaviours. Considered, responsible consumer (buying) behaviour can bring about changes in food production. However, for this to happen, it will be necessary to overcome the problem of the consumer-citizen gap, also known as the attitude-behaviour gap. When it comes to sustainable consumption, good intentions often fail to translate into concrete action at the supermarket checkout. At least in some respects, people have hitherto been reluctant to put their money where their mouth is.

In fairness, it is not made easy for consumers to judge a product's sustainability. Even for cheap products, advertising and other channels sometimes create unrealistic expectations about how a product was made and how sustainable it is. The limited information that is typically available about a product's characteristics and how it was produced does little to help consumers make responsible choices. More useful guidance could be provided through digital information systems based on blockchain technology[95], coupled with independent trust marks (i.e. transparent labelling that provides adequate guarantees that the product claims are actually true) and an obligation for producers to provide the relevant information. Information stored in the blockchain could be accessed by consumers via an app, for example.

The existing mandatory animal welfare labelling for eggs could provide a model for other products such as meat, for which labelling is currently voluntary. Mandatory labelling also helps producers to plan ahead. While consumers cannot change production conditions on their own, agriculture, industry and the retail trade will respond to sustained changes in demand that reflect changing values. Ultimately, markets change as a result of both the "push" from suppliers (e.g. offering new meat substitutes) and the "pull" from consumers.

To provide a realistic reflection of a product's sustainability, prices must reflect negative externalities such as biodiversity loss or greenhouse gas emissions – otherwise, it will be future generations that have to bear the costs and consequences of the product's environmental impacts. Although this "internalisation of externalities" will make the product more expensive, technologies such as blockchain can be used directly at the point of sale to help people see and understand how the environmental, animal welfare and social costs have affected its price. In practice, however, it is far from easy to reliably identify and price all the relevant externalities, not least because there are so many of them.

Interest in sustainable eating and demand for more sustainable food have in fact been on the rise for several years. According to the 2020 Nutrition Report, meat consumption was already declining before the coronavirus crisis. More and more people are becoming flexitarians, eating less meat and choosing plant-based protein instead.[96] Healthy, organic and regional food products have all come to be regarded as more important during the coronavirus crisis.[97] However, the region where a product was produced does not in itself guarantee that it was produced sustainably – to prove this, additional information must be provided about how the product was grown or produced. Information about the product's source (where it was grown), CO_2 emissions and processing locations would serve to increase transparency.[98] Additional information could also shed light on social standards in food production both at home and abroad, for example by guaranteeing that no child labour was used in the production of imported goods.

Changes in consumer behaviour can be stimulated and supported through a variety of traditional and more innovative demand-side policy instruments. Besides information, education and hard instruments such as bans, taxes and subsidies, recent years have also seen attempts to guide consumer behaviour through "nudging".[99] This approach focuses on making it as simple and effortless as possible for consumers to make a particular decision. For example, staff canteens that provide people with more opportunities to try

95 | See acatech 2019.
96 | See BMEL 2020a.
97 | See Busch et al. 2020.
98 | A number of initiatives already exist, for example the "Regionalfenster" (regional window), a product labelling system that provides guaranteed traceability for consumers.
99 | See Reisch/Sunstein 2017.

healthy and sustainably produced foods can also influence their behaviour in their own homes, helping to reduce meat consumption and the associated resource consumption. Transparent nudging can provide a valuable addition to the arsenal of consumer policy instruments. It can also be an effective tool for reducing food waste – smaller plate sizes in staff canteens can encourage people to take smaller portions, for example. Restaurants can also contribute by making voluntary commitments to minimise food waste and enabling transparent verification of their compliance. The effectiveness of nudging increases if the desired social norms become established and communication reinforces the message that food is "too good for the bin".[100]

Consumer cooperation in reducing waste is key to the development of a more circular economy. It is essential for households to feed raw materials back into the processing cycle – household waste sorting is vital to raw material recycling, for example. A circular economy cannot succeed without this essential contribution from households – the public has to support the underlying values and act accordingly. Moreover, doing your bit for the circular economy should be rewarding, self-explanatory, quick and easy. Government can support a circular society through appropriate measures such as providing simple instructions on how to recycle and ensuring that recycling banks are easily accessible.

Regardless of a product's sustainability footprint, initiatives to minimise food waste can make an important contribution to efficient resource utilisation. Households are responsible for 55% of food waste in Germany, whereas significantly less food is thrown away in the food processing industry (15%), out-of-home eating sector (13%), agriculture (11%) and food retail sector (4%).[101] Prior to the coronavirus crisis, private households in Germany threw away an average of 75 kg of food per person every year. It is estimated that between half and two thirds of this food waste is preventable.[102, 103] Since around a third of people say they have been doing more home cooking since the start of the crisis[104], it can be assumed that food waste has increased even further during this period. At present, private households often have to rely on their own subjective experience and the best-before date when deciding whether food is unfit to eat and should therefore be thrown away . A number of innovative solutions to provide additional support are currently being trialled. These include a prominent sensor or scanner on the packaging that displays the current freshness of individual meat products or vegetables at all times. A basic knowledge of what is involved in food production, storage and preparation can also be extremely useful for consumers. People who have acquired these food skills either at school or through other educational channels are better equipped to use food carefully and thus to avoid waste.

100 | See Kameke/Fischer 2018.
101 | See Universität Stuttgart 2019.
102 | See BMEL 2020a.
103 | See Verbraucherzentrale NRW e.V. 2020.
104 | See BMEL 2020a.

5 Conclusion and outlook

The coronavirus crisis and its impacts have severely tested the structures and resilience of food supply systems all over the world – and Germany was no exception. However, even at the start of the pandemic's first wave in March/April 2020, Germany's food supply proved to be largely resilient, despite a few shortages of certain products and somewhat higher food prices, primarily for fruit and vegetables. Some uncertainty was initially caused by ad hoc measures that imposed restrictions at very short notice on goods transport and labour mobility between European countries. However, the relevant adjustments allowed most of these short-term restrictions to be quickly lifted. On the other hand, closures and restrictions in the hospitality industry continue to affect entire value chains for products used primarily in the catering trade, including various dairy products and potatoes grown for processing. Businesses throughout the relevant value chains now find themselves facing a financially insecure future. Particularly in Germany's meat industry, the entire value chain was also affected by the closure of a few major processing operations due to the highly concentrated nature of the abattoir sector. In the vast majority of cases, however, the combination of regional value chains and the food industry's access to global markets provided a resilient structure that has so far been able to cope well with the coronavirus crisis.

Internationally, the economic implications of the coronavirus pandemic are every bit as serious as its public health consequences. Although agricultural markets have stabilised following some initial volatility, millions of additional people in emerging and developing countries now have only limited access to food. People's purchasing power is being eroded due to loss of income caused by the economic downturn and as a result of the restrictions introduced by governments to tackle the pandemic. As well as poverty and hunger, this means that there is also a danger of hidden hunger, which occurs when people do not have enough micronutrients and trace elements in their diet. Germany has a responsibility to increase its international engagement to help tackle the impacts of the coronavirus crisis in the world's poorest countries.

It is not enough to judge the resilience of our food supply purely on its ability to cope with the short-term effects triggered by pandemics, natural disasters and other extreme events. There are a number of long-term challenges to the resilience of the food supply, especially in the agricultural sector, which will have to adjust to different environmental conditions as a result of climate change. A sufficient quantity of good-quality agricultural land must be maintained, while action must also be taken to address the severe decline in biodiversity. The coronavirus crisis hit Germany at a time when very dry summers in the previous couple of years had already demonstrated the impacts of climate change on crop performance. Land use conflicts and biodiversity loss also raise as yet unanswered questions about whether agricultural production volumes can be sustained. Addressing these challenges has become even more urgent in the light of a crisis that has highlighted the need for a sustainable and resilient food industry not just during the current pandemic but also beyond.

In view of the above, it will be important to focus on priority areas that strengthen the resilience of the food supply while at the same time improving compatibility with sustainability goals. This will require the involvement of a broad spectrum of actors. As far as the general public is concerned, changes in consumer behaviour can help to reduce food waste and increase demand for sustainably produced products. Changes to agricultural management practices that take changing and regional climatic conditions into account can support more sustainable food production by reducing emissions and other environmental impacts. More widespread use of new technologies, especially in the areas of smart farming and plant breeding, has particular potential to deliver the desired combination of efficiency and sustainability. Policymakers must therefore create a legal framework that supports the use of these technologies while also ensuring that innovations are used responsibly.

The transformation to resilient, sustainable agriculture will also require closer cooperation between researchers and farmers, coupled with an education campaign at every level of the agricultural education system. In the long run, the development and implementation of new processes and (substitute) products – for instance for more efficient protein production – can also contribute to a more resilient and sustainable food supply by diversifying value chains and saving resources. At a policy level, significantly greater prioritisation of and support for sustainable innovations and management practices in both Germany and Europe (primarily through the CAP) will be key to the transformation. In order to achieve sustainability and lasting resilience, individual measures and innovations must be anchored within an overarching systemic approach that looks beyond the immediate impacts of the current crisis and addresses the other, longer-term challenges. Sustainable agricultural intensification is a sustainable, efficient, profitable and resource-efficient approach that can serve as a model for the future.

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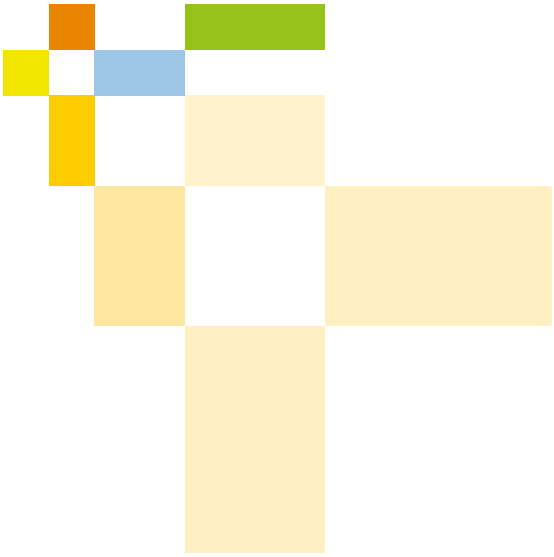

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The coronavirus crisis and its impacts have severely tested the structures and resilience of food supply systems around the world. Thanks to its combination of regional and global value chains, Germany's food supply is proving to be largely resilient, despite some problems at the start of the first wave in March and April caused by factors such as restrictions on entry to the country. Internationally, the economic crisis triggered by the coronavirus pandemic is having a particularly serious impact on access to food.

The mostly short-term effects of the coronavirus pandemic provide an opportunity to reflect on the future of our food supply. Agriculture in particular faces a number of major long-term challenges due to the effects of phenomena such as climate change and biodiversity loss. In order to meet these challenges and ensure that our food supply has the necessary resilience, we must develop solutions that guarantee future productivity while also improving the food industry's compatibility with sustainability goals. This IMPULSE examines different agricultural, technological and social priority areas that can play their part in achieving this objective.