

Eco-Ready Deliverable 1.4: Storylines developed for the Living Labs



**Eco
Ready**

Markus Dettenhofer¹, Giri Prasad Kandel¹, Kwadwo Gyapong Agyenim-Boateng¹,
Jana Poláková¹, Nina Muntean¹, Nils Bunnefeld², Marjana Vasiljević³

¹Czech University of Life Sciences, Prague, Czech Republic

²AlterNet - Eklipse, Belgium

³Institute of Field and Vegetable Crops (IFVC), Serbia



The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201

Technical References

Project Acronym	ECO-READY
Project Title	Achieving Ecological Resilient Dynamism for the European food system through consumer - driven policies.
Project Coordinator	Czech University of Life Sciences (CZU)
Project Duration	48 months

Deliverable No.	D1.4
Dissemination level ¹	
Work Package	WP1
Task	T1.3 (subtask 1.3.3 & 1.3.4)
Lead beneficiary	CZU
Contributing beneficiary(ies)	UED, IFVC, IFOAM, IUCN, ALTERNET, CUT
Due date of deliverable	31.07.2024
Actual submission date	

¹ PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)



**Funded by
the European Union**

The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201

Document history

V	Date	Beneficiary	Author
1	30.07.2024	CZU, ALTERNET, IFVC	CZU (Markus Dettenhofer, Giri Prasad Kandel, Kwadwo Gyapong Agyenim-Boateng, Jana Poláková, Nina Muntean), ALTERNET (Nils Bunnefeld), IFVC (Marjana Vasiljević)



Executive summary

Eco-Ready aims at “achieving ecological resilient dynamism for the European food system through consumer-driven policies, socio-ecological challenges, biodiversity, data-driven policy, and sustainable futures.” The end goal of this project is to be able to devise strategies to provide sustainability through an available, accessible, utilizable and stable food system in Europe. The ecosystem involving humans, plants, animals and microorganisms is very delicate and susceptible to multiple shocks, a major one being climate change, which has broad reached ramifications on our food system. For instance, food security is significantly affected by changes in climate beyond temperature rise (e.g., droughts, flooding, extreme weather events, heat waves). Similarly, the dynamic shifts in the biodiversity of species, above and below ground will affect the system of food production by disturbing the balance of healthy ecosystems. Furthermore, economies are also affected by the losses in food products and the systems supporting food production and supply chains. Projections for 2030 and 2050 do not give an optimistic look for the ecosystem, should the *status quo* remain unchanged. As it stands now, this trajectory will lead to a complicated future which warrants intervention. Once futures which indicate a threat to food security are recognized, plans for mitigation need to be initiated that consider approaches which are systemic and wholistic. The ten Eco-Ready living labs from the North, South, East and West of Europe have selected key drivers for their food priorities specific to their regions. Additionally, the scenario development teams, consisting of interdisciplinary teams of specialists, together with the living labs representatives, developed five scenarios for each of the ten living labs, resulting in a total 50 scenarios. These scenarios explore agricultural practices, policy changes, innovative farming ideas, and consumer-producer interactions to help mitigate future shocks.



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1 Introduction

Eco-Ready is a European project that accounts for the significant impact of climate change, biological factors, and other socio-economic challenges on food systems and food security at both regional and European levels. The Eco-Ready team is focused on addressing these issues with the mission of “achieving Ecological Resilient Dynamism for the European food system through consumer-driven policies, socio-ecological challenges, biodiversity, data-driven policy, and sustainable futures.”

To achieve this mission, Eco-Ready has selected ten living labs located in ten countries across Europe through an open selection process. These living labs cover the North, South, East, and West of Europe, encompassing all bio-climatic regions and their diverse weather and climatic conditions. The project assembled a team of experts in food security, economics, policy, plant breeding, entomology, water and climate dynamics, soil health, and animal sciences to work with the living labs, analyse the products selected by the living labs, and develop scenarios which will fit in with the goals of Eco-Ready. Details on the products and scenario development are addressed in sub-sections of this document.

In the section on selected products of the living labs, we provide a synopsis of the living labs and countries involved, the products studied, and their significance in these regions. Some products have cross-regional importance, overlapping in different climatic zones, indicating consumer perception, importance, and cultural significance. Conversely, some products are restricted to specific zones, revealing historical and cultural attachments to these products.

Each chapter of this document is designated for the host country of the living lab and presented in alphabetical order from the Czech Republic to Sweden. The chapter starts with the country profile that discusses the economy, climate, farming practices, and other areas of significance. Further, we describe climate change projections for 2030 and 2050, as detailed by the Intergovernmental Panel on Climate Change (IPCC) and other significant sources. These reports focused on mean air temperature, precipitation, sea level rise, extreme weather events, ecosystem and biodiversity and



socioeconomic impacts in these ten countries and, in some instances, the regions where the living labs are located.

Discussions with the living labs helped to identify the drivers influencing the food production system through the lens of climate change, biodiversity and food security. These drivers impact the projections of agriculture production and the potential shocks they pose on the food system, which include common stressors, such as drought, flash floods, and pest invasion, as well as economic and social aspects. A critical step in this process was the co-creation and training workshop, in Den Haag, Netherlands, on 27-28 June 2024, organised for the scenario development team members and the living labs. This workshop helped the team understand the vulnerabilities associated with climate change in their areas, systemic shocks, and the multidimensional consequences of these emerging dynamics. In addition to the co-creation workshop, a series of video calls between the living labs and a team of experts helped further identify gaps between the current state and the desired future state of food security, considering which drivers impact the resilience of food systems of the living labs.

Following the identification of product drivers, scenarios were developed that reflect the status quo of 2030 and 2050 for the food products identified (one per each living lab). The scenario development team identified shocks or extreme events (two per each living lab) which could drastically alter the expected trajectory of product security. Based on this analysis, the team further developed a range of approaches aimed at intervening or mitigating these shocks in the form of intervention scenarios (two per each living lab). These strategies included adaptive measures to enhance the resilience of agricultural practices, innovative approaches to improve biodiversity conservation, and policy recommendations to support sustainable food systems. The goal was not only to reduce the adverse effects of these shocks but also to proactively address vulnerabilities and build a more resilient and sustainable food system capable of withstanding future challenges. Each of the ten living labs have five custom-designed scenarios, with a total of 50 scenarios for all living labs combined, which are reflected in the subsequent chapter.



The discussion section of this document combines insights from all that has been studied in the different countries to provide a brief summary of the major categories of issues identified. The areas discussed resulted from the co-creative process of formulating this deliverable, which we found to be significantly important and will be crucial for achieving a sustainable agricultural/food system. This includes various dimensions such as farming practices, biodiversity in agriculture, the need for systemic changes, breeding and varieties, soil health, and interdisciplinary and transdisciplinary solutions and engagements, as well as policies.

Finally, we would like to show our gratitude to all who played a role in producing this document, Eco-Ready Deliverable 1.4. These include the living labs: THALLA, EcoReadyMasuria, CONCAT LL, LivOrganic, AideMec, ESAPPIN, PROBIO, SECO-Collab, LOFS and EcoVitaLL. We also acknowledge the contributions of the following individuals and organisations: Klara Bartonova, Kamila Báb'ková, Michaela Kolarova, Jan Kopecky, Stanislav Korenko, Mansoor Maitah, Marie Manasova, Marketa Mareckova, Marketa Miháliková, Vera Potopova, Trifan Tudor, and Miroslav Zouhar of Czech University of Life Sciences Prague (CZU); Andreas Katsiotis, and Nikolaos Nikoloudakis of Cyprus University of Technology (CUT); Andrea Wilson and Masoud Ghaderi Zefreh of University of Edinburgh, Tyler Arbour of IFOAM-Organics Europe; and Elodie Champseix of IUCN.



2 Selected products - Living Labs

Brief Introduction to the Products in Countries/Living Labs

The living labs across Europe are focusing on various agricultural products that are crucial to their respective regions. These products vary based on the bio-climatic zones and their specific regional importance, with some overlaps indicating broader significance across regions. Here, we show the products highlighted by each living lab or country, emphasizing both their unique and overlapping characteristics within different regions. The table 2.1 and figures 2-1 below show the living labs/countries, their regions and their products.

Table 2.1: Living labs and the selected products of importance

Country	Region	Products of Cross Regional Importance	Products of Regional Importance	6 th additional product
Czech Republic	Central and Eastern Europe	Pork, buckwheat, alfalfa	Organic crimson clover, spelt	
Denmark	Scandinavian and Baltic	Milk, apples, potatoes	Sugar beets, rapeseed	
France	Northwestern Europe	Wheat, milk (grass-fed cows), lettuce	Rapeseed, mushroom	
Germany	Northwestern Europe	Barley, strawberries/raspberries, Mushrooms, rapeseed oats		
Greece	Mediterranean and Southwest Europe	Honey, tomato, wheat	Gilthead seabream, European seabass, table olives	
Hungary	Central and Eastern Europe	Wheatgrass, baby-leaf salad, Millet	Red clover, sunflower	Amaranth
Italy	Mediterranean and Southwest Europe	Barley, tomato, wheat	"Coratina" olives, Local beans varieties	
Poland	Central and Eastern Europe	Milk, fodder maize, barley	Red clover, sunflower	
Spain	Mediterranean and Southwest Europe	Poultry, apples, wheat	Flathead grey mullet (<i>Mugil cephalus</i>), Olive oil	
Sweden	Scandinavian and Baltic	Leafy greens, microgreens, herbs	Chilis, brassica	





Figure 2-1: The distribution of the products across Europe as displayed on the European map

Shared Products across living labs

In figure 2-2, we show the distribution of the products according to their regions. Several products appear across multiple regions, indicating their broad importance. Barley is seen in Germany (Northwestern Europe), Italy (Mediterranean and Southwest Europe), and Poland (Central and Eastern Europe), reflecting its adaptability to different climates. Milk is also seen to be selected in Poland, France, and Denmark, signifying its essential role in the agricultural economy of Central and Northwestern Europe as well as in the Scandinavian and Baltic regions. Rapeseed is important in Sweden, Denmark, Germany, and France, highlighting its significance across varying climatic zones in Europe, including the Scandinavian and Baltic regions and Northwestern Europe. Apples are present in both Spain and far north in Denmark living labs.

indicating broad applicability. Despite its primary importance in Mediterranean countries like Greece, Italy, and Spain, wheat is selected in France, indicating its flexibility across different regions.

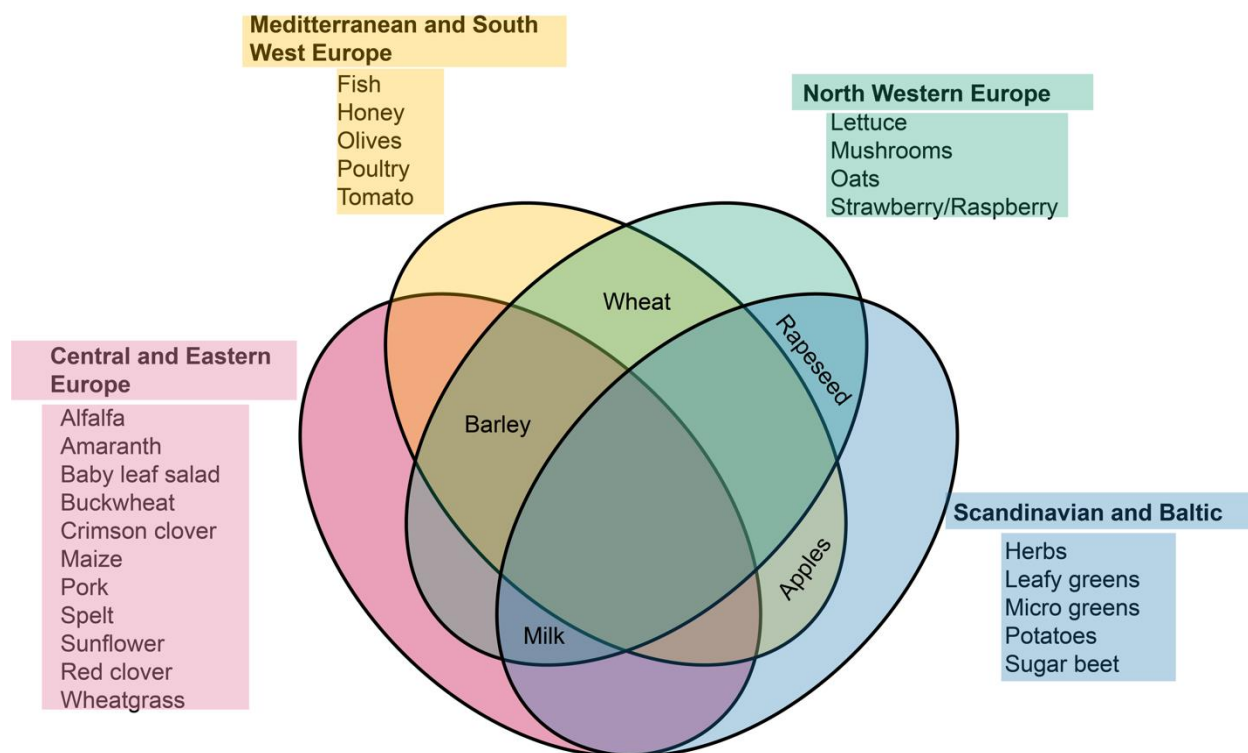


Figure 2-2: The products selected according to the different bio-climatic regions and ones that overlap across regions

Unique Products in Different Regions

In the Mediterranean region, wheat and olives are significant in Greece, Italy, and Spain, indicating their importance in Mediterranean agriculture. Similarly, tomatoes are also being selected in Italy and Greece. In Central and Eastern Europe, sunflower and red clover are selected in Poland and Hungary. In Northwestern Europe, mushrooms are selected in both France and Germany, highlighting their relevance in this region. In the Scandinavian and Baltic regions, there are potatoes, herbs, leafy greens, and micro greens, which may reveal a certain importance attributable to culture or adaptation due to the climate of the region.

3 Eco-Ready Living Labs

The Eco-Living Labs form a network of 10 Living Labs, each representing one of 10 different countries. These labs were initially selected to cover a wide range of regions across Europe. Each country hosts one Living Lab working with several partners. The following sections are organised according to the countries where the Living Labs are located.

3.1 Czech Republic

3.1.1 Dossier of Living Lab- country profile

Country - Czech Republic

Region in EU - Eastern Central Europe

Name of living lab - BIO Region Velke Hosteradky (PROBIO)

Partners - Czech Organics, s.r.o., Ekofarma PROBIO, s.r.o., PRO-BIO, obchodní společnost s. r.o.

Products - Pork, Buckwheat, Spelt, Alfalfa, Crimson clover



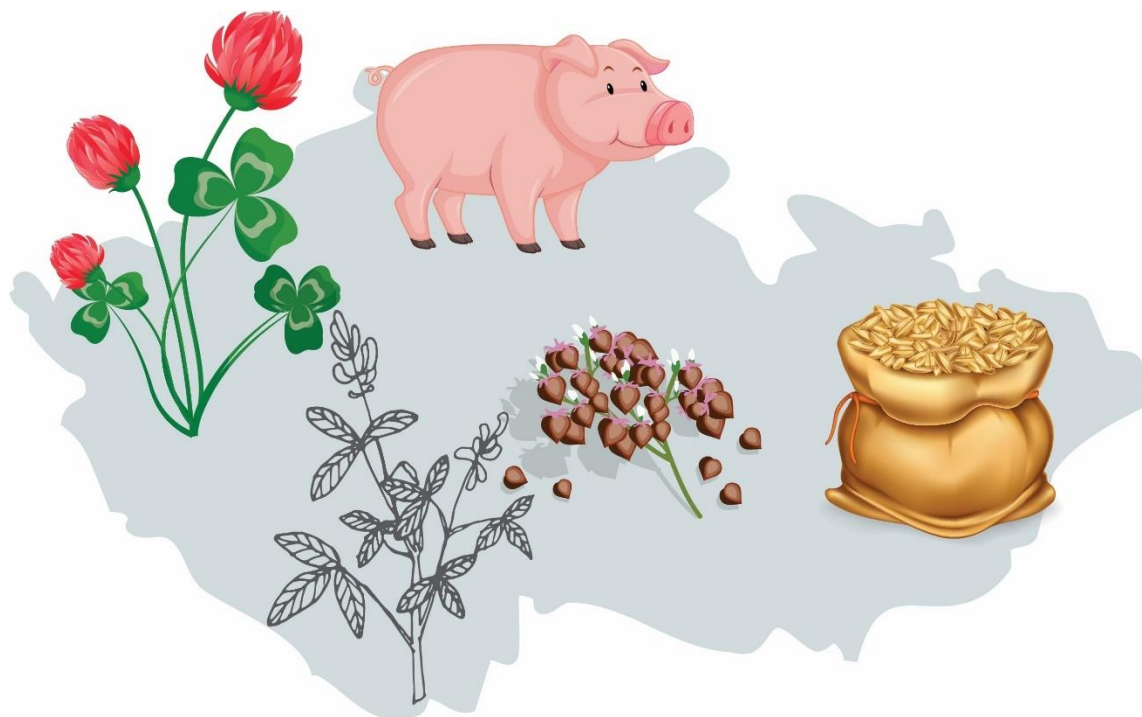


Figure 3-1: Map of the Czech Republic with products

Partner background information

Economics - The South Moravian Region has the largest number of agricultural units engaged in crop production in the Czech Republic. There are 3 448 agricultural holdings in South Moravia, the highest number in the whole of the Czech Republic which account for 363 173 hectares of land. It is the third largest area of arable land in the country. A total of 25 300 people work in agriculture in South Moravia, a quarter of them on a temporary basis. A third of the 18.2 thousand permanent farmers are women. Half of them is involved in wine production. Wine production is typical of agricultural production in South Moravia, with 94 percent of all vineyards in the country located in the region. "Since 1920, when the Statistical Office started monitoring the area of vineyards, the area has almost tripled," said Kratochvílová, adding that the latest agricultural data was collected by the Statistical Office last year as part of the Agrocensus structural survey project. The South Moravian Region is also the statistical leader in the area of orchards, with one fifth of the total area in the Czech Republic. The region grows 82% of domestic apricots and 73% of peach trees. Less well known is the fact that South Moravia produces more than half of the country's sunflowers. The



production of grain maize is also significantly higher than in other regions of the Czech Republic. Livestock farming in South Moravia is mainly focused on poultry and pig farming. Farmers in South Moravia breed 4.7 million poultry, the highest number in the country. Fattening chickens are the most common, with more than four million chickens accounting for more than a quarter of chicken farming in the Czech Republic. Winter barley is the most harvested crop in South Moravia and the yield of 6.65 tonnes per hectare is one of the highest recorded by farmers in the region since at least 2010. The yield of the most cultivated crop, winter wheat, is also very high for the dry conditions of South Moravia. The yield per hectare so far is 6.51 tonnes and more than half of it has been harvested, according to data published by the Ministry of Agriculture.

Policies - In the Czech Republic, the Eco-scheme programme provides financial incentives for farmers to adopt more sustainable practices. These include whole farm payments for different land uses such as grassland, arable land, set-aside land, specific crop types (orchards, vineyards, hops) and even short rotation coppice and tree nurseries. In addition, under the agri-environment-climate measure, premiums are available for specific measures. These include the conversion of arable land to grassland, the use of technologies that reduce greenhouse gas (GHG) and ammonia (NH₃) emissions (e.g., precision farming), the promotion of soil health through practices such as cover crops, integrated production or organic farming, and the maintenance of extensive grassland. Overall, agri-environment schemes aim to incentivise farmers to switch to practices that not only improve soil health and biodiversity, but also contribute to climate change mitigation through reduced emissions.

Farming practices - Common farming practices encompass a range of production systems, including conventional, organic, low-input, regenerative and no-till. Among these, organic farming is one of the fastest growing sectors. The number of organic farming units has increased significantly and now accounts for 15.96% of the total agricultural area. Crop rotation practices are diverse and include factors such as the name of the crop, its use (e.g., grain, silage, biomass), whether the crop is used internally and whether a cover crop is used. In this context, maize is particularly noteworthy as it is the most commonly used crop for anaerobic digestion in the country.



Viticulture is an important agricultural activity, with more than 19 000 farmers engaged in viticulture in the regions of Bohemia and Moravia. Recent changes in agricultural management practices have led to a reduction in grassland area and an increase in average field size. In addition, 38% of the Czech population grow their own fruit or vegetables. In terms of irrigation and fertilisation, Czech farmers predominantly use manure and slurry rather than mineral fertilisers, reflecting a trend towards more traditional and organic methods of soil enrichment.

Potential drivers

Biodiversity - Common drivers in biodiversity includes new breeding objectives, land-use change for breeding, seasonal grazing, genetic diversity, inbreeding (measure of genetic diversity within breeds), effective population size and predator abundance.

Climate - The city of Brno lies 241 metres above sea level and has a temperate oceanic climate. The long-term average annual temperature is 8.7 °C and the long-term average annual rainfall is 490 millimetres. January is the coldest month, with a long-term average daily temperature of -2.5 °C, while July is the warmest, with a long-term average daily temperature of 18.5 °C. June is the wettest month, with 72 millimetres of rainfall, while February is the driest, with only 22 millimetres of rainfall. The country faces several climate-related risks. Drought during the sowing and flowering seasons is a major challenge, with the greatest impact during grain filling. Heat stress during the growing season critically affects flowering. Winter brings the threat of black frost, and the Czech Republic is also exposed to fire, floods, hail and winterkill. In terms of climate and biodiversity, factors such as average daily temperature and relative humidity (THI), forage and fodder quality, methane emissions and manure management play a crucial role. These elements are integral to understanding and mitigating the impacts of climate change on agricultural practices in the region.

Food security - in the Czech Republic is a vital aspect of the country's overall well-being, combining agricultural productivity, trade policies, food safety regulations, social welfare programs, and environmental considerations. It has a diverse agricultural sector, with fertile land suitable for cultivating a variety of crops, including grains,



vegetables, fruits, and hops. Livestock farming, particularly pork and poultry production, is also significant. While the agricultural sector contributes to domestic food production, the country relies on imports for certain commodities such as fruits, vegetables, and grains. The government supports domestic farmers through subsidies, agricultural policies, and investment in agricultural infrastructure. However, achieving complete self-sufficiency is challenging due to limitations such as climate constraints and land availability. Czechia enforces stringent quality and safety standards in food production and processing to protect consumers' health and well-being. Regulatory agencies, including the Czech Agriculture and Food Inspection Authority (CAFIA), monitor food establishments, inspect products, and enforce food safety regulations. This ensures that food products meet high standards of hygiene, quality, and safety. The country imports a variety of food products, including fruits, vegetables, grains, and specialty items, from other European Union (EU) countries and beyond. Trade agreements and partnerships facilitate the importation of food items while also promoting exports of Czech agricultural products. The Czech Republic recognizes the importance of environmental sustainability in ensuring long-term food security. Sustainable agricultural practices, including organic farming, agroecology, and conservation agriculture, help protect natural resources, promote biodiversity, and mitigate the impacts of climate change on food production. In the context of food security and biodiversity, several key factors are influential. Vaccination and therapeutic treatments are essential to maintain animal health and food safety. Improved monitoring systems and AI methods are increasing agricultural efficiency. New breeding techniques and targeted breeding traits aim to develop more resilient livestock. Feed prices, water availability and changes in consumer diets also have a significant impact on food security and agricultural biodiversity.

Farming conditions

Water - During the last century, irrigation infrastructure was built on about 155 000 ha of agricultural land. The area equipped for irrigation was at its maximum in the period 1995-1997 at 132 401 ha. The area irrigated was largest in 1988 (99 115 ha) and declined later to about 48 000 ha at the beginning of the 1990s, about 35 000 ha in the mid-90s,



and 16 238 ha in 1997. Irrigation is nowadays only being used for crops that cannot be grown without irrigation or for those for which irrigation generates high-added value (vegetables, hop fields, orchards, vineyards, and potatoes). EUROSTAT reported areas irrigated of 16 870 ha in 2003 and 17 320 ha in 2005. The low figures for areas irrigated in the last ten years indicate that a large part of the former irrigation infrastructure seems to be dead and no longer usable. Therefore area equipped for irrigation was estimated for eight regions by choosing the maximum of the irrigable areas as reported by EUROSTAT for the years 2003 and 2005. The area equipped for irrigation per region estimated that way is summing up to 50 590 ha. It is visible in the table below. The main irrigation areas of the country were digitized from an irrigation map. The map showed areas in operation, areas under construction, and planned irrigation areas.

Table 3.1: Irrigated area in the Czech Republic

NUTS1-region	Area equipped for irrigation (ha)		Area actually irrigated (ha)	
Jihovýchod	21 120	834	20 286	6 687
Jihozápad	1 410	157	1 253	223
Moravskoslezsko	280	280	0	220
Praha	260	130	130	197
Severovýchod	4 380	365	4 015	1 277
Severozápad	9 340	325	9 015	2 987
Střední Čechy	12 180	868	11 312	5 993
Střední Morava	1 620	378	1 242	453
Czechia total	50 590	3 337	47 253	18 037

The area equipped for irrigation with groundwater was computed based on the data collected by the EU farm structure survey 2003 as described before. Area irrigated was computed for each region as an average of AAI reported by the EU farm structure surveys 2003, 2005, and 2007. AAI per region estimated that way is summing up to 18 037 ha.

Diseases, pests and plant protection

Several diseases pose significant challenges to pig health in the Czech Republic. These include *Streptococcus suis* infection, porcine epidemic diarrhoea (PED), porcine proliferative ileitis and porcine dysentery. African swine fever has been detected in wild boar populations but has not yet spread to domestic pigs. In addition, porcine reproductive and respiratory syndrome (PRRS) remains a concern for the pig industry.

Table 3.2: Diseases, pests and plant protection

Crop	Harmful organism	Species names	Plant protection practices
Alfalfa	Pest	Alfalfa leaf midge, alfalfa weevil, mirid bug, bishop, pea aphid, cowpea aphid, Curculionidae, alfalfa flower midge, thrips, lucerne leaf beetle, Small mammals, common vole.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Wilt (<i>Vetricillium albo-atrum</i> , <i>Fusarium oxysporum</i>); root and crown rot (different causal agents).	Clean seed, certified pathogen-free seed, seed treatment, land selection, cultivar selection, crop rotation, proper time of cutting, adequate fertility management.
	Weed	<i>Taraxacum sect.</i> <i>Taraxacum</i> , <i>Rumex</i> sp., <i>Tripleurospermum inodorum</i> , <i>Elytrigia repens</i> , <i>Poa annua</i> .	Mechanical weeding; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, clean seed); proper soil management.
Spelt, wheat, oat, barley, rye, einkorn, emmer	Pest	Powdery mildew; rusts; leaf spots of cereals: Septoria leaf blotch of wheat; tan spot of wheat; Ramularia leaf spot of barley; net blotch of barley; leaf stripe of barley; scald of barley; head blight; wheat bunts; eyespot; take-all; Barley yellow dwarf virus; Wheat dwarf virus.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management.
	Disease	Powdery mildew; rusts; leaf spots of cereals: Septoria leaf blotch of wheat; tan spot of wheat; Ramularia leaf spot of barley; net blotch of barley; leaf stripe of barley; scald of barley; head blight;	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess

		wheat bunts; eyespot; take-all; Barley yellow dwarf virus; Wheat dwarf virus	moisture in the field (plant density), adequate fertility management.
	Weed	Winter cereals - <i>Fallopia convolvulus</i>, <i>Tripleurospermum inodorum</i>, <i>Chenopodium album</i>, <i>Polygonum aviculare</i>, <i>Galium aparine</i>, <i>Cirsium arvense</i>, <i>Viola arvensis</i>, <i>Stellaria media</i>, <i>Elytrigia repens</i>. Spring cereals - <i>Fallopia convolvulus</i>, <i>Chenopodium album</i>, <i>Polygonum aviculare</i>, <i>Viola arvensis</i>, <i>Cirsium arvense</i>, <i>Tripleurospermum inodorum</i>, <i>Thlaspi arvense</i>, <i>Galium aparine</i>, <i>Anagallis arvensis</i>, <i>Capsella bursa-pastoris</i>, <i>Elytrigia repens</i>.	Mechanical weeding; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, clean seed); proper soil management.
Crimson clover	Pest	Alfalfa snout beetle (<i>Otiorynchus ligustici</i>), pea aphid (<i>Acyrtosiphon pisum</i>), Curculionidae (<i>Sitona lineatus</i> , <i>Sitona macularius</i> , <i>Sitona spp.</i>), Small mammals, common vole (<i>Microtus arvalis</i>).	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Root and crown rot (different causal agents).	Clean seed, certified pathogen-free seed, seed treatment, land selection, cultivar selection, crop rotation, proper time of cutting, adequate fertility management.
	Weed	<i>Elytrigia repens</i> , <i>Capsella bursa pastoris</i> , <i>Tripleurospermum inodorum</i> , <i>Stellaria media</i> , <i>Lamium purpureum</i> , <i>Galium aparine</i> .	Mechanical weeding; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, clean seed); proper soil management.

Soil - The Czech Republic covers an area of 78 871 km², of which 53.3% is agricultural land, including 37.5% arable land and 13.0% grassland. Forests cover 33.9% of the area, water 2.1% and built-up and other areas 10.7%. The dominant soil type is Cambisol, covering about half of the total area. Other soil types such as Gleysols, Stagnosols,

Chernozems, Fluvisols, Luvisols and Podzols each cover

The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201



less than 8% of the area. The region of South Moravia is characterised by a high proportion of Chernozems.

The main threats to soil quality and the sustainability of agro ecosystems in the country are soil water erosion, which affects 53.8% of agricultural land, reduced water retention capacity, soil compaction, which affects 40% of land, soil structure degradation, acidification, which affects 62% of soils, and soil sealing, with an average loss of 20 ha per day over the last 20 years.

3.1.2 Climate change and biodiversity projection for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:

3.1.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

The Czech Republic is experiencing a warming trend, particularly noticeable in the winter and summer. In winter, there is less frost and snow than in the past. In summer, the number of tropical days and heavy rainfall has increased. As a result, the vegetation in the region is beginning to resemble that of the Mediterranean. Since 1850, the average temperature in the Czech Republic has risen by about 2.4°C. By 2050, it is



projected to increase by another 1.4 to 1.9 °C. However, the extent of future warming depends on emissions of different greenhouse gases, which threaten the survival of many forests in our landscape. In the absence of substantial efforts to mitigate global warming, a 4 °C increase in temperatures in the Czech Republic by the end of the century, compared to the period between 1981 and 2010, could have significant consequences.

Projected Average Mean Surface Air Temperature Czech Republic; (Ref. Period: 1995-2014), Multi-Model Ensemble

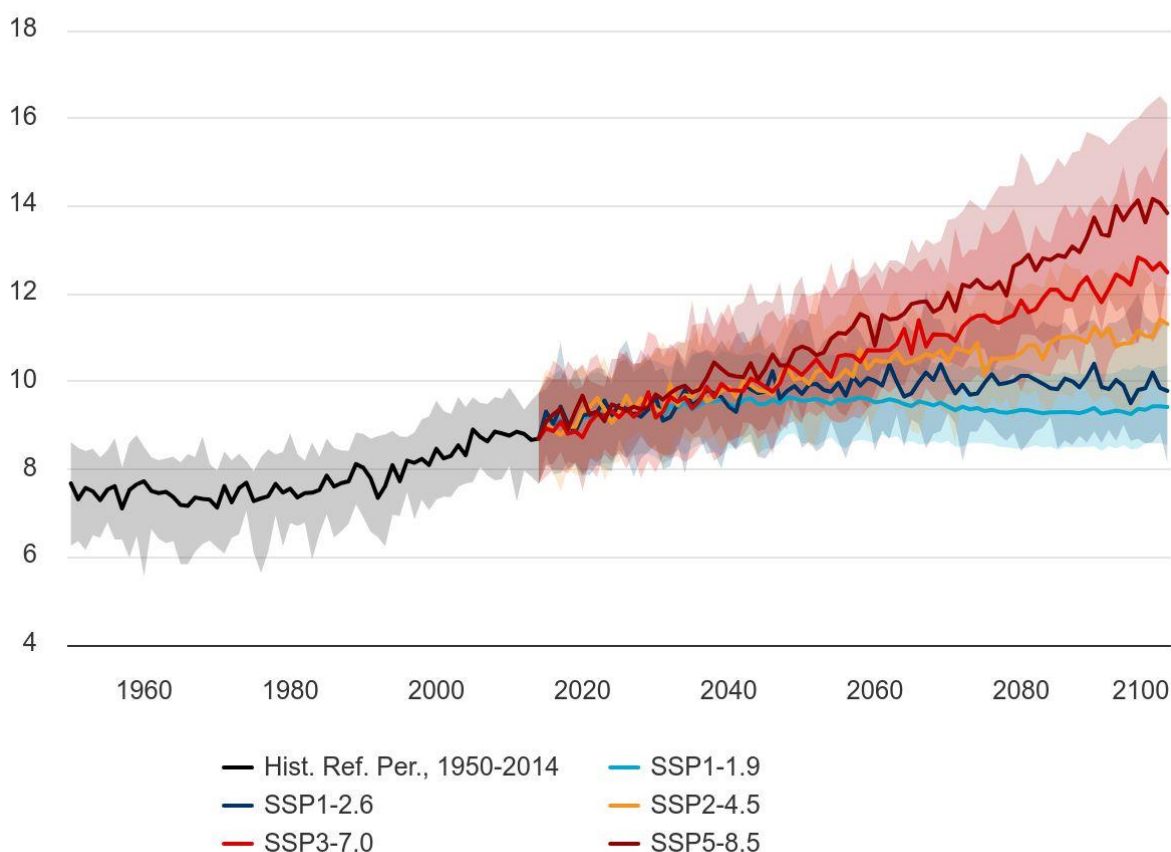


Figure 3-2: Projected average mean surface air temperature for Czech Republic

3.1.2.2 Precipitation patterns

Globally, precipitation patterns are expected to undergo notable shifts, with regions currently experiencing high levels of precipitation becoming even wetter and those currently experiencing lower levels of precipitation becoming drier. It is projected to be a significant decrease in rainfall in areas such as the Mediterranean, southern Africa,

and parts of Australia. Conversely, Northern Europe and parts of Asia are anticipated to experience increased precipitation.

The Czech Republic currently experiences an average annual precipitation of approximately 600-700 mm. Projections from 2030 to 2050, as detailed in the IPCC's Sixth Assessment Report, indicate that while yearly overall precipitation levels might not change significantly, the seasonal distribution will likely shift. Winter precipitation is anticipated to increase, frequently in the form of rain rather than snow. Conversely, the summer months may experience a reduction in rainfall, resulting in drier conditions. This altered precipitation pattern could intensify the frequency and severity of droughts and floods, with subsequent impacts on agriculture, water resources, and overall ecosystem health in the region. These changes underscore the necessity for implementing adaptive measures to mitigate the adverse effects of climate variability and ensure the sustainability of water management practices.



Projected Precipitation Czech Republic; (Ref. Period: 1995-2014), Multi-Model Ensemble

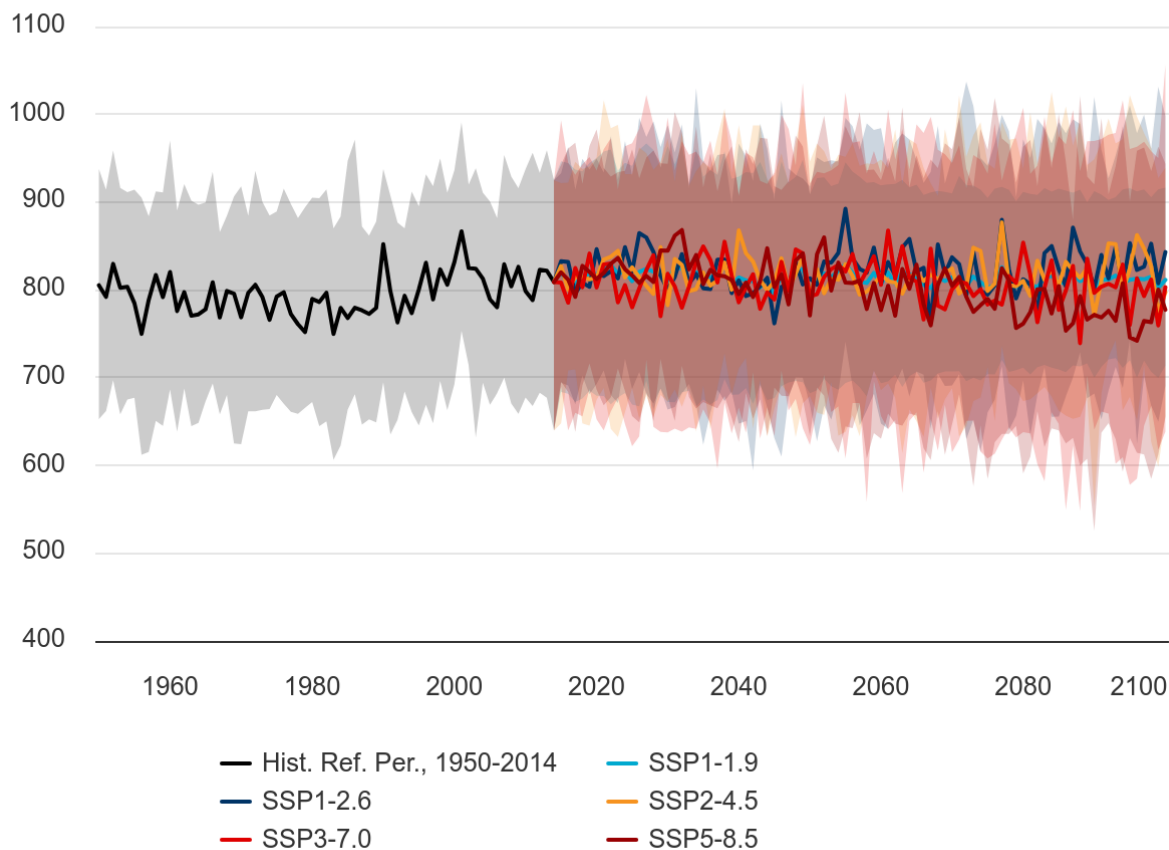


Figure 3-3: Figure 11. Projected precipitation patterns in Czech Republic

3.1.2.3 Extreme weather events

Climate change is causing an increase in the frequency and intensity of extreme weather events such as heatwaves, heavy rainfall, floods, droughts, and storms. This is primarily driven by the rise in global temperatures, which affects the water cycle, shifts weather patterns, and melts land ice. Regional variations in extreme weather events are significant. For example, the UK is experiencing more heatwaves, storms, and flooding, while the US is seeing more heatwaves, heavy downpours, and major hurricanes. These changes in extreme weather patterns will have significant impacts on various sectors, including agriculture, water resources, and ecosystems, and will require effective climate change mitigation and adaptation strategies.



The frequency and intensity of extreme weather events such as heat waves, heavy precipitation, droughts, severe storms and unseasonal frost are projected to increase in the Czech Republic due to climate change. By 2050, average temperatures are expected to increase by 1.5 to 2.5 °C, leading to more frequent and severe heatwaves with increased health risks. The frequency and severity of droughts are projected to increase, particularly in already arid regions, exacerbating water scarcity and affecting agricultural productivity. The frequency of heavy precipitation events is projected to increase by 10-20%, increasing the risk of flash floods and river flooding, putting strain on infrastructure and requiring improved flood management and urban planning. In addition, severe storms, including thunderstorms, hailstorms and windstorms, are expected to become more intense, causing damage to buildings, transport networks and power lines. Unseasonal frosts, particularly late spring frosts, could damage crops and adversely affect agricultural productivity. These changes will pose significant challenges to the Czech Republic's agriculture, health and infrastructure.

3.1.2.4 Ecosystem and biodiversity impacts

The rich diversity of life on Earth is rapidly declining due to climate change. Rising temperatures are forcing species to migrate towards the poles in search of habitable environments. The natural balance of ecosystems is disrupted as extreme weather events become more frequent and severe. Warming oceans are devastating coral reefs, while rising sea levels flood coastal habitats. These changes are not isolated; the effects of climate change are visible worldwide, from melting tundras to drying rainforests. The decline in wildlife populations is staggering, with a 69% decrease since 1970. Species with limited ranges, like polar bears on shrinking ice floes and isolated island species, are at the highest risk of extinction. Climate change is not just a future threat; it is a current crisis for biodiversity, demanding urgent action.

Climate change is having a profound impact on ecosystems and biodiversity in the Czech Republic. The rise in temperatures and changing precipitation patterns are leading to shifts in vegetation zones, biodiversity loss and disruption of ecosystem functioning. Changes in phenology, such as shifts in the timing of biological events, affect plant

flowering, migration patterns and hibernation cycles. In The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201



addition, water availability and quality fluctuations affect freshwater ecosystems and species dependent on them. The increased risk of invasive species and habitat loss due to extreme weather events and rising sea levels further exacerbate biodiversity loss. These changes affect natural ecosystems and threaten the provision of essential ecosystem services on which human well-being depends. Urgent action is needed to mitigate these impacts and safeguard the Czech Republic's rich biodiversity and ecosystems for future generations.

3.1.2.5 Socioeconomic impacts

The socioeconomic impacts of climate change are significant and far-reaching, affecting various aspects of human life and the environment. Climate change is expected to lead to substantial economic losses, particularly in developing countries, and push more people into poverty, especially in Africa. The negative impacts on health could exceed US\$2 billion by 2030, and more than 50 million people in Africa could face water distress due to climate change. Energy security, food security, and water resources will also be affected, with increased energy demand and changes in precipitation patterns, stream flow, and groundwater levels. The generation potential of some energy sources, such as solar, wind, and thermal power, will be negatively impacted. These socioeconomic impacts will vary spatially and temporally, with developing economies and the long-term experiencing more severe consequences.

Food security: Climate change threatens agricultural productivity in the Czech Republic, with crop yields projected to decline. By 2050, wheat yields could fall by up to 16%, affecting food availability and prices.

Economic costs: Climate change-related events such as floods and droughts are significant. In the Czech Republic, economic losses from floods increased by 73% between 1980 and 2014.

Health risks: Climate change exacerbates health risks, including heat-related illnesses and vector-borne diseases, leading to additional health burdens and costs.



3.1.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in the Czech Republic and their specific focus on different products.

Table 3.3: Drivers of products for the Czech Republic

Products- Czech Republic					
	Pork	Buckwheat	Alfalfa	Crimson clover	Spelt
Drivers	1. Summer heatwave 2. Animal and crop integration system 3. Feed 4. New breeding 5. Pathogens	1. Earlier harvesting 2. New breeding 3. Sustainable intensification 4. Precipitation changes 5. Nutritional quality	1. Precipitation changes 2. Soil moisture 3. Crop rotation 4. Resistant cultivar 5. Animal diet	1. Soil moisture 2. Using a diverse crop portfolio 3. Animal diet 4. Crop mixture 5. Resistant cultivar	1. Precipitation changes 2. Sustainable intensification 3. Crop mixture 4. Using a diverse crop portfolio 5. Nutritional quality

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.1.4 Living Lab scenarios

BIO region Velke Hosteradky

The Living Lab BIO Region Velke Hosteradky is a farmer's cluster that lies in the South Moravia Region of Czech Republic. EKOFARMA PROBIO, the local farm at Velke Hosteradky, decided to convert to organic farming within 371 ha of arable land. Besides organic farming, heritage and traditional varieties of cereals and buckwheat have been reintroduced and cultivated to better adapt the crop production to climate change but also to prevent further soil quality deterioration. Biodiversity oriented measures have been implemented such as cover crops, flower strips, nest boxes, planting of fruit trees etc.

Products \ Scenarios	Pork	Buckwheat	Alfalfa	Crimson Clover	Spelt
1. Status quo for 2030 - 2050	X	X	X	X	X
2. Shifting Sands of South Moravia: Extreme weather fluctuations	X	X	X	X	X
3. The Organic Squeeze: Market disruption	X	X	X	X	X
4. Enhancing Soil Health and Biodiversity for Sustainable Farming	X	X	X	X	X
5. Seeding Organic Stewards	X	X	X	X	X

Scenario 1: Status quo for 2030-2050

Czech is expected to continue to experience a warming trend, particularly noticeable in the winter and summer. In winter, there is less frost and snow, but more rain than in the past. In summer, the number of tropical days and heavy intermittent rainfall has increased, however with a reduction in overall rainfall, resulting in drier conditions. Due to the weather and climatic conditions, the region is well known for being the most fertile, but at the same time, the most drought-prone area of the country. The main drivers are the high temperatures, unbalanced distribution of precipitation (drought and flash floods), artificial drainage of the landscape and intensive agricultural land use. The majority of the agricultural activity in the region still remain conventional, which either empowers the negative effects of climate change (e.g., soil erosion) and results in biodiversity deterioration.

Pork production

- **2030:** Organic pork production will focus on animal welfare, sustainable land practices, and providing high-quality meat. While a smaller market compared to conventional pork, it's will face market competition. Pigs are raised with outdoor access, being fed organic fed, free of synthetic fertilizers or pesticides. The driver of increased drought brings heat stress to pigs, which affects their productivity. Local heat stress will be measured by local meteorological stations.



- **2050:** If economic conditions change and consumers become more price-sensitive, demand for organic pork might decline, additionally alternative labels, such as “free-range” or “antibiotic-free” pork may cut into the organic market share. More frequent disease outbreaks, potential organic feed shortages, and overall land availability may become important risks. A customer shift in dietary preference may witness a move away from pig to other meats or plant-based substitutes. Changes in organic policy standard and labelling could impact this market.

Buckwheat production

- **2030:** Sowing of buckwheat typically occurs in spring, but with extending of the growing season, it will be possible to grow buckwheat as a second cash crop after early harvested crops such as barley, peas or crimson clover. Buckwheat will continue to be incorporated into a crop rotation cycle helping to maintain all year-round soil cover, suppressing weeds and mobilising phosphorus in the soil. Natural pest control methods like attracting beneficial insects and birds will continue to be critical to prevent chemical use.
- **2050:** The supply chain of organic seeds may not be stable due to lack of customer demand in the future. Extreme weather events like droughts or heavy rainfall could disrupt buckwheat growth and yields and its reliance on cooler climates could also be challenged by rising temperatures. Without the use of synthetic pesticides, organic buckwheat might be more susceptible to pest and disease outbreaks. Developing effective organic pest and disease management strategies is crucial for long-term sustainability.

Alfalfa production

- **2030:** Alfalfa is a nitrogen-fixing legume and planted in a multi-year rotation with smothering crops like corn or cereals helps suppress weeds. Alfalfa thrives with moderate rainfall, but extended dry periods can stress the plants, slow down establishment of the crop and reduce yields. While alfalfa is generally winter-hardy, harsh winters with extended periods of freezing temperatures can



damage the plants. Pests such as Alfalfa weevils, aphids, and mainly fungal diseases will cause yield losses.

- **2050:** Droughts are expected to become more frequent and severe which will put a strain on alfalfa's water needs leading to yield reductions. Erratic rain patterns - heavy downpours can lead to soil erosion, while prolonged dry periods can stress the plants. pests and diseases that target legumes might adapt and become more resistant to organic control methods. Organic certification regulations may change, raising potential risks to alfalfa production.

Crimson clover production

- **2030:** Crimson clover is a nitrogen-fixing legume and planting it in rotation with other crops can help to suppress weeds. Crimson clover is planted in the late summer, typically at the end of August, and can be harvested for hay, silage when the flowers are in bloom (typically in May or June) or for the seeds production (typically in end of June). Extended periods of freezing can damage seedlings and long dry spells are not well tolerated, as crimson clover thrives in a moist environment. Also, this crop is susceptible to fungal diseases, particularly mildew.
- **2050:** Future excessively hot summers can lead to stress on the emerging plants, reducing yields and seed production. Droughts or erratic rainfall patterns can make it difficult to establish and maintain the clover crop. On sloping fields, repeated cultivation without preceding cover crops in summer can increase the risk of soil erosion, especially during heavy rainfall events. Over time, pests and diseases that target legumes might adapt and become more resistant to organic control methods. Organic certification regulations may change, raising potential risks to crimson clover production.

Spelt production

- **2030:** Spelt, which is typically planted in the late fall, can tolerate a wider range of soil conditions compared to common wheat varieties. Spelt is harvested later than most wheat varieties and requires less nitrogen inputs. Spelt is affected by



many of the same pests as conventional wheat varieties, although is more resistant due to its hardier husk.

- **2050:** Spelt is a niche grain compared to wheat. Consumers might not be familiar with it or its benefits, leading to lower demand. Due to lower yields and additional processing steps (dehulling), spelt products can be more expensive than wheat counterparts, potentially discouraging some consumers. Large-scale spelt production could face similar sustainability challenges as conventional wheat farming, such as water usage and soil health, as well as emerging pests.

Scenario 2: Shifting Sands of South Moravia: Extreme weather fluctuations

In the future, the negative impacts of global warming and climate change will be increasingly more apparent. Therefore, in order to meet the demands of the food and feed industries, crop production must adjust to unfavourable growing circumstances.

Shocks: Extreme weather fluctuation will become more frequent. These include:

1. Droughts
2. Soil erosion
3. Ground water depletion
4. Pest invasion
5. Tornadoes (wind-driven rainstorms)
6. Hail damage
7. Storm damage resulting in lost yield
8. Lodging (roots not strong enough)

- **Pork:** Extreme weather can indirectly affect pork production by impacting the availability and price of feed crops like spelt, alfalfa, and clover. Droughts or floods can reduce harvests, leading to higher feed prices and potentially impacting farm profitability.
- **Buckwheat:** This cereal is known for its resilience in poor soil conditions and cooler climates. However, heavy rain or flooding can damage buckwheat crops.



- **Crimson Clover and Alfalfa:** These leguminous forage crops that are often grown for animal feed. They are relatively cold hardy but can be susceptible to drought and heat stress. During dry periods, reduced forage production can impact livestock feed availability.
- **Spelt:** Spelt is generally considered more tolerant of harsh conditions than common wheat. However, extreme weather events like hailstorms or extreme heat can still significantly reduce yields.

Soil erosion, loss of organic matter and climate change effects cause a decline in the soil retention properties. The current state of agricultural landscape and farming intensity have an adverse effect on biodiversity and ecosystems. The development, yield, and quality of crop plants are all negatively impacted by drought stress which directly influences lower productivity of field crops. When it comes to water quality issues and viable agricultural land, erosion is a major worry. This can be mitigated by diversifying crops and selection of less susceptible plant genotypes to abiotic stressors.

Mitigation activities to this scenario are addressed in Scenario 4.

Scenario 3: The organic squeeze: Market disruption

The organic food market is growing each year on a global scale. In comparison with other Central European and Eastern European countries, the Czech organic food market can be described as developed. Many studies on organic agriculture suggest that organic practices are less harmful for the environment, may foster social well-being and may lead to economic resilience. Others argue that organic systems yield, on average, about 20 percent less than comparable conventional systems. The matter of potentially lower yield, and decreasing demand from consumers will, in this shock scenario, create a situation where the organics market faces even greater pressure from market forces.

Shocks: Economic/trade matters, inflation pressures, combined with increasing prices of farming inputs, transportation, and storage costs make organic farming no longer economically viable.

Factors influencing the market pressures:

Organics prices are too high - the average consumer cannot afford these products. The consumer base is reduced due to affordability issues. Potential market shrinkage results if prices are not controlled, with a need for price stabilization measures to maintain consumer interest and market growth, (e.g., implementing principles of True cost accounting).

The market's changing demands for organic - price fluctuation influences the farmers profit margins pushing production away from organics.

Although trade with EU favours an open market, the fluctuation in traditional demand for Czech organic products from Western EU demand decrease. With an increase in domestic production in other EU member states, the demand for Czech organic products suffers.

Inflationary control has been an ongoing issue for the local market (Czech Republic). As the Czech Republic is on its own currency (CZK), it does not have the buffering capacity of the Euro and will be susceptible to future inflationary pressures.

European policies which favour organic production, such as the Green Deal and the Farm-to-Fork policies could slide into reversal. Thus, it would be envisioned that priorities for subsidies would be given to others farming initiatives other than organics. Threats due to other labels such as “non-GMO” or “raised without antibiotics, may gain acceptance at the expense of an organic or “bio” label. Labelling changes to organic requirements may additionally raise costs.

Extreme events such as war and trade embargoes could further damage the organics market.



Scenario 4: Enhancing soil health and biodiversity for sustainable farming

Food and nutrition security can be improved through the introduction of various crops which at the same time enhance agricultural biodiversity (genetics, species, and environment). This is because it protects against insects and diseases that cause diseases, restricts growth of unwanted plants and helps to prevent erosion of soil, while maintaining soil moisture.

Interventions: Resilience to extreme climate fluctuation can be derived from an intervention focused on enhancing biodiversity and growing soil organic matter.

2030: By having a large diversity in crop rotations and longer rotation cycles, farmers support the development of soil biodiversity and work to reduce the prevalence of pests and fungi. In addition to biodiversity directly related to productive organisms (agricultural crops and animals), the crop associated biodiversity (biodiversity of non-productive organisms) that inhabits agricultural landscapes, play crucial roles in maintaining the health, stability, and productivity of these systems. Their roles in pollination (e.g., bees, butterflies, birds), pest control (natural predators such as ladybugs, spiders, predatory beetles or parasitoids such as certain wasps), nesting sites, soil health (bacteria, fungi, micro-, mezo- and macrofauna acting as decomposers, nitrogen fixators), water management (organisms improving soil structure and thus water retention and infiltration), climate resilience (non-productive organisms such as weeds can promote local biodiversity, especially by creating a suitable habitat for several pollinator species, and waste and pollution management (composting, bioremediation, waste decomposition) highlights the importance of these organisms within agricultural landscapes.

An organic farming approach in itself is a good guarantee for maintaining and enhancing biodiversity of ecosystems. Besides this, other ways can be maintaining and restoring natural habitats such as hedgerows, buffer strips, field margins, as well as intercropping, establishing conservation areas or reserves within or adjacent to



agricultural lands to preserve native biodiversity. An important aspect would be providing education and training for farmers and communities about the benefits of biodiversity and how to implement practices that enhance it by conducting regular assessments of biodiversity to monitor the effectiveness of conservation practices and using monitoring data to adapt and improve management practices continuously.

2050: Soil organic matter is predicted to decrease under all IPCC scenarios. Increasing and maintaining the soil organic matter is the most important measure to tackle extreme weather conditions (with regards to strong precipitation events and droughts). Farmland production in the long-term would rise, ensuring better quality products, however more mixed cropping and stock alternatives would be needed to achieve these goals. Resource conservation agricultural practices, such as organic agriculture, conservation agriculture, climate-smart agriculture, agroforestry and agro-ecology, may help stabilize or even boost agricultural productivity in the long run. The planting of trees within the region of South Moravia, in the form of mixed forests for landscape improvement will help prevent the damages caused by some extreme weather conditions such as windstorms, prevent further soil erosion and increase soil biodiversity in adjacent fields.

Climate change affects disease outbreaks, particularly heat stress in pigs, may allow for pathogens to infect animals with weakened immune responses. This can be mitigated on the medium- to long-term by breeding pigs that are more resilient to climate extremes and resistant to pathogens which become more prominent with increased temperatures.

Look to the increase in crop diversification. This would also have positive effects on the soil and biodiversity. The suitability of certain crops, such as cereals, buckwheat or legume crops in erosion-prone hilly areas, is affected by rising temperatures and changing rainfall patterns. These climate change impacts can be measured using satellite data on soil organic matter and weather stations. Farmers can also diversify their crops, for example, by growing spelt, a drought-resistant crop, or pulses such as beans and peas, which improve soil health and biodiversity. Implementing these



changes can be supported by EU subsidies for organic farming and policies to encourage crop diversification.

By following the basic principles of organic farming and by following the phytosanitary periods between each crop family (how often the same crop is grown in the same field), we can control disease outbreaks at the moment. With climate change predictions (warmer winters) and longer vegetation period, these methods will be adapted based on the individual pest/disease outbreaks for individual crops/products.

Scenario 5: Seeding organic stewards

Organic agriculture is generally considered as an important path of sustainable agriculture; however, it will be under threat without devising measures to ensure its economic viability. This intervention scenario tackles this challenge through the development of education programmes for a new generation of farmers, enabling a local supply chain, and revamping policies.

Interventions: Enable young people to become farmers and develop the community/market support, as well as policies to enable organic farms.

Under the Green Deal's Farm-to-Fork strategy, the European Commission has set a target of "at least 25% of the EU's agricultural land under organic farming and a significant increase in organic aquaculture by 2030". Both the Farm-to-Fork Strategy and the Biodiversity Strategy for 2030 address the need to increase the share of organic farming, decrease the use and risk of pesticides, fertilizers, and antimicrobials in agriculture, and increase the share of landscape elements and space set aside for nature.

Education:

- Integrate hands-on agriculture programmes into schools, starting from elementary levels. These programmes would involve students in activities like planting seeds, tending to gardens, and learning about local food systems.

Secondary and technical school programmes would offer advanced courses in



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sustainable farming practices, including organic methods, soil health, and agritech applications.

- Pair aspiring young farmers with experienced organic farmers for mentorship and apprenticeship opportunities. This provides hands-on learning and fosters a sense of community within the agricultural sector.

Awareness rising:

- Implement awareness rising campaigns to highlight the nutritional values of organics. Organic sections should be enlarged in the supermarkets and displayed more prominently. Marketing should include the whole production system benefits especially from the farmers perspective.
- Include clear presentations of the benefits of no added chemicals to food and the ill effects to health. Note - the environmental benefits to farm organic could be used to target young people as a form of educating consumers.

Local market supply chain:

- Encourage the formation of farmer cooperatives to aggregate produce, streamline logistics, and improve bargaining power with distributors and retailers.
- Facilitate the growth of Community Supported Agriculture, which connects farmers directly with consumers through subscriptions. This strengthens the local food system and creates a loyal customer base for organic farmers.
- Develop online platforms specifically for local organic produce, connecting farmers directly to consumers and restaurants seeking fresh, locally sourced ingredients.
- By building the community of farmers, also enable the seed supply chain to strengthen.



Policy & subsidies:

- Offer government-backed loan guarantees and grants to young farmers starting organic farms. This reduces financial barriers to entry and encourages investment in the sector.
- Implement initiatives to make farmland more accessible to young farmers. This could involve land trusts, land-lease programs, or tax breaks for landowners who lease to young organic farmers.
- Develop policies to promote utilization of less productive land for organic meat production (ruminants) and less dependence on imported grains. This approach allows more productive land to be dedicated to growing human food, ensuring better land, higher efficiency and price stabilization. Such policies should be followed measure to allow for diet changes and waste reduction with livestock production
- Provide financial incentives for farmers transitioning to organic certification. This could offset the initial costs and encourage wider adoption of organic practices.
- Provide systematic support for organic farming, not only the production of end-product foods, but rather the whole process of farming practices. Put differently, ensuring practices which aim for resource conservation such as conservation agriculture, climate-smart agriculture, agroforestry, agro-ecology, regenerative agriculture and crop rotation for the long-term, beyond 5 years, are supported. Consider matters beyond immediate yield to promote sustainable long-term land-use and growing soil organic matter, for the fertility of crop lands.



3.2 Denmark

3.2.1 Dossier of Living Lab- country profile

Country - Denmark

Region in EU - Baltic and Scandinavian

Name of living lab - Building resilient organic food production systems - a multi-actor approach for Danish living lab (LivOrganic)

Partners: IFAU Institute for Food Studies & Agri Industrial Development ApS, Aarhus University, department of Agroecology, Organic Denmark, MAA.C ApS.

Products - Milk & Dairy (cow's milk), Apples, Potatoes, Rapeseed, Sugar beets.



Figure 3-4: Map of Denmark with products



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Partner's expertise

1. *IFAU Institute for Food Studies & Agri Industrial Development ApS*- data analysis, digitization, robotic adaptation in agriculture, for sustainable and resilient agri-food sector.
2. *Aarhus University, department of Agroecology* - crop cultivation, research, field and laboratory facilities.
3. *Organic Denmark* - association of organic companies, farmers, professional kitchens and consumers, bring together smaller companies to work professionally with retail, and also help the individual retailer develop their organic marketing strategy.
4. *MAA.C ApS* - Promoting organic food producers.

Infrastructure - Offices, Laboratories and fields/greenhouses.

Partner background information

Economics - Similar to the entirety of Denmark, the main crops grown in the Aarhus Region are small grains, primarily wheat and barley. These crops encompass over half of the total agricultural area in Denmark. Fodder crops: Mainly grass and maize for silage, these crops account for a significant portion of the land, contributing to the region's strong livestock sector.

The region's agricultural output is diversified and economically valuable due to the inclusion of important crops such as rapeseed, sugar beets, and various types of grass seeds. Vegetables and potatoes, while covering a smaller area compared to other categories, these crops play a vital role in the region's food production and contribute to dietary needs. Denmark is a major exporter of rapeseed and rapeseed oil. The total area under rapeseed cultivation in Denmark varies each year. However, to provide a sense of scale, in recent years it has fluctuated between approximately 150 000 to 250 000 hectares. According to the latest data from the Food and Agriculture Organization of the United Nations (FAO), Denmark's rapeseed production in 2021 was around 1.05 million tonnes. Denmark is an exporter of sugar. In 2021 Denmark produced



approximately 7.2 million tonnes of sugar beets, according to FAO. The area dedicated to sugar beet cultivation also changes each year, but in recent times it has generally been around 30 000 to 40 000 hectares.

Livestock: Denmark is a major producer of dairy products, and the Aarhus Region contributes significantly to this production.

Fish Industry: The Aarhus Region itself doesn't hold a significant position in the Danish fish industry. This is mainly due to two key factors:

Geographic Location: The major fishing ports and key fishing grounds in Denmark are located on the western coast of Jutland and the northern tip of the country, far from Aarhus on the eastern coast. These areas, like Skagen and Hirtshals, boast closer proximity to the North Sea, a critical factor for the industry.

Historical Context: While the Aarhus River was once used for commercial fishing, particularly for eel, its decline and eventual transformation into an urban waterway have significantly diminished any local fishing activity.

Despite the lack of a major fishing industry in the Aarhus Region, Denmark as a whole is a significant player in the global seafood market. It holds the fifth place in the world for fish and fish product exports. Although not a major producer, Aarhus does enjoy a thriving seafood culture.

Policies - *Eco-scheme for new regulatory model*; Eco-scheme for organic farming; Eco-scheme for environmentally and climate-friendly grass; Eco-scheme for extensification with ploughing; Eco-scheme for plants; Eco-scheme for biodiversity and sustainability. *Agri-environment-climate* - AEKO Management of grassland and natural areas (N2000) AEKO One-off compensation for the retention of wetlands and lowland projects.

Farming practices - It includes conventional, organic, regenerative, no-till Farming. Organic farming contains about 11,54 % of total Agri-land in Denmark. *Re-circulation* of nutrients and organic matter (as organic fertilizers) from urban to rural areas. *Crop rotation* and planting catch crops are practised (Ryegrass, red and white clovers, yellow mustard, winter radish, common and winter vetches, winter rape, and mixes of these crops are used as cover crops. As of 2018, Denmark has the highest organic market share globally (11%) and is the first country to pass the 10% mark. Organic market demands



are increasing; the share of agricultural land in organic farming was 8.1% in 2016, mostly based on dairy farming systems. *Irrigation* is mainly used in horticulture or to grow semi-intensive or intensive field crops like maize, potatoes, and sugar beets on coarse-textured or shallow soils. Irrigated areas comprised less than 50% of the areas equipped for irrigation in 2003.

Potential drivers

Biodiversity - it includes new breeding objectives, land use change for breeding, seasonal grazing, genetic diversity, inbreeding (measure of genetic diversity within breeds), effective population size and predator abundance.

Climate - Located 9 meters above sea level, Copenhagen has a temperate oceanic climate. The annual long-term mean temperature is 8.8 °C, and annual long-term precipitation is 636 mm. The coldest month is January when the long-term daily mean temperature is 0.5 °C, and the warmest month is July, long-term daily mean temperature of 17.2 °C. The wettest month is July, with 69 mm of precipitation, and the driest month is February, with 31 mm of precipitation. *Climate risks such as low temperatures, frost days, and excess of water and snow.* *Climate and biodiversity:* It includes average daily temperature and relative humidity (THI), diet and feed quality, methane emission and manure.

Food security - is characterized by a high level of stability and reliability. Denmark is renowned for its strong agricultural sector, advanced food production technologies, and efficient distribution systems. *Self-Sufficiency:* Denmark places a significant emphasis on domestic food production. The country's agricultural sector is highly developed and diversified, producing a wide range of crops, livestock, and dairy products. *Quality and Safety Standards:* This country is known for its stringent quality and safety standards in food production. The government, along with various regulatory agencies, enforces strict regulations to ensure that food produced and consumed in the country meets the highest standards of hygiene, nutrition, and safety. This includes monitoring of agricultural practices, food processing facilities, and distribution networks. *Innovation and Technology:* Danish agriculture is characterized by its innovative and



technologically advanced practices. Farmers and food producers in Denmark utilize cutting-edge technologies and sustainable farming methods to increase productivity, minimize environmental impact, and enhance food quality. Social Welfare: Denmark has a strong social welfare system that ensures access to food for all its citizens, regardless of socio-economic status. Government programs aid vulnerable populations to ensure they have access to nutritious food. Global Trade: While Denmark prioritizes domestic food production, it also engages in global trade to supplement its food supply and promote economic growth. The country exports a significant portion of its agricultural products, including dairy, pork, and grains, to international markets. At the same time, Denmark imports various food items to meet consumer demand and diversify its food supply. Food security and biodiversity: in includes vaccination and therapeutic treatments, improved monitoring/recording system, AI methods, new breeding techniques and breeding goal traits, price of animal feed, water availability and changes in consumer diet. Food security and biodiversity: this includes vaccines and therapeutic treatments, improved monitoring/recording systems, AI methods, new breeding techniques and target traits, feed prices, water availability and changes in consumer diets.

Farming conditions

Water- In Denmark, 12 regions were derived from the EU farm structure survey 2003. Irrigated areas per region are summing up to 448 818 ha (AEI) and 204 070 ha (AAI).

Table 3.4: Irrigated area in Denmark

Region	Area equipped for irrigation (ha)	Area actually irrigated (ha)
Arhus	19 590	7 468
Bornholm	226	101
Fyn	10 224	4 662
Hovedstadsregionen	5 393	1 551
Nordjylland	34 201	8 542
Ribe	93 722	43 222
Ringkobing	141 126	89 834
Sonderjylland	70 071	20 766
Storstrom	6 131	1 442



Vejle	32 826	15 662
Vestsjælland	8 424	1 703
Viborg	26 884	9 117
Denmark total	448 818	204 070
with groundwater	448 818	
with surface water	0	

Irrigated area was therefore assigned to all regions of coarse soil texture [DK04] classified as non-irrigated arable land (211), fruit trees and berry plantations (222) or complex cultivation patterns (242) in the Corine 2000 land cover data base for Europe [DK05] by using the priorities shown in table above. According to the data released by the EU farm structure survey 2003 all irrigation is from groundwater.

Diseases, pests and plant protection

Table 3.5: Diseases, pests and plant protection in Denmark

Crop	Harmful organism	Species names	Plant protection practices
Apples	Pest	Rosy apple aphid; Spirea aphid; Codling moth; Plum curculio; scale insects,	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Apple scab; Apple canker; Apple fire blight; Powdery mildew	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, preventing excess moisture in the field (plant density), adequate fertility management.
	Weed	Creeping buttercup; Dandelion; Chickweed; Ground elder; Yorkshire fog; Quackgrass	Mechanical weeding: preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management.
Potatoes	Pest	Potato tuber moth; Aphids (various species); Wireworms;	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; eradication of host

		Flea beetles; Potato psyllid; Colorado potato beetle	weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Late blight; Potato cyst nematodes; Early blight; Common scab, Blackleg	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, preventing excess moisture in the field (plant density), adequate fertility management.
	Weed	Common groundsel; Mare's tail; Chickweed; Black nightshade; Annual bluegrass; Quackgrass	Mechanical weeding: preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management., herbicides; mulching, mechanical cultivation
Sugar beet	Pest	Sugar beet cyst nematode; <i>Ditylenchus dipsaci</i> ; aphids; sugarbeet flea beetle; beet worm; beet leaf miner; pygmy mangold beetle; click; <i>Pentastiridius leporinus</i> ; beet moth.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Ramularia leaf spot; Cercospora leaf spot; powdery mildew; rust; Virus yellows.	Crop rotation, tillage (residue management), cultivar selection, preventing excess moisture in the field (plant density), vector (aphids) control.
	Weed	<i>Chenopodium album</i> , <i>Fallopia convolvulus</i> , <i>Poa annua</i> , <i>Polygonum aviculare</i> , <i>Tripleurospermum inodorum</i> , <i>Viola arvensis</i> , <i>Stellaria media</i> , <i>Galium aparine</i> .	Considerable time and effort to mechanical weed control or by machine, especially in the early stages of growth; robotic; manual weeding; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); physical methods (thermic); soil management.
Rapeseed	Pest	Brassica pod; rape beetle; cabbage flea beetle; rape stem weevil; cabbage seed weevil; cabbage stem weevil; cabbage gall weevil; aphids; black cutworm; turnip sawfly.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.

	Disease	Phoma stem canker = blackleg; Sclerotinia stem rot; club root; Verticillium stem stripping.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management.
	Weed	<i>Sinapis arvensis</i> , <i>Stellaria media</i> , <i>Veronica arvensis</i> , <i>Capsella bursa-pastoris</i> .	Mechanical weeding: preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management.

Diseases

1. Lameness is an abnormal gait or stance of an animal that is the result of dysfunction of the locomotor system.
2. Bovine mastitis is the persistent, inflammatory reaction of the udder tissue due to physical trauma or microorganism infections.
3. Paratuberculosis is a chronic disease of ruminants and many non-ruminant animals caused by the bacterium *Mycobacterium avium* subsp. *paratuberculosis*.

According to the report from the Danish Veterinary and Food Administration, as of August 2022, Denmark is free from bovine spongiform encephalopathy (mad cow disease), bovine virus diarrhoea, enzootic bovine leukosis, bovine rhinotracheitis/pustular vulvovaginitis, Aujeszky's disease, bovine brucellosis, bovine tuberculosis, *Brucella melitensis*, haemorrhagic septicaemia, blue tongue disease.

Soil - Aarhus area. Soil types found in Denmark include eight groups, Alisols, Arenosols, Cambisols, Fluvisols, Gleysols, Luvisols, Podzols and Podzoluvisols. Podzols and Luvisols cover almost two-thirds of the country. By texture, major soil types are coarse sand, mostly in the country's west, whereas fine sandy clay to clay soils occupy a major part of the centre and towards the southeast. The northern parts are rich in fine sand and fine clayey sand. Podzols occupy the major portion of western Denmark where the soils developed on sandy parent material, whereas eastern Denmark including the islands mostly contains Luvisols developed on loamy basal till. Approximately two-thirds of the country area is exploited by agriculture with heavy agricultural machinery, fertilization and liming.



Major threats to soil quality and agroecosystem sustainability include soil sealing (400-500 ha yr⁻¹), soil organic matter decline (10% of all agricultural soils), compaction (18%) and erosion by water (6%) and tillage (not regulated, up to 20 t ha⁻¹ yr⁻¹). The Aarhus area is heterogeneous in soil types with prevailing Luvisols and Podzols, affected by soil organic matter loss, soil compaction, and N and P leaching.

Pastureland - Pasture-grazing (grazing over spring/summer and indoors) for 25% of cows. Fully indoor for the 75% rest of the cows.

3.2.2 IPCC projections on Climate Change Indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:

3.2.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

In Denmark, the temperature rises follow those of the global average temperature. The observed annual average mean surface air temperature for Denmark in 2022 was 9.77 °C, and in 2021 was 8.96 °C. By 2030, the average mean surface air temperature is projected to be 8.24 °C (optimistic) and in the worst-case scenario, be increased to



10.64 °C. Projections suggest that the annual mean surface air temperature will range between 9.23 °C and 11.92 °C at both ends of the spectrum in 2050.

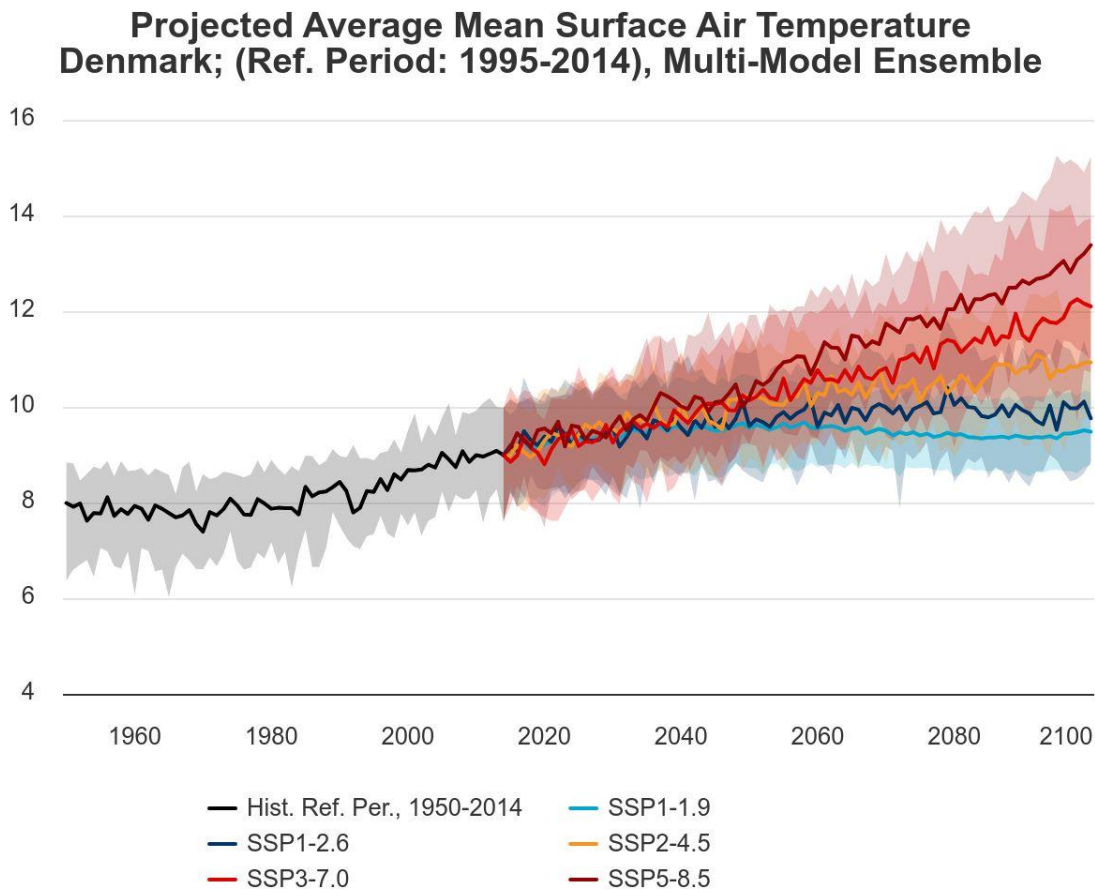


Figure 3-5: Projected average mean surface air temperature for Denmark

3.2.2.2 Precipitation patterns

Denmark experiences moderate precipitation, with an annual average of 700-800 mm, distributed evenly throughout the year. The IPCC's Sixth Assessment Report indicates that climate projections for the period 2030-2050 suggest that Denmark is likely to experience changes in precipitation patterns due to climate change. Such alterations may encompass augmented winter precipitation and more intense rainfall episodes, while summers may become drier, thereby exacerbating drought conditions. The extent of these changes is contingent upon future greenhouse gas emissions. It is anticipated that higher emissions will result in more pronounced shifts in precipitation patterns.

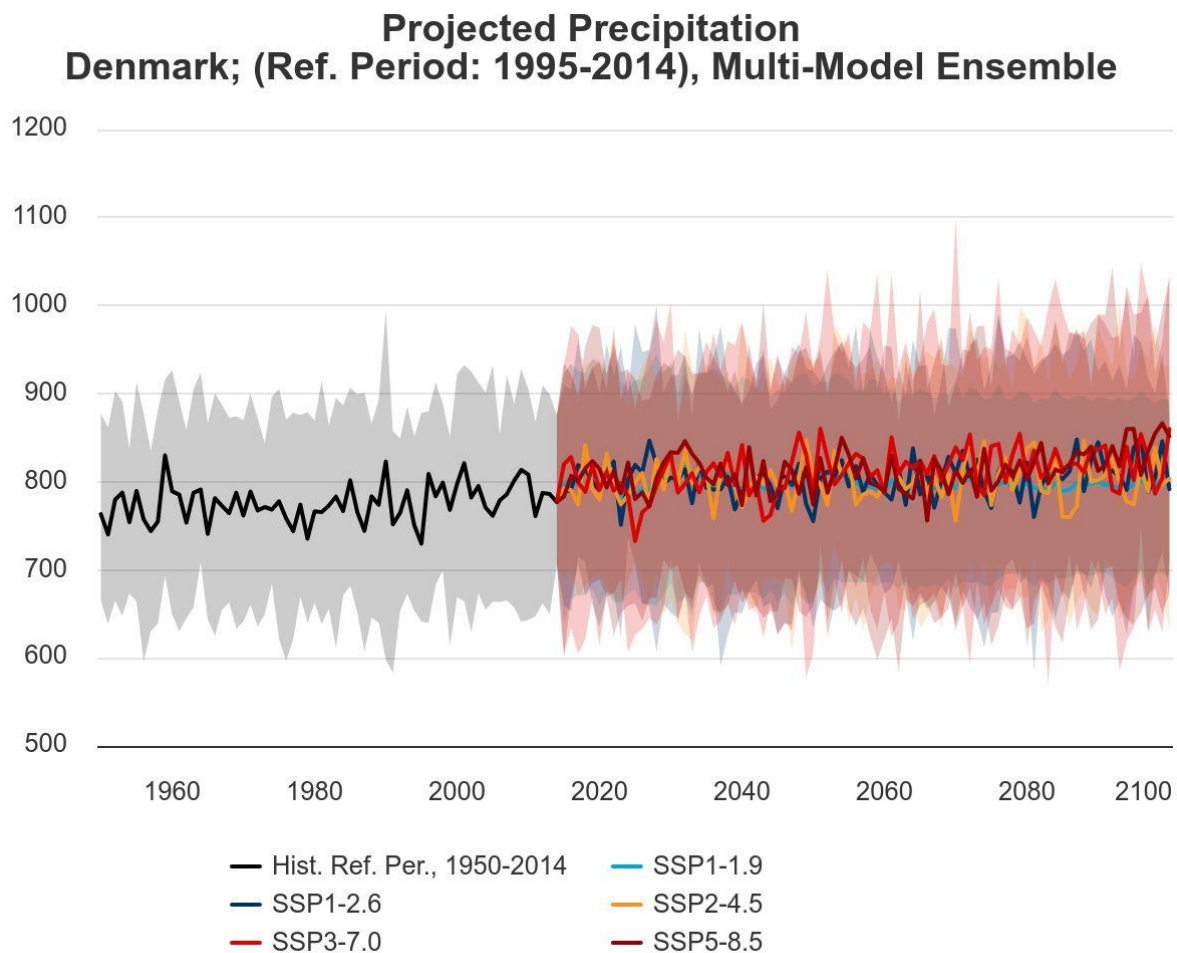


Figure 3-6: Projected precipitation patterns in Denmark

3.2.2.3 Sea level rise

Global Mean Sea Level (GMSL) has risen about 21 cm since 1900, at an accelerating rate. Based on different models, sea levels are projected to rise by about 0.2 to 0.3 meters by 2050 compared to the 1986-2005 baseline. This rise will vary regionally due to factors such as ocean currents and melting of glaciers and of the Antarctic and Greenland ice sheets. Under low emission scenarios (SSP1-1.9), global climate models project that in 2100 (relative to 1995-2014), GMSL rise will be in the range of 0.28-0.55m, 0.44-0.76m for an intermediate emissions scenario (SSP2-4.5) and 0.63-1.02m for a very high emissions scenario (SSP5-8.5). Model simulations that include the possibility of fast disintegration of the polar ice sheets, which are assessed to have a low likelihood, project a GMSL rise of up to about 5m by 2150 under a very high emissions scenario



(SSP5-8.5). The frequency and intensity of extreme sea level events, such as storm surges and high tides, will increase, exacerbating coastal flooding risks.

Sea levels in Denmark are projected to rise under different shared socio-economic pathways (SSP). Under the low emissions scenario SSP1-2.6, sea levels in Denmark are expected to rise by 11.01 cm over the next few decades and by 20.74 cm by mid-century compared to the historical baseline. Sea levels will continue to rise, reaching 36.51 cm by 2099 under the same scenario.

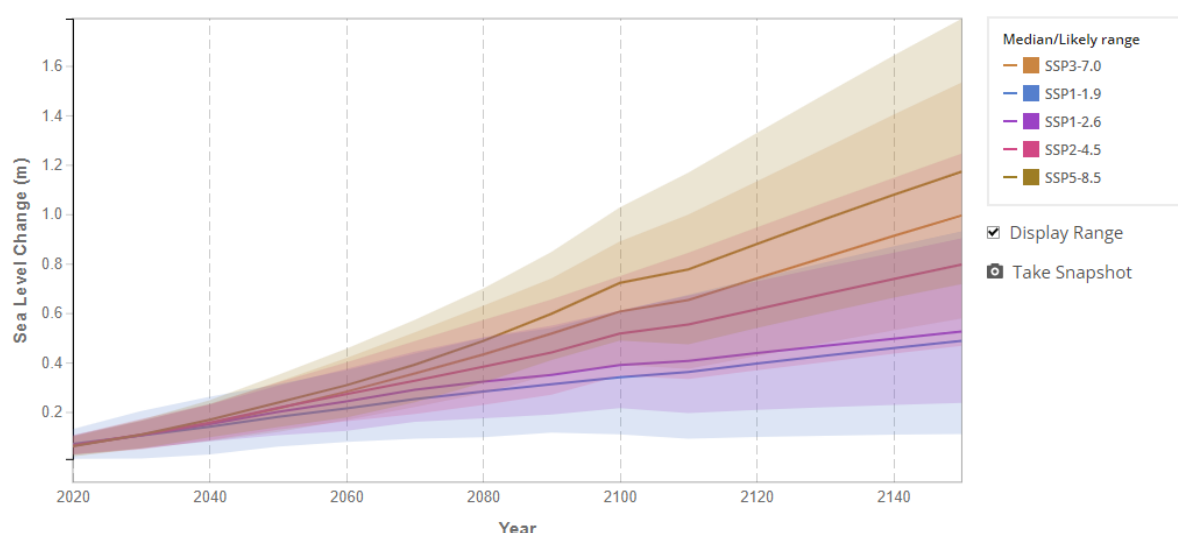


Figure 3-7: Figure 22. Projected sea level changes in Denmark

3.2.2.4 Extreme weather events

By 2030, an increase in the frequency and intensity of severe storms is expected in Denmark, with windstorms and storm surges becoming more frequent. The intensity of such storms is expected to increase by about 5-10%, occasionally causing damage to infrastructure. Longer dry periods and droughts during the summer are expected to become more frequent, with droughts increasing by up to 10%. By 2050, these trends will intensify further, with the intensity of severe storms projected to increase by 10-20%, posing more significant risks to buildings, transport networks and power lines. Droughts and dry spells are also projected to become 20% more frequent and severe, significantly impacting water availability and agricultural productivity.

3.2.2.5 *Ecosystem and biodiversity impacts*

In Denmark, climate change is profoundly altering ecosystems and biodiversity. Vegetation zones are shifting, leading to habitat loss and changes in species distribution, as temperatures are predicted to rise by 1.5 to 2.5 °C by 2050. Phenological changes, including shifts in the timing of flowering and migration, are already being observed, with some species experiencing these changes by weeks and even months. In addition, heavy precipitation events are expected to increase by 10-20%, increasing flood risks and affecting freshwater ecosystems. These changes threaten Denmark's rich biodiversity, with over 42% of species already experiencing negative impacts from climate change.

3.2.2.6 *Socioeconomic impacts*

Food security: Denmark's agricultural sector faces climate change challenges, including crop suitability shifts and increased pest pressure. Potato yields could fall by up to 22% by 2050, affecting food production and exports.

Coastal vulnerability: Rising sea levels and storm surges threaten coastal infrastructure and tourism, with annual coastal protection costs estimated at 0.1% and 0.4% of GDP by 2050.

Energy transition: The transition to renewable energy sources to mitigate the effects of climate change requires significant investment but offers opportunities for economic growth and job creation.

3.2.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Denmark and their specific focus on different products.



Table 3.6: Drivers of products for Denmark

Products- Denmark					
	Milk & Dairy	Apples	Potatoes	Sugar beets	Rapeseed
Drivers	1. Drought	1. <i>Increased air temperature</i>	1. Crop rotation	1. Crop rotation	1. Crop rotation
	2. Greenhouse gas	2. Pest invasion	2. Intercropping	2. Intercropping	2. Intercropping
	3. Methane emission	3. Fungi	3. Increased air temperature	3. Increased air temperature	3. Increased air temperature
	4. Heat stress	4. Pollination services	4. Extreme weather event	4. Extreme weather event	4. Extreme weather event
	5. Seasonal grazing	5. Precipitation	5. Soil moisture	5. Soil moisture	5. Soil moisture

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.2.4 Living Lab scenarios

LivOrganic

This document describes the five scenarios to be applied by LivOrganic. For each scenario, we describe the anticipated future and the assumed impact on organic agricultural production. The baseline scenario is more detailed as we have provided more information about the current structure, policy framework, and production in Danish organic farming. The Danish living lab targets only the organic agri-food system in Denmark. The products to be studied and their assumed relevance for the five scenarios is shown in the Table below.

Products Scenarios	Milk/Diary	Apples & potatoes	Spring barley & oats	Sugar beet	Rapeseed
1. Business as usual	X	X	X	X	X
2. Climate change A	X	X		X	
3. Climate change B	(X)	X	X	X	X
4. Biodiversity		X	X		
5. Special scenario: Land use	X		X	X	X

We present the five scenarios and a preliminary assessment of the impact on Danish agricultural production in the following sections. Information about agronomic

practices and mitigation strategies has been obtained from interviews with agricultural advisors specialized in organic farming and is presented in a separate section. The scenarios' impact on organic agricultural production is still to be validated by our organic community (Danish organic farmers).

Scenario 1: Business as usual for organic farming in Denmark

There are slightly less than 4,000 organic farms in Denmark, and they cultivate ca. 300,000 hectares. These numbers seem quite stable (L&F 2023). Yields from organic grain fields are typically 10-30% lower than for conventionally farmed grain fields, and 50% of organic farmed land is used for cereals. Organic milk is produced from 80,000 cows.

To comply with organic production methods the farmer cannot use pesticides and synthetic fertilizers. Therefore, the farmer will make use of a diversified crop rotation system; natural fertilizers from livestock or cultivation of leguminous plants; mechanical tools to reduce weeds, and use of natural extracts and minerals to protect crops. For example, baking powder is used against fungi in organic apple production. It is important in organic farming to increase the carbon content in the soil (carbon sequestration). A common practice in Danish organic farming is to use clover grass and cover crops.

Potatoes is one of the five products chosen by the Danish living lab because 25% of the potato area is farmed organically and organic potatoes account for 23% of the Danish potato consumption. Organic milk production accounts for 13% of the milk produced. 18% of sugar consumption and 50% of oat consumption is organic. 60% of Danish consumers buy organic food products regularly and 80% anticipate buying the same quantity or more organic products in five years from now (L&F, 2023).

Import of organic products has increased by ten-fold (500 million DKK to 5 billion DKK) from 2005 to 2021 and, in the same period, exports increased from 450 million DKK to 3.3 billion DKK (L&F, 2023 based on Statistics Denmark).



Organic production is regulated by the EU Directive on organic agriculture. Certified organic products may use the organic label when traded in the business-to-business and consumer markets. The EU Commission has presented the Organic Action Plan that aims at increasing the European area under organic farming practices to 25% by 2030. Through the CAP system, Denmark has a support scheme targeted at organic farmers and producers of organic food and feed. Also, EU rules about green public procurement stimulates demand by the public sector for organic food.

The products for which we anticipate the strongest impact: all 5 products chosen for the Danish living lab

Scenario 2: Climate change A: Increased precipitation and higher temperatures in the winter season

If the temperature increases by 1 degree C, the growth season will be prolonged by 1 month under Danish climatic conditions. This means an earlier start for the cropping season and reduced risk of frost when the fruit trees are blossoming. More winter precipitation increases the prevalence of fungi, particularly in potatoes and sugar beet, leading to reduced yields. Another consequence of increased winter precipitation is reduced growth of winter barley due to water saturated soil and drowning of the roots. Milder climatic conditions in autumn promote the establishment of cover crops such as clover grass and extend the season for use of pastureland as feed source for dairy cows. Increased precipitation and temperatures also affect the prevalence of endemic diseases in dairy cattle, especially liverfluke, worms, and other parasites that spend part of their lifecycle in the pasture. These types of parasites thrive better under these conditions, and often survive the winter.

Farmers may be in a position to achieve 5 cuttings of the grass (make silage 5 times) instead of the current 4 times per year to produce a larger stock of feed for the winter season. However, achieving 5 cuttings requires that the grass is provided sufficient nutrients through manure or other sources. Milder winters may lead to increased disease and pest pressure in winter cereal crops, but this can be counteracted by changing to

summer crops. Higher temperatures during the autumn

The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201



season enables later planting of winter cereals and conditions of a reduced pressure from weeds, particularly grass. Farmers' mitigation strategies are mentioned after scenario 3 as these strategies are relevant for both climate change scenarios.

The products for which we anticipate the strongest impact: Dairy, sugar beet and potatoes.

Scenario 3: Climate change B: Warmer temperatures and periodic risk of drought in the summer season

Under this scenario, there is rainfall all year round but the risk of periodic drought during the spring and summer increases. The warmer climate means opportunities to produce more fruit of better quality, so apple production would increase. The longer growth season and higher temperatures introduces new weed species or higher prevalence of weeds (e.g., *A. senecio*) to Danish organic agriculture with an uncertain impact on pest pressure. Rising temperatures and dry conditions affect the growth of grass negatively. With sufficient rainfall, sugar beet production could remain unchanged. However, a warmer climate and new weed species could have a negative impact on sugar beet because of heavy competition with the crop. Potatoes are grown on sandy soils and yields may decrease if irrigation cannot be undertaken. Too much rain in the spring season promotes fungi in potatoes and this is a big problem in organic farming. Earlier start of the cropping season favours spring cereals and rapeseed as yields are considered as stable under warmer and more arid conditions compared to winter cereals. A warmer summer can lead to poor quality grass and heat stress affecting productivity by dairy cows and requirements for supplemental feeding. Long periods of drought and heat could promote the development of pest populations in arable crops.

The products for which we anticipate the strongest impact: Spring barley and oats, apples, dairy and rapeseed.



Scenario 4: Biodiversity: Biodiversity related to productive organisms (crops and farm animals) is considered fundamental in organic production

Under this scenario, farmers use biodiversity of productive organisms (crops and farm animals) as a tool to succeed with agricultural production. Biodiversity can be used actively to reduce the prevalence of pests and fungi, for example by planting more crop varieties, e.g., apples, spring barley. Farming practices such as intercropping, and livestock-crop production systems are important for working actively with biodiversity to achieve resilient agricultural production. In a long-term perspective, also the use of more breeds is a way to enhance biodiversity in dairy farming. Biodiversity is also an asset for diversifying the crops in the market, for example by growing blue potatoes or heritage varieties of cereals. By having a large diversity in crop rotations and longer rotation cycles, farmers support the development of soil biodiversity and work to reduce the prevalence of pests and fungi. In addition to biodiversity directly related to productive organisms (agricultural crops and animals), the crop associated biodiversity (biodiversity of non-productive organisms) of agricultural landscapes play crucial roles in maintaining the health, stability, and productivity of these systems. Their roles in pollination (e.g., bees, butterflies, birds), pest control (natural predators such as ladybugs, spiders, predatory beetles or parasitoids such as certain wasps), soil health (bacteria, fungi, micro-, mezo- and macrofauna acting as decomposers, nitrogen fixators), water management (organisms improving soil structure and thus water retention and infiltration), biodiversity (non-productive organisms such as weeds provide habitats for a wide range of species, promoting biodiversity within the agroecosystem), climate resilience (non-productive organisms such as weeds can influence local microclimates, providing shade, reducing wind speeds, and maintaining humidity levels, which can buffer crops against extreme weather conditions), and pollution management (bioremediation, waste decomposition) highlight the importance of these organisms within agricultural landscapes.



The products for which we anticipate the strongest impact: spring barley and oats, apples and potatoes

Farmers' mitigation strategies:

The three main intervention points for farmers seem to be soil management, farm machinery, and choice of crop. Additionally, action points targeted at biodiversity are suggested.

Soil management: It includes considerations about farm machinery and water management. On heavy soils it is an option to use deep ploughing (15-20 cm deep) in the autumn to turn the soil over to reduce the prevalence of weeds and cut through the layer of grass roots. Grass for silage, pastures, or set-aside is an integrated part of organic crop rotations. Grass is also good for capturing water. Another practice is to use excavation of soil to achieve an improved drainage effect. Systems for irrigation could be established on sandy soils if the municipality would allow it. To improve the passage of water, farmers establish cover crops with long roots (e.g., clover grass).

Farming machinery: It is an important element in the adaptation strategies. For example, by exchanging wheels with belts on tractors, these machines can be used for harvesting potatoes on wet or flooded land. By using wider tires, tractors leave less track markings in wet fields and grass lands. By establishing buffer tanks near the fields, manure can be distributed through cables and so reduce the need for driving in wet fields. To combat weeds, organic farmers make use of a light harrow. The latest technology application is a robot weeding device driven by solar panels ("Farm droid"). This device can be programmed for use in sugar beet fields as the device can distinguish between the sugar beet plant and the weed.

The choice of crop: It connects with the crop rotation scheme, type of soil, and biodiversity. The spring barley and oats should be planted as early as possible to prevent weeds. Barley does not do well in water-saturated soil; oats can better adapt to wet soil. Potatoes are very susceptible of humid conditions, and in organic farming variety selection would be a key intervention point. To combat weeds, organic farmers make



use of cover crops, for example spring cereals with lay-out of grass or clover grass. Choice of clover depends on next year's cereal: white clover if spring barley is to be planted, or the taller red clover if the next cereal would be rye. Alternatively, the cover crop is ploughed into the field before planting the winter cereals. Generally, organic farmers prefer spring cereals to winter cereals as the winter cereals come with a higher weed pressure, particularly grass. By planting winter cereals one week later than "normal", the prevalence of weeds is reduced because of ploughing.

Example of a 6-7year crop rotation scheme in Danish organic farming:

1. Clover grass, ploughed into the field in the autumn to increase N-content in the soil
2. Winter rapeseed
3. Spring wheat fertilized with manure and lay-out of clover grass
4. Spring barley with lay-out of white clover
5. Winter rye with lay-out of clover as winter cover crop
6. Field peas (feed crop)
7. Winter wheat (or grass for seeds or winter rapeseed)

The crop rotation scheme requires 4-year intervals for rapeseed crops and for peas.

Action points targeted at biodiversity issues:

Enhancing the biodiversity of non-productive organisms: Farmers and landowner could by maintaining and restoring natural habitats such as hedgerows, buffer strips, field margins, establishing conservation areas or reserves within or adjacent to agricultural lands contribute to preserve native biodiversity.

There will be an increasing need for early warning systems from the European to the local level. If it gets warmer with periodic risk of drought, invasive species of pathogens, invertebrates and plants can migrate from bordering countries, colonize agroecosystems and become potential pests and weeds. Monitoring of their distribution and spread across Europe will provide early protective measures at the local level.



Scenario 5: Special scenario - Land use: The impact from policies about nature restoration, climate change mitigation, or renewable energy on farmers' decision to undertake agricultural production

This scenario is relevant in a Danish context for several reasons: Denmark will impose a CO₂ tax on agriculture with the expected consequences of reduced farming of wetlands, reduced number of dairy cows, and setting-aside of 100,000 hectares of farmland for nature restoration. Speculation about the impact on land price from the CO₂ tax could well have an impact on the economic feasibility of farming, and thereby impact the choice of crops planted. The CO₂ tax will come into effect by 2030, with the details still to be defined by the Danish government. Another factor is the government's plan for renewable energy production leading to more solar farms being established on farmland. The farmer's motivation to rent land to a solar farm company for 30 years is the annual fee they would receive. Today, there are several solar farms in Denmark, each covering 100-200 hectares with the biggest being 340 hectares.

The products for which we anticipate the strongest impact: dairy, crop



3.3 France

3.3.1 Dossier of Living Lab- country profile

Country - France

Region in EU - Northwestern Europe

Name of living lab - Loire Valley Observatory for Food Security (LOFS)

Products - milk and meat, grassland (ryegrass, clover, fescue, cocksfoot, etc.), forage (silage maize), salads, asparagus, condiment bulbs for specialized farms, soft wheat, durum wheat, breeding wheat, sunflowers, rapeseed, protein peas, beetroot, potatoes, grain maize, winter and spring barley under various technical itineraries, lentils.

Partners - Vegepolys Valley, ARVALIS - Institut du Végétal, Chamber of Agriculture of Pays de la Loire, IDELE, SCA Cultures France Champignon.

Selected product types for region: Wheat, Milk (grass-fed cows), Lettuce, Rapeseed, Button mushroom





Figure 3-8: Map of France with products

Partner background information

Economics - The Centre-Val de Loire region is a major agricultural area in France, employing over 30 000 people. It has an agricultural area of almost 2.4 million hectares. This illustrates the importance of agriculture for the economy and the labour market in these regions. In 2021, the Centre-Val de Loire region in France was the second largest producer of cereals in the EU, with a production value of EUR 2.2 billion. This region, together with four others in France, including Pays-de-la-Loire, was among the eight

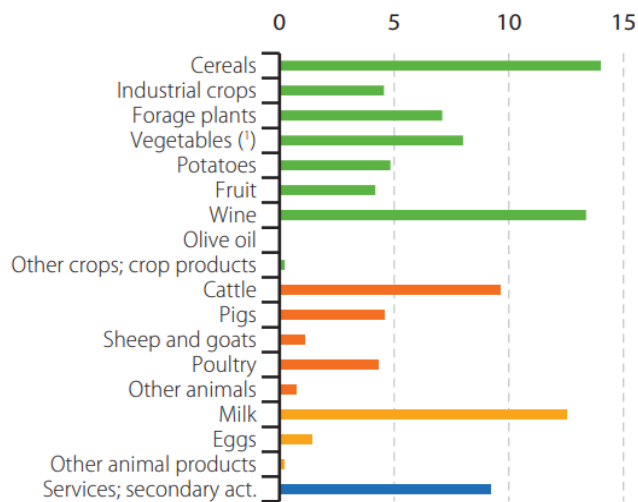


**Funded by
the European Union**

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regions in the EU where cereal production exceeded EUR 1 billion. In 2017, the Pays de la Loire region utilised a total agricultural area of 805 570 hectares, with wheat accounting for 50%, maize for 12%, barley for 11% and rapeseed for 9%. Similarly, in the Centre-Val de Loire region, wheat accounted for 41% of the utilised agricultural area, followed by rape (19%) and barley (18%). Pays de la Loire is a major player in the agri-food sector, being the third largest region in France in this sector. It accounts for 51% of meat products, 19% of milk and 67% of natural cereal production (cereals) in the region. According to the 2022 FADN (Farm Accountancy Data Network) data, the Centre-Val de Loire region had 15 542 farms, of which almost 10 000 specialised in arable crops. The average production value of these crops per holding was EUR 324 000. In particular, holdings specialising in granivores (grain-eating animals) had the highest average production value per holding, at around EUR 707 094, with 347 holdings. Milk production also played an important role, with an average production value of EUR 528 000 per holding on 454 holdings.

Figure 11.11b: Output value of the agricultural industry, 2019
(% of total output, at basic prices)



(*) Including also horticultural plants.

Source: Eurostat (online data code: [aact_eaa01](#))

Figure 3-9: Output value of the agricultural industry

Source: Eurostat

Horticulture and winemaking are also significant, each with similar average production values per farm of around EUR 486 000. Wine production, in particular, is



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widespread in this region, which hosts the most dairy farms at 4 600. Looking at France as a whole, the primary agricultural outputs are cereals, followed by wine and milk. In terms of livestock, cattle and pigs are the most prevalent. Dairy production is also significantly widespread across the country. The vineyards in the Loire Valley span nearly 70 000 hectares across four wine-producing areas: Pays Nantais, Anjou, Touraine, and Centre, annually yielding three to four million hectolitres of wine. In the Centre-Val de Loire region, wine production is notably significant, averaging a value of EUR 318 000 per farm, with a total of 1 020 farms in the sector. This indicates that wine production in this region is highly significant, with only a EUR 6 000 difference in average production value per farm compared to those specializing in arable crops. This highlights the importance of viticulture in the region.

Mushroom cultivation holds considerable significance for France, particularly in areas with suitable natural conditions such as the Loire Valley. France is one of the major mushroom producers in Europe, with the Loire Valley being a prominent region for this production due to the local limestone environment, which is ideal for cultivation. Annually, France produces nearly 90 000 tons of mushrooms, with button mushrooms making up most of this production, positioning France as the fourth-largest producer in Europe, following the Netherlands, Poland, and Spain. 97% of French mushroom production comprises button mushrooms.

Policies - Eco-schemes in France can be divided into several categories. Firstly, by practice, these schemes include the maintenance of extensive permanent grassland, crop diversification and the integration of grass into permanent crops. Secondly, by farming system, they include organic farming, high nature value farming and other forms of environmental certification. Thirdly, by biodiversity elements, the focus is on the proportion of non-agricultural features within agricultural landscapes. There is also an ecosystem bonus scheme for the sustainable management of hedgerows.

The agri-environment-climate (AEC) measures are also important. Measure 70.06 targets water quality and water saving in arable crops, while 70.07 addresses the same issues in permanent crops. Measures 70.08 focus on soil protection, 70.09 on animal welfare and food self-sufficiency and 70.10 on biodiversity in specific environments



such as Natura 2000 sites. Measures 70.11 and 70.12 deal with pollinator biodiversity and species protection respectively. Measures 70.13 deal with forest fire management and 70.14 with the maintenance of agro-ecological features, including hedges, isolated and aligned trees, riparian forests, ponds and ditches.

Farming practices - Agricultural production systems include conventional, organic, low-input, regenerative and no-till. Organic farming currently accounts for about 9.95% of the total agricultural area. Integrating biodiversity-rich grasslands with commercially productive grasslands can increase farm productivity and self-sufficiency. These less productive grasslands provide many benefits, including protection of water quality, soil carbon sequestration, protection against wind erosion and maintenance of biodiversity, with some grasslands being of high nature value. The objectives of grazing management vary, with most grasslands being managed by commercial farmers. There is considerable potential for ruminant livestock to produce high quality, human-edible protein from diverse biomass. In addition, crop rotation practices include specifying the name of the crop, its use (such as grain, silage or biomass), whether the crop is used internally, and the type of cover crop used.

Potential drivers

Biodiversity - New breeding objectives. Land use change for breeding. Seasonal grazing. Genetic diversity. Inbreeding (measure of genetic diversity within breeds). Effective population size. Predator abundance.

Climate - situated 27 metres above sea level, Nantes has a temperate oceanic climate. The long-term average annual temperature is 11.9 °C and the long-term annual rainfall is 789 millimetres. The coldest month is January, with a long-term average daily temperature of -5.4°C, and the warmest month is July, with a long-term average daily temperature of 19.1°C. The wettest months are January and November, with 87 mm of precipitation, and the driest months are June and August, with 45 mm of precipitation. Climate risks in the region are drought, heat stress, frost and fires. Climate and biodiversity: Mean daily temperature and relative humidity (THI) also include feed and fodder quality, methane emissions and livestock manure.



Food security- in France is a key component of the country's policy, which is characterized by a strong emphasis on agricultural productivity, quality standards, trade relations, social welfare measures and environmental sustainability. France has a diverse and dynamic agricultural sector, with a mix of large industrial farms and smaller family farms. The country produces a wide range of agricultural products, including cereals, vegetables, fruit, dairy products, wine and meat. French agriculture benefits from advanced technology, efficient farming practices and a favourable climate, which contribute to high levels of productivity and quality. While the country is one of the leading agricultural producers in Europe, it also imports certain commodities, such as tropical fruits and specialties. The country exports a wide range of food products to markets around the world, including wine, cheese, dairy products, processed foods and agricultural machinery. The French government supports domestic farmers through subsidies, agricultural policies and investment in research and development to improve agricultural productivity, sustainability and competitiveness. France maintains strict quality and safety standards in food production, processing and distribution. Regulatory bodies such as the Ministry of Agriculture and Food and the National Agency for Food, Environmental and Occupational Safety (ANSES) monitor and enforce food safety regulations to ensure that food products meet high standards of hygiene, quality and safety. Regular inspections and tests help to maintain consumer confidence in the safety of the food supply. France has a comprehensive social welfare system that ensures access to food for all its citizens, particularly vulnerable or low-income groups. Social benefits such as the Revenu de Solidarité Active (RSA) and the Allocation de Solidarité Spécifique (ASS) help to support individuals and families facing food insecurity. The country recognises the importance of environmental sustainability in ensuring long-term food security. The government promotes sustainable agricultural practices, including organic farming, agroecology and biodiversity conservation, to protect natural resources, reduce environmental impact and mitigate the effects of climate change on food production. Initiatives such as the Ecophyto plan aim to reduce the use of pesticides and promote alternative pest management strategies. France aims to ensure a stable and reliable food supply for its population, while promoting the health, sustainability and resilience of the agricultural sector. Ensuring food safety and



animal biodiversity requires a multi-pronged approach. Vaccination, novel treatments, improved surveillance through AI and targeted breeding (e.g., for disease resistance) are essential. Sustainable resource management, including feed prices, water availability and changing consumer diets, must also be considered for a future that balances both safety and biodiversity.

Farming conditions

Water - The irrigable area of the country increased steadily from 2 099 700 ha in 1990 to 2 510 410 ha in 1995 and 2 723 700 ha in 2003. The area irrigated was lower but increased also from 1 484 840 ha in 1990 to 1 629 580 ha in 1995 and 1 938 730 ha in 2003. According to the Agricultural Census 2000, the main irrigated crops were maize (56 percent of the irrigated area), vegetables and potatoes (12 percent of the irrigated area), and fruits and vines (9 percent of the irrigated area). The irrigated area by region is visible in the table below.

Table 3.7: Irrigated area in France

Region	Area equipped for irrigation (ha)			Area actually irrigated (ha)
	total	with groundwater	with surface water	
Alsace	73 328	57 721	15 607	57 403
Aquitaine	365 766	151 060	214 706	272 310
Auvergne	48 613	8 926	39 687	30 680
Basse-Normandie	10 447	7 413	3 034	5 007
Bourgogne	53 998	31 626	22 372	17 050
Bretagne	41 555	6 940	34 615	15 987
Centre	511 945	376 740	135 205	320 137
Champagne-Ardenne	67 354	56 575	10 779	17 150
Corse	20 209	567	19 642	12 667
Franche-Comté	13 064	10 469	2 595	3 777
Haute-Normandie	10 446	9 556	890	5 800
Ile-de-France	64 933	39 614	25 319	31 800
Languedoc-Roussillon	167 669	29 115	138 554	65 217
Limousin	6 556	79	6 477	2 253
Lorraine	757	473	284	397
Midi-Pyrénées	429 553	55 771	373 782	250 183
Nord-Pas-de-Calais	42 496	19 507	22 989	13 593



Pays-de-la-Loire	233 673	72 261	161 412	134 297
Picardie	130 571	93 503	37 068	38 840
Poitou-Charentes	243 911	165 069	78 842	165 143
Provence-Alpes-Côte d'Azur	188 928	31 797	157 131	111 323
Rhône-Alpes	180 309	56 888	123 421	122 123
France total	2 906 081	1 281 673	1 624 408	1 693 137

Diseases, pests and plant protection

Table 3.8: Diseases, pests and plant protection

Crop	Harmful organism	Species names	Plant protection practices
Grassland	Pest	Minor	-
	Disease	minor	-
	Weed	no major weeds	-
Silage maize	Pest	Western corn rootworm (<i>Diabrotica virgifera virgifera</i>); frit fly (<i>Oscinella frit</i>); aphids (<i>Rhopalosiphum padi</i>); click beetle (<i>Elateridae</i>); black cutworm (<i>Agrotis segetum</i>); European corn borer (<i>Ostrinia nubilalis</i>).	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of biopesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides; GMO (BT Maize).
	Disease	Common smut (<i>Ustilago maydis</i>); Fusarium spp. (1. Fusarium ear and kernel rot; 2. Fusarium head blight; 3. Fusarium stalk rot; 4. Fusarium Root and Crown Rot); Gibberella stalk and ear rot (<i>Giberella zeae</i>).	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	<i>Chenopodium album</i> , <i>Echinochloa crus-galli</i> , <i>Setaria veridis</i> , <i>Setaria pumila</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.

Alfalfa, clover	Pest	Thrips; alfalfa leaf midge (<i>Dasineura medicaginis</i>); aphids (<i>Acyrtosiphon pisum</i>); clover weevil (<i>Sitona</i> sp.); alfalfa bug (<i>Adelphocoris lineolatus</i>); bishop bug; clover seed weevil (<i>Apion apricans</i> , <i>A. trifolii</i>); alfalfa flower midge.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	Wilt of alfalfa (<i>Vetricillium albo-atrum</i> , <i>Fusarium oxysporum</i>); root and crown rot (different causal agents).	Clean seed, certified pathogen-free seed, seed treatment, land selection, cultivar selection, crop rotation, proper time of cutting, adequate fertility management.
	Weed	<i>Cirsium arvense</i> , <i>Lolium perenne</i> , <i>Lolium multiflorum</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.
Salads, asparagus	Pest	Thrips; aphids; asparagus beetle; asparagus fly.	Cultivar selection; crop rotation; adequate fertility management; use of insecticides.
	Disease	Lettuce: downy mildew (<i>Bremia lactucae</i>); anthracnose (<i>Marssonina panattoniana</i>); gray mold (<i>Botrytis cinerea</i>); white mold, asparagus: <i>Fusarium</i> crown and root rot (<i>Fusarium</i> spp., <i>F. oxysporum</i> f. sp. <i>asparagi</i>) "	Lettuce: cultivar selection, preventing excess moisture, avoiding irrigation by sprinkling, residue management, adequate fertility management, land selection, crop rotation, fungicide application asparagus: pathogen-free seedlings, soil selection, minimizing plant stress, good field sanitation, proper time of harvesting.
	Weed	All spring/summer germinating weeds such as <i>Chenopodium album</i> , <i>Solanum nigrum</i> , some perennials such as <i>Convolvulus arvensis</i> , <i>Elytrigia repens</i> , or toxic weeds such as <i>Datura stramonium</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.

Wheat, barley	Pest	Cereal leaf beetle; saddle gall midge; aphids; leafhoppers; cereal cyst nematode; thrips; frit fly; corn ground beetle; wheat bulb fly; orange wheat blossom midge; yellow wheat blossom midge; barley leaf miner; barley gout fly; click beetle; barley root-knot nematode.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	Powdery mildew; rusts; leaf spots of cereals: Septoria leaf blotch of wheat; tan spot of wheat; Ramularia leaf spot of barley; net blotch of barley; leaf stripe of barley; scald of barley; head blight; wheat bunts; eyespot; take-all; Barley yellow dwarf virus; Wheat dwarf virus.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application, fungicide application.
	Weed	<i>Alopecurus myosuroides</i> , <i>Avena fatua</i> , <i>Bromus sterilis</i> , <i>Lolium sp.</i> , <i>Galium aparine</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.
Sunflower	Pest	European corn borer (<i>Ostrinia nubilalis</i>); click beetle (<i>Elateridae</i>); bugs (<i>Miridae</i>); aphids (<i>Brachycaudus helichrysi</i> , <i>Aphis fabae</i>).	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	<i>Sclerotinia sclerotiorum</i> (1. Sclerotinia root and basal stalk rot, and wilt; 2. Sclerotinia stem rot; and (3) Sclerotinia head rot and midstalk rot); gray mold; downy mildew; Alternaria blight; black stem; stem canker; charcoal rot.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.

	Weed	<i>Chenopodium album</i> , <i>Echinochloa crus-galli</i> , <i>Setaria veridis</i> , <i>Setaria pumila</i> , <i>Amaranthus retroflexus</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.
Rapeseed	Pest	Brassica pod midge; rape beetle; cabbage flea beetle; rape stem weevil; cabbage seed weevil; cabbage stem weevil; cabbage gall weevil; aphids; black cutworm; turnip sawfly.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	Phoma stem canker = blackleg (<i>Leptosphaeria maculans</i> , <i>L. biglobosa</i>); Sclerotinia stem rot (<i>Sclerotinia sclerotiorum</i>); club root (<i>Plasmodiophora brassicae</i>); Verticillium stem stripping.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	Summer species when oilseed rape establish such as <i>Chenopodium album</i> , <i>Stellaria media</i> , <i>Senecio vulgaris</i> but mainly grasses such as <i>Alopecurus myosuroides</i> , <i>Lolium sp.</i> , or dicot such as <i>Galium aparine</i> , Apiaceae species such as <i>Daucus carota</i> , <i>Anthriscus caucalis</i> , or <i>Capsella bursa pastoris</i> , <i>Sinapis arvensis</i> , or <i>Geranium dissectum</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management.
	Pest	Potatoes: Colorado beetle. Beetroot: Sugar beet cyst nematode; sugarbeet flea beetle; beet worm; beet leaf miner; pygmy mangold beetle; <i>Pentastiridius leporinus</i> ; beet moth; Maize: Western corn rootworm; frit fly; European corn	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides; GMO (BT Maize).

Potatoes, beetroot, maize		borer; <i>All</i> : Aphids; click beetle; black cutworm.	
	Disease	<i>Potato</i> : potato viruses; late blight of potato; early blight of potato; black scurf of potato; black leg; bacterial soft rot; dry rot; common and netted scab of potato, <i>Maize</i> : common smut of maize; <i>Fusarium spp.</i> (1. <i>Fusarium</i> ear and kernel rot; 2. <i>Fusarium</i> head blight; 3. <i>Fusarium</i> stalk rot; 4. <i>Fusarium</i> root and crown Rot); <i>Giberella</i> stalk and ear rot.	<i>Potatoes</i> : clean seed tubers, certified pathogen-free seed tubers, crop rotation, residue management, cultivar selection, proper timing of planting, removal of volunteer plants, eradication of all sources of inoculum, preventing excess moisture in the field (plant density), adequate fertility management, locality selection, harvest of sufficiently mature tuber, limitation of damage during harvesting, good farm hygiene, to allow rapid wound healing, isolation distances. <i>Maize</i> : clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	<i>Chenopodium album</i> , <i>Echinochloa crus-galli</i> , <i>Setaria veridis</i> , <i>Setaria pumila</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management.

Diseases: Mastitis. Brucellosis. Lameness. Digital dermatitis. Bovine viral diarrhea. Blue Tongue.

Soil - The whole of France can be classified as a zone of brown earths of excellent agricultural value. There is some climatic variation within the French brown earth group; the high rainfall and somewhat cooler conditions of north-west France tend to leach carbonates and other minerals downwards, producing a degraded brown earth soil of higher acidity and lower fertility; locally this can approach the nature of northern European podzol. In France, agricultural land accounts for 45% of the country's surface area, but the proportion varies greatly from region to region. It is highest in Normandy, the Loire Region and Hauts-de-France (over 68%). The Loire region is considered to be one of the most fertile areas and generally consists of sandy soils, chalk tuffeau, clay-limestone, sandstone shale, granite and gravel. Large-scale arable farming without the

use of livestock manure leads to soil degradation and erosion in some places. France pays more attention to monitoring soil biodiversity than other EU countries. In terms of pastureland, in 2020, France used about 26.74 million ha for agriculture, of which 41.4% will be grassland, i.e., about 11.072 million ha.

3.3.2 IPCC projections on climate change indicators for 2030 and 2050

3.3.2.1 Temperature

In 2022, France recorded an annual mean surface air temperature of 13.16°C, up from 11.58°C in 2021, indicating an increase of approximately 12%. Climate projections suggest that by 2030, the annual mean surface air temperature will range between 12.07°C and 12.42°C. By 2050, the average mean surface air temperature is projected to be 12.34°C under an optimistic scenario and could increase to 13.38°C in the worst-case scenario.



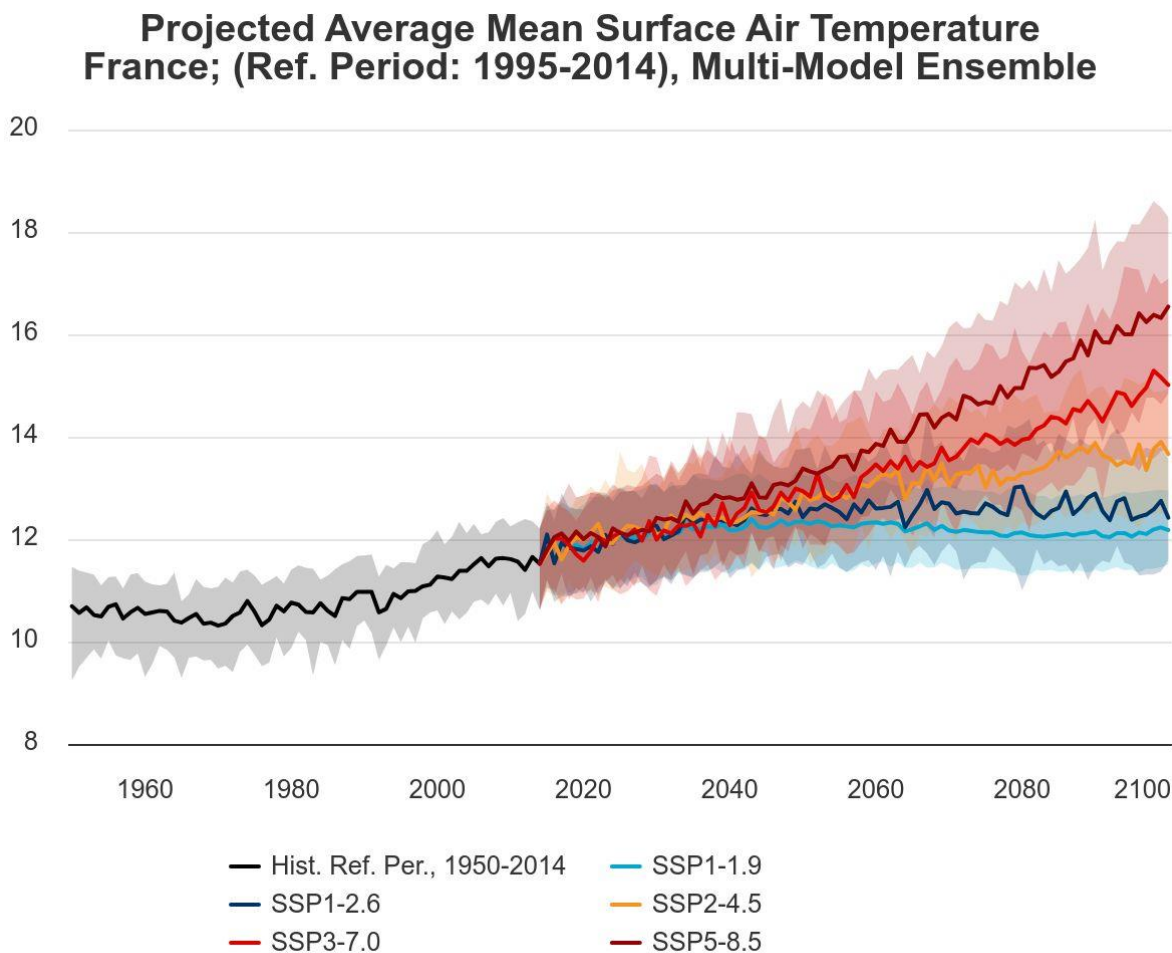


Figure 10. Projected average mean surface air temperature for France

The living lab for France is located in the Pays de la Loire region. Projections for this region indicate that by 2030, the annual mean surface air temperature will range between 12.58°C and 12.86°C. By 2050, the projections show that the annual mean surface air temperature will range from 12.92°C in the best-case scenario to 13.80°C in the worst-case scenario.

3.3.2.2 *Precipitation patterns*

Mainland France in the 20th century has seen changes in precipitation patterns by an increase in autumn and winter rainfall (5-35%) and a drop in summer rainfall. Since 1985, daily rainfall in Southern France has shown an increasing trend in extreme daily rainfall, with a significant increase in the mean intensity of annual maximum daily



rainfall and a doubling of the frequency of events exceeding high thresholds. Observed annual precipitation patterns show a drop from 835.42 mm in 2021 to 645.11mm in 2022 (World Bank), which could be as a result of the variations in the regions in France. Projections for 2030 show that annual precipitation will be 957.43 mm (in the best-case scenario) and 986.08 mm (Best case scenario). In 2050, precipitation is predicted to be 939.22mm (best case scenario) and 940.77mm (worst case scenario).

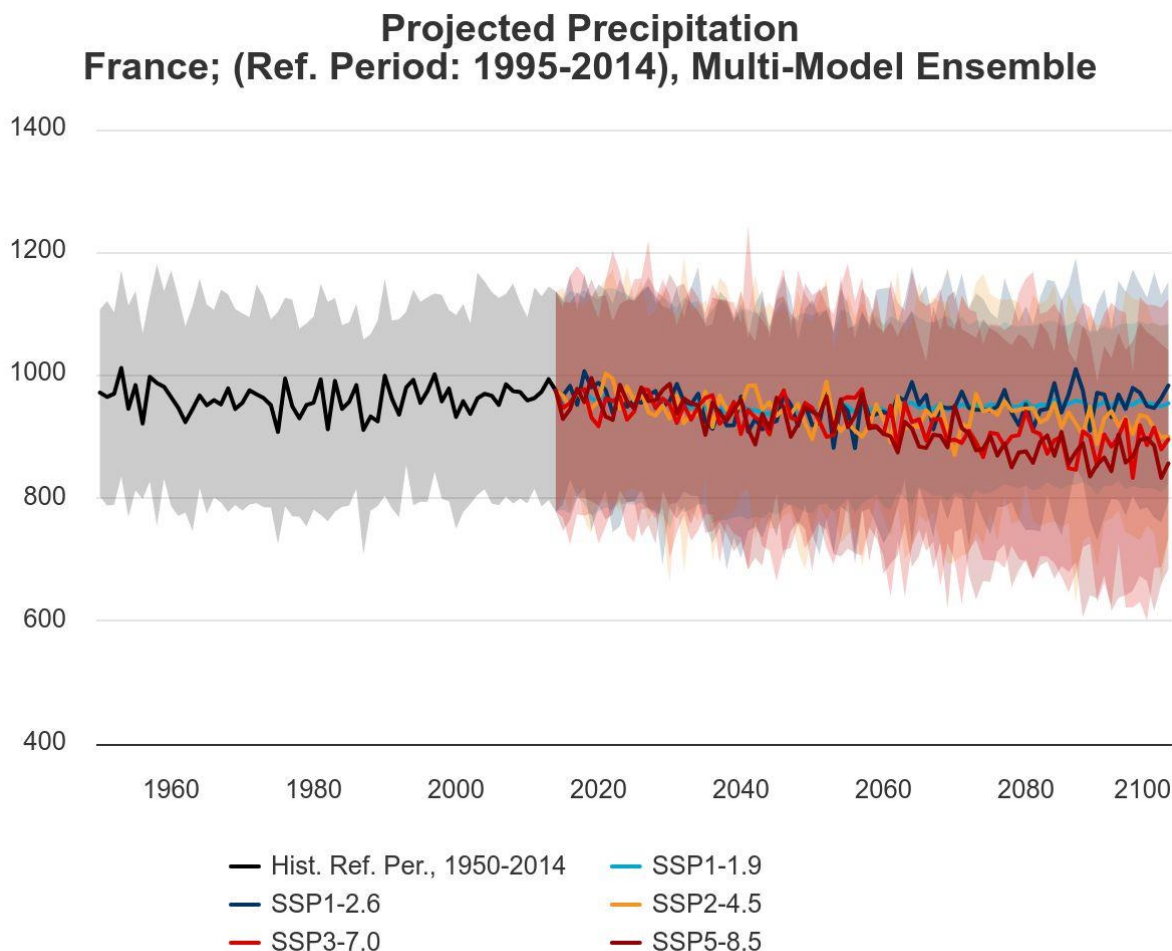


Figure 20. Projected precipitation patterns in France

Pays de la Loire is projected to have precipitation of 760.62 mm (SSP1-1.9) and 783mm (SSP5-8.5) by 2030. By 2050, under SSP1.1-9, precipitation will be 738.51mm and 741.51mm. This shows a decreasing trend of rainfall in this area.

3.3.2.3 Sea level rise

French coastal cities, renowned for their beauty and historical significance, are facing an unprecedented threat due to rising sea levels. Cities like Marseille, Nice, and others along the French Riviera, as well as those bordering the Bay of Biscay, are particularly vulnerable. For the living lab in Pays de la Loire, the gauge at St. Nazaire projects a sea level change of 0.09 meters to 0.10 meters by 2030. By 2050, this change is expected to increase to a range of 0.17 meters to 0.22 meters across all scenarios.

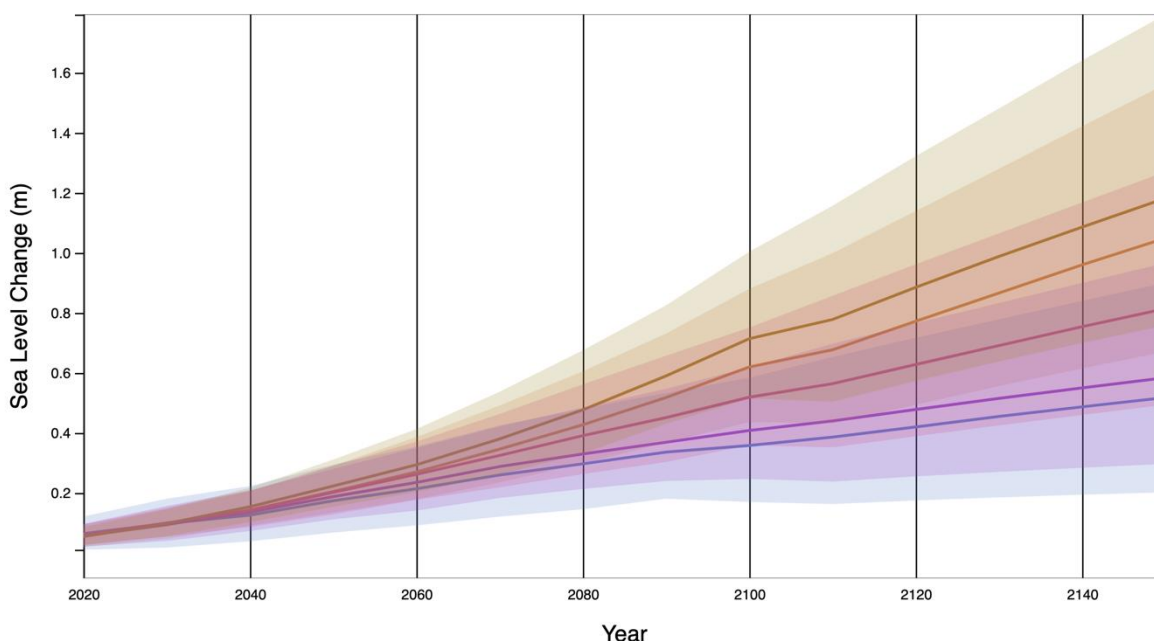


Figure 29. Projected sea level changes in France

3.3.2.4 Extreme weather events

France has experienced various extreme weather events in recent years. In 2021, moderate flooding struck the northeast, particularly Lorraine, damaging homes, roads, and crops. An intense late freeze in early 2021 caused significant agricultural losses across most of the country. Droughts and subsidence, while not occurring in 2021, have become more frequent, with droughts being the most common "extremely severe" event according to the CCR. Additionally, severe thunderstorms like the derecho that ravaged Corsica in August 2022 are becoming a growing threat. Studies suggest these derechos



are becoming more frequent in France, potentially due to climate change-induced atmospheric instability.

3.3.2.5 Ecosystem and biodiversity impacts

France has a very rich natural heritage with over 180 000 species recorded, but biodiversity is being eroded at an alarming rate globally. 60% of wild animals have disappeared in the last 50 years and 1 million species are threatened with extinction. The overseas territories in France are home to most of the endemic species in France are at great risk, with over half having a higher extinction risk index. By 2050, the mean species abundance in mainland France could increase by 11% under an optimistic scenario or decrease by 6% under a pessimistic scenario, showing the significant impact climate change could have on biodiversity.

3.3.2.6 Socioeconomic impacts

Agriculture and Food Security: Food availability and accessibility will be reduced. Crop yield and livestock productivity will be severely impacted

Fisheries: Climate change will alter fish population and distribution affecting the fisheries sector.

Economic Losses: By 2070, climate change-induced economic losses in France will be approximately €1.3 trillion in present value terms.

3.3.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in France and their specific focus on different products.



Table 3.9: Drivers of products for France

Products- France					
	Wheat	Milk	Lettuce	Rapeseed	Mushroom
Drivers	1. Crop rotation 2. Global warming 3. Productivity 4. Water consumption 5. Integrated agriculture	1. Increased air temperature 2. Precipitation changes 3. CO2 concentration 4. Drought 5. Seasonal grazing	1. Increase air temperature/dryness 2. Water consumption and availability 3. Extreme precipitation and hail 4. Organic fertilizer availability and NPKS availability 5. Water management and biological pesticides	1. Productivity 2. Dryness at the beginning of the cycle and during the filling phase 3. Pest Invasion 4. Pesticide resistance 5. Availability of fertilizers	1. Groundwater availability 2. Summer heatwave 3. Precipitation changes 4. Seasonal variation 5. Pathogens

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.3.4 Living Lab scenarios

Loire valley Observatory for Food Security - LOFS

The French Living Lab will be based in the Val de Loire, in the bioclimatic area of the Atlantic Arc. The project will focus on 2 regions in the Loire Valley: Pays de La Loire and Centre-Val de Loire. In these two regions, agriculture accounts for around 70% of the land surface, for both crop and livestock production. The Centre-Val de Loire region specializes in crop production (cereals, animal feed crops and rapeseed), while the Pays de la Loire is more diversified, with a long history of fruit and vegetable production. Livestock farming is also well developed here, and forage requirements are high. Mushroom production is important in both regions, with the main national producers present in the area.

Products \ Scenarios	Wheat	Mushroom	Rapeseed	Lettuce	Milk
1. Status quo for 2030 - 2050	X	X	X	X	X
2. A Thirsty Land: The Looming Crisis of Water in the Loire	X	X	X	X	X



3. From Bounty to Barren		X		X	
4. Harvesting Resilience: Diversification for Stronger Crops and Soils	X			X	X
5. Loire Agrotech Revolution		X	X	X	

Scenario1: Status quo for 2030 - 2050

France and the Loire valley, specifically, will experience milder winter, and hot, dry summers in the future. Sea levels are expected to continue to rise by up to 0,22m from the present day by 2050, while overall precipitation will decrease. Loire is influenced by its proximity to the Atlantic Ocean.

Wheat production

- **2030:** Wheat is a significant crop and is typically grown on flat or gently sloping land away from the riverbanks in the Eastern Loire Valley. The majority of farmers use modern mechanized methods for large-scale wheat production. Soil compaction is becoming a problem in loamy soil, compounded by reduced water sourcing, consisting of spring heat waves and summer drought will stress wheat yields. Grasses weeds are a growing problem impacting directly yield in quantity and quality.
- **2050:** Greater frequency in heavy rainfalls will lead to waterlogging and disease outbreaks. On the other end of the climate spectrum warmer temperatures will favour the spread of pests, diseases and physiological issues. These temperatures offer the possibility of new crop cultivation. Global trade and market forces will impact wheat prices and put pressure on farmers to further increase yield. Reduced water sourcing and deteriorating soil health will hinder productivity in the long-term.

Mushroom production

- **2030:** Current mushroom cultivation includes the preparation of the culture medium, with the culture of the mycelium, in air-conditioned room. The composted straw and manure is used as a substrate in container. Growing in air-conditioned rooms, on average for 2 months before harvesting.



- **2050:** Changing climate including reduced groundwater availability and high heat during the summers threaten mushroom cultivation. This will also contribute to a shift in pathogens impacting mushroom production. The increasing heat in the summers will drive cooling costs up and also leave to shifting work-environment conditions.

Rapeseed production

- **2030:** Rapeseed is typically sown in the early autumn and harvested the following summer (July-August) when the seed pods mature. Rapeseed requires well-drained soil with the application of fertilizer, pesticides and herbicides. The harvest is mechanised, and pods are then brought for crushing and oil extraction. Proper water management has become a threat to yield.
- **2050:** The long-term challenges include the over-reliance on pesticides and herbicides which will lead to resistant species being prevalent. Pests will become a greater concern, for example fungal diseases during the periods of heavy rainfall, as well as the threat of waterlogging. Climate change can negatively impact bee populations, reducing pollination efficiency and ultimately affecting rapeseed yields. Rapeseed may face competition on the part of farmers' decision to plant other more profitable crops. Economically, rapeseed oil is susceptible to the fluctuating global market forces.

Lettuce production

- **2030:** The production of lettuce for the domestic market peaks during the spring months. Lettuce requires consistent watering, leading to increased weed growth, and will be challenging with the extended summer water scarcity. Lettuce varieties will need to be changed regularly as the threat of new pests will emerge. Consumer demand for lettuce year-round will influence a change in cultivation practices with regards to water management.
- **2050:** The long-term viability of lettuce farming via conventional farming practices will be severely threatened. This is due to water demand and scarcity, heat waves, and flooding. Greater occurrence of extreme weather events will damage harvests. Unsustainable agricultural practices like intensive tillage or



overuse of fertilizers can lead to soil erosion and the depletion of essential nutrients, impacting lettuce yields and quality in the long run. Overreliance on certain pesticides could lead to pest resistance, necessitating the development of alternative control methods such as biological pesticides. Consumer demand for lettuce year-round will influence a change in cultivation practices with regards to water management.

Milk production

- **2030:** Dairy cow milk production is based a mix of grass and maize forage production primarily in the Western Loire valley. Thus, milk production is very dependent on the quality and yield of grass and maize. These factors heavily depend on rainfall distribution, temperatures and droughts (lack of rain and evapotranspiration). Excess of rainfall can also limit access to grassland both for harvest and grazing.
- **2050:** Increasing overall summer temperatures and water scarcity will impact grass yields during those months but grass growth will benefit from milder winters, springs and autumn, overall causing a shift in grazing management. Yields in harvested forages, and specifically in maize, will become more variable due to climate hazards. However, air concentration in CO₂ will affect positively forage production as it is said to improve the photosynthesis of “C3 plants” as well to “C4 plants” to a lower extent. Moreover, more frequent heatwaves will provoke heat-stress to livestock leading to loss in milk yield and reproduction performance. The rise of temperatures throughout the year will increase disease burdens.

Scenario 2: A thirsty land: The looming crisis of water in the Loire

By 2050, the Loire Valley, one of France's most renowned regions for agriculture, vineyards and cultural heritage, faces a critical water crisis during the summer months. This scenario explores the increasing challenges of water scarcity due to climate change, balanced with excess water during winter. This lack of water include decrease

Shock: Decreased availability of water



**Funded by
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The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201

in summer precipitation and also potential reduction in irrigation available volume. Drought is going hand-in-hand with salinity, which leads to a stress of irrigation with water containing salts. Subterranean water evaporation may lead to increased salt concentration, in the regions of Loire closer to the sea, however further inland may not be affected.

Current situation: The Loire Valley is already experiencing signs of water stress. Annual rainfall patterns have become increasingly erratic, with prolonged droughts coupled with periods of intense rainfall, becoming more frequent. Shifts in rainfall patterns, with longer drought periods and more sporadic heavy rainfall, are starting to impact crop yields and livestock production. Key agricultural outputs, such as grapes for wine, wheat, and vegetables, are particularly vulnerable. Aquatic ecosystems in the Loire River and its tributaries are degrading due to lower water levels and increased pollution concentration.

Key strategies and solutions: Transition to less water-intensive crops and incorporation of drought-resistant varieties. Implement soil moisture retention techniques (such as integrating temporary grasslands in crop rotations) and mulching to reduce evaporation and maintain soil health. Expand the use of precision irrigation technologies, such as drip and subsurface irrigation, to minimize water wastage. Develop infrastructure for rainwater harvesting and storage. Using advanced data analytics and IoT (Internet of Things) sensors to monitor soil moisture levels and optimize irrigation schedules. Invest in research and development for innovative water-saving agricultural technologies. Initiatives to restore natural water bodies and wetlands to improve groundwater recharge and support biodiversity. Providing continuing education and training programs for farmers on water conservation techniques, sustainable agricultural practices and the use of new technologies.



Scenario 3: From Bounty to Barren

High temperatures in the Loire Valley are already being witnessed and are projected to become more extreme particularly in the summer months. Heat stress will impact all crops profiled in this Living Labs, with lettuce and mushrooms (i.e., inability to control heat in facilities) being particularly hard hit. Moreover, extreme weather events such as hail and windstorms could wipe out total harvests overnight.

Shock: More frequent extreme weather events

The following occurrences can be anticipated within this scenario:

Droughts:

- As temperatures rise, evaporation increases, leading to drier conditions. This can put a strain on water resources for both agriculture and human consumption.
- Salination
- The Loire River and its tributaries and subterranean water may see lower water levels, impacting navigation, irrigation, and hydropower generation.

Flooding:

- While more frequent, heavy rainfall events associated with storms could lead to flash floods that damage infrastructure, properties, and agricultural land.

Other potential events:

- Strong winds can damage buildings, power lines, and crops.
- Hailstorms can damage crops rapidly, impacting harvests.

Long-term trend - CO₂ will impact positively plant growth

- Increased weeds growth

Overall Impacts:

- Extreme weather events can significantly impact the yield and quality of crops grown in the region.
- Competition for water will likely increase, especially during droughts, putting a strain on water management systems.
- Changes in temperature and precipitation patterns could disrupt the delicate balance of the ecosystem, leading to loss of plant and animal species.



Scenario 4: Harvesting resilience: diversification for stronger crops and soils

This scenario focuses on addressing both the climatic challenges as well as on the increasing pressure from pests and emerging pathogens. Mitigation strategies include crop diversification, and better soil and land-use management.

Current situation: The Loire Valley has traditionally been a robust agricultural region, with wheat, lettuce and dairy cattle being significant contributors to its economy. However, recent years have seen a surge in fungal diseases: *Wheat*: The region's wheat crops are under siege from various fungal pathogens, particularly *Septoria triticii*, Fusarium head blight and yellow rusts (yellow and stem rusts). These diseases not only reduce yields but also affect the quality of the grain, leading to economic losses for farmers. *Milk*: When temperatures are high and humidity is high, cows can become overheated, leading to decreased milk production, reduced fertility, and even death. Forage quality and quantity is also negatively impacted by more frequent and intense droughts, which mean purchasing of fodder or selling livestock by farmers. *Lettuce*: Dryness in lettuce leads to physiological stress.

Proposed solutions:

- *Diversification of crops:*

General introduction of crop rotations for wheat, lettuce and grazing lands. Wheat can be rotated with legumes (e.g., peas, soybeans, lentils) - these fix nitrogen in the soil, reducing fertilizer needs for wheat; followed by oilseeds (e.g., rapeseed, sunflower) - deep-rooted oilseeds help improve soil drainage and structure; and cover crops (e.g., clover) to suppress weeds and add organic matter to the soil. Lettuce should be grown with a rotating mixture of leafy greens and different salad varieties (e.g., kale, arugula, spinach) and harvest in staggered stages. For milk production, diversification of the forage resources and better herd management are key. Solutions exist to extend grass growth in the summer such as working with species resisting to droughts (tall



fescue, cocksfoot, alfalfa, red clover, chicory, plantago). Introduction of relay cropping in rotations can be a way to produce more forage (sowing grassland under cereal crops, fodder rape after a cereal etc...) and working with fodder species more resistant to droughts (fodder beets, sorghum, moha/millet). More grazing in autumn, winter and spring is a way to reduce the need for harvested forage over the year. Milk production can be maintained for the same amount of forage requirement by reducing the age at first calving and the cow renewal rate. Seasonality of calving could also be worked to match the grass consumption and production.

- Pests

To combat these escalating pest pressures, is the introduction and cultivation of diverse wheat varieties, including both modern and older (having higher quality but lower yield), forgotten genetic strains. This approach aims to enhance the resilience of wheat crops against fungal diseases and viruses transmitted by insects. Utilization of crossbreeding techniques to combine the resilience traits of older varieties with the high-yield characteristics of modern varieties. Development of new genotypes or mixtures of genotypes that offer both disease resistance and optimal yield. Conduct workshops and training sessions for local farmers to introduce them to the benefits and cultivation techniques of these diverse wheat varieties. Promote the adoption of integrated pest management practices that complement the use of resistant varieties. introducing a diverse array of wheat varieties, including older and forgotten genetic strains

- Soil Health

The Loire Valley can implement a comprehensive strategy to optimize soil health as a key intervention to combat water scarcity and the depletion of soil biodiversity. Transformation of agricultural practices, focusing on increasing soil organic matter, adopting low/no-tillage strategies and increasing biodiversity through the integration of hedges, trees and beneficial microorganisms.

Composting: Large-scale composting programs are established, converting organic waste into nutrient-rich compost to be applied to fields. *Microorganisms:* Introduction



of beneficial microorganisms through bacteria-coated seeds and direct soil inoculation to enhance soil fertility and structure. *Adoption of No-Till Practices*: Farmers transition to low-/no-till practices, reducing soil disturbance and promoting root persistence. *Cover Crops*: Use of cover crops to protect soil, add organic matter, and prevent erosion during non-growing seasons. *Water Retention*: Planting hedgerows and trees around plot perimeters to retain water, reduce wind erosion, and create habitats for beneficial organisms. *Biodiversity Corridors*: Establishing biodiversity corridors that connect different plots, enhancing movement and habitation of natural predators like birds and spiders. *Natural Predators*: Encouraging the presence of natural predators through habitat creation, reducing the need for chemical pest control. *Weed Management*: Allowing certain beneficial weeds to grow, which can improve soil structure and provide habitats for insects and birds. *Farmer Training Programs*: Continuous education for farmers on sustainable soil practices, biodiversity benefits, and new technologies. *Community Engagement*: Engaging local communities in soil health initiatives through workshops and collaborative projects.

Policies: to ensure that crops in one area of a country does not wipe out the whole supply. Promoting diversity of crops in the region.

The long-term vision for the Loire Valley is to establish itself as a leader in sustainable agriculture, where optimized soil health forms the foundation of resilient and productive agricultural systems. By 2050, the region can demonstrate how integrated soil health practices and crop diversification can ensure food security, environmental sustainability and economic prosperity.

Scenario 5: Loire Agrotech revolution

This scenario proposes to address some of the critical shocks by proposing a series of high-tech solutions for several of the profiled crops of the LOFS Living Lab. For this scenario to be fully deployed it would require a re-think of current practices, up-skilling of a workforce toward tech solutions, plus some investment into new equipment and infrastructures.



Rapeseed:

- *Precision agriculture:*

The introduction of satellite imagery and on-field sensors to monitor crop health and soil moisture will allow for targeted resource allocation. Farmers can apply fertilizer and water only where and when needed, thus maximizing efficiency and minimizing waste. Using automated equipment, farmers can adjust fertilizer and water application rates based on real-time data, ensuring optimal conditions for each part of the field.

- *Advanced breeding techniques:*

Marker-Assisted Selection can be a deployed technique allows breeders to identify desirable traits like disease resistance and higher yields in rapeseed at the seedling stage, accelerating breeding programs.

- *Sustainable irrigation:*

Drip Irrigation will be deployed to deliver water directly to the plant roots, minimizing evaporation and maximizing efficiency, particularly crucial in drought-prone areas. The use of soil moisture sensors will provide real-time information on soil moisture levels, allowing farmers to irrigate only when necessary.

- *Digital farming platforms:*

Cloud-based platforms will aggregate data from sensors, weather stations, and other sources to provide farmers with valuable insights into their fields. This data can then be used to make informed decisions about planting, irrigation, and pest management. Tools to help farmers analyse their data and make informed decisions about their crops. For example, a tool could recommend the best time to apply fertilizer based on the current weather forecast and soil conditions.

Lettuce:

In addition to sustainable irrigation systems noted above, the following scenarios should be considered for this technological future.

- *Forecasting*

Advanced weather forecasting allows farmers to anticipate droughts and heatwaves, enabling them to take proactive measures like adjusting planting schedules or implementing temporary shading solutions.

- *Hydroponics and vertical farming*



Lettuce can be grown indoors in controlled environments using hydroponic systems. This allows for year-round production, reduces reliance on outdoor conditions, and minimizes water usage. Further, vertical farming or stacked layers of growing beds allow for lettuce cultivation in urban areas or on limited land, making it a suitable option for the Loire Valley.

- *Drought-resistant Lettuce Varieties*

Research and development of lettuce varieties tolerant of high temperatures and low water availability can improve crop yields.

Mushrooms:

- Vertical or multi-level contained systems

Multi-level, stackable vertical farm growing systems optimize space and create ideal conditions for mushroom cultivation. Sensors and automated systems maintain optimal temperature, humidity, and CO2 levels for various mushroom varieties. Growing mushrooms in a controlled, water-based environment minimizes water usage and disease risk. Automated systems deliver precise nutrient solutions, ensuring optimal growth and yield. Robots can handle tasks like planting, harvesting, and packing, reducing labour costs and increasing efficiency. Improve insulation.

Benefits:

- **Increased Yields:** The use of these technologies can lead to higher crop yields, boosting the profitability of this new crop for Loire Valley farmers.
- **Reduced Environmental Impact:** Precision agriculture and sustainable irrigation practices can help conserve water and resources, minimizing the environmental footprint of rapeseed cultivation.
- **Improved Sustainability:** Advanced breeding techniques and digital farming platforms can contribute to the long-term sustainability of rapeseed production in the Loire Valley.

Note - the vertical farming besides the benefits, requires significant up-front costs in infrastructure, and in energy running costs. It is necessary to have an innovative business model in order for this operation to function, such as direct customer engagement with operations and farming and/or community education about the



practices. Energy costs can be reduced via a conversion to renewable energy sources, such as wind generators or photovoltaics and insulation.



3.4 Germany

3.4.1 Dossier of Living Lab- country profile

Country - Germany

Region in EU - Northwestern Europe

Name of living lab - Ensuring Security of Agricultural and Processed Products in NRW (ESAPPIN).

Partners - ZENIT GmbH, Technische Hochschule Ostwestfalen-Lippe (TH-OWL), FlyPard Analytics GmbH.

Products - Barley, Raspberries / Strawberries, Oat, Rapeseed for edible oil and protein extraction, Champignons.





Figure 3-10: Map of Germany with products

Partner background information

Economics - The agricultural sector is a small part of the economy in the region of North Rhine-Westphalia (NRW). In 2017, around 1.3% of the workforce was employed in this sector, which is a relatively small proportion of the total population. However, the region is home to 34 300 agricultural holdings, which manage a total area of 1.5 million



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hectares. Nevertheless, there has been a downward trend in agricultural employment. According to the latest available statistics from the Federal Statistical Office, 119 400 people were employed in the agricultural sector in 2022, representing 0.67% of the total population. About half of Germany's land area is used for agricultural purposes. In 2022, this includes 70% arable land, 29% permanent grassland and 1% permanent crops such as fruit trees or vineyards. Agriculture in North Rhine-Westphalia shows significant regional differences due to the diversity of landscape, climate and soil types. Cereals for grain production are the dominant crop. More than half of the arable land is used for cereals. The most important cereal in Germany is winter wheat, followed by barley, which is used for various purposes, including animal feed and brewing barley. According to available statistics, wheat is the most widely grown crop in North Rhine-Westphalia. In 2022, wheat was grown on 22% of the arable land, followed by barley (17%), maize (15%), rape (12%), potatoes (5%) and sugar beet (4%). Barley is the second most important crop after wheat, accounting for 17% of arable land. In addition, silage maize, which occupies 15% of the area, is mainly used as animal feed. This is followed by rape (12%), which is grown for both oil production and animal feed. Less common crops include potatoes (5%) and sugar beet, which occupies only 4% of the area. The cultivation of legumes, such as peas, beans, and soy, has significantly increased in recent years but still occupies a relatively small portion of the arable land.

Horticulture is prevalent in this region, with approximately 50 000 individuals employed across 4 700 enterprises. This sector, particularly recognized for its greenhouse cultivation, generates substantial annual revenues exceeding 2.4 billion euros.

Fruit cultivation also represents a certain share of agriculture, yet it does not contribute as significantly to the German economy as cereals do. Asparagus and strawberries are primarily cultivated, with Lower Saxony and North Rhine-Westphalia yielding the largest harvests and cultivated areas, respectively. Mushroom cultivation is widespread in Germany; however, data for this region is not available, but in 2022, mushroom production amounted to 76,085 tonnes nationally.

The production of milk and milk products is an important agricultural sector, accounting for the largest share of the EU milk market. A significant proportion of farms



in Germany, almost a quarter, are engaged in dairy farming, making milk production a key component of agricultural output. This sector makes a significant contribution to the total production value of German agriculture. Germany is the largest milk producer in the EU, producing around 31.9 million tonnes of cow's milk in 2022. It is also a leading producer of drinking milk (19% of the EU total), butter (20%), fermented milk products such as yoghurt (29%) and cheese (22%). Cattle play a crucial role in Germany, which has the second largest cattle population in the EU, with 16.8 million cattle in 2023. This underlines the significant economic importance of the dairy industry. France has the largest cattle population. Dairy cattle thrive in Germany for a number of reasons, including the region's temperate climate and the abundance of pasture and feed available for cattle rearing.

Policies - The farmer chooses the ecosystems in which he participates: a) provision of land to improve biodiversity and maintain habitats (fallow/flowering/old grass strips and areas), b) diversified crop production with at least five main crop species in arable farming, including at least 10% legumes, c) maintenance of agroforestry on arable land and permanent grassland, d) extensification of permanent grassland, e) performance-based payments for permanent grassland with proof of at least four regional indicator species, f) no use of plant protection products, g) management in Natura 2000 areas in accordance with the protection objectives. The agri-environment and climate programme in North Rhine-Westphalia promotes a diverse and sustainable agricultural landscape through a variety of measures. These include growing a crop mix of large grain legumes, establishing perennial wildflower strips and wild plant mixtures, and incorporating small arable fields alongside cereals in wider rows with optional stubble fallow. The programme also encourages the establishment of riparian and erosion control strips to protect water resources and soil health. It also supports the breeding and rearing of endangered livestock breeds and promotes contractual conservation practices. This comprehensive approach promotes biodiversity, improves soil health and encourages sustainable agricultural practices in the region.

Farming practices - Despite facing environmental challenges due to intensive practices (Wendland et al., 2020), North Rhine-Westphalia (NRW) uses different farming systems



such as conventional, organic and no-till. The north is characterised by extensive arable crops and livestock, while the south tends towards cereals and less intensive livestock production (2018). Crop rotations vary, with maize often following maize and, in some areas, self-cropping for winter wheat. Irrigation is used for specific crops such as sugar beet and potatoes, with studies also identifying water requirements for major horticultural crops. A study in North Rhine-Westphalia (NRW) examined crop rotations and irrigation practices, focusing on five major crops: maize, winter wheat, sugar beet, oilseed rape and potatoes. The analysis revealed a high prevalence of monoculture in maize, with 46.9% of fields following a previous maize crop. Winter wheat also showed some self-cropping practices, observed on 30% of the arable land. In contrast, oilseed rape and sugar beet were generally found in established rotations. The study also looked at irrigation use, identifying sugar beet, potatoes, maize and wheat as the main beneficiaries among arable crops. The researchers also identified irrigation requirements for thirteen major horticultural crops, including cauliflower, French beans, peas, strawberries, carrots and onions. These results provide valuable insights into agricultural practices and water resource management in NRW.

Potential drivers

Climate - Situated 152 metres above sea level, Essen has a temperate oceanic climate. The average annual temperature is 9.9°C, with the warmest days in July (17.9°C) and the coldest in January (2.4°C). Rainfall is moderate throughout the year, averaging 935 mm annually. June and December are the wettest months (93 mm), while February is the driest (58 mm). However, this apparently mild climate poses challenges for agriculture. Drought during sowing and flowering, especially during grain filling, can significantly affect crop yields. Heat stress during the growing season, especially during flowering, is another concern. Winter frosts and extreme weather events such as hail, floods and fires also threaten agricultural production. Understanding these climate risks is crucial for farmers in Essen to adopt resilient agricultural practices and ensure food security in the region.



Food security - agriculture in Germany is a key aspect of the country's policy to ensure a stable and reliable food supply for its population. The country produces a wide range of agricultural products, including cereals, vegetables, fruit, dairy products and meat. German agriculture benefits from modern technology and sustainable practices, contributing to high levels of productivity and efficiency. While the country produces a significant proportion of its food domestically, it also relies on imports for certain commodities, such as fruit, vegetables and tropical products. The government supports domestic farmers through subsidies, agricultural policies and investment in research and development to increase agricultural productivity and competitiveness. Germany has strict quality and safety standards for food production, processing and distribution. Regulatory agencies such as the Federal Office of Consumer Protection and Food Safety (BVL) and the Federal Institute for Risk Assessment (BfR) monitor and enforce food safety regulations to ensure that food products meet high standards of hygiene, quality and safety. Regular inspections and tests help to maintain consumer confidence in the safety of the food supply. Social benefits, such as unemployment benefits and income support, help to support individuals and families facing food insecurity. In addition, food banks and charities play a role in distributing surplus food to those in need. The government promotes sustainable agricultural practices, including organic farming, agro-ecology and resource-efficient production methods, to conserve natural resources, reduce environmental impacts and mitigate the effects of climate change on food production.

Farming conditions

Water - Surveys by the German Sprinkler Association in 1995 and 2001 indicate that about 500,000 ha in Germany are equipped for sprinkler irrigation. An area of about 5,000 ha is under micro-irrigation (mainly drip irrigation in vineyards). In the north-eastern part of the country there are about 600,000 ha of equipped lowlands. Combined drainage/sub-surface irrigation systems have been installed to manage peat soils and groundwater near sandy soils. Surface irrigation methods are no longer used. Irrigation is mainly practised on arable land and in most irrigated areas only specific crops in a crop rotation are irrigated (e.g., potatoes, sugar beet, maize and vegetables).



Therefore, the irrigated area was only 236 797 ha in 1998 and 220 907 ha in 2002. About 79% of the irrigated area was used for arable crops, 17% for horticulture and 4% for perennial crops. For Lower Saxony, where about 47% of the irrigated area is concentrated, statistics per county were provided by the local branch of the irrigation association, while for Saxony-Anhalt, also at county level, statistics were derived from the literature. The total irrigated area was 515 731 ha. Irrigation in the equipped lowlands was neglected because it was reported that the operation and maintenance of subsurface irrigation systems was drastically reduced during the transformation process of irrigated agriculture in East Germany. Therefore, these systems are not included in the water use statistics. There are initiatives to reactivate the system of ditches, control structures, weirs and pumping stations, as the climatic conditions in north-east Germany require a high level of water retention and impoundment for irrigation of cultivated grassland. However, the focus is on protecting peat soils and wetlands rather than increasing agricultural production. The AElS reported for the Länder of Bavaria, Brandenburg, Hesse, North Rhine-Westphalia and Schleswig-Holstein were then downscaled to NUTS2 regions or districts with regard to the proportion of irrigated area reported in various publications for 2002. The irrigated area per Land is shown in the table below.

Table 3.10: Irrigated area in Germany

Federal state	Area equipped for irrigation (ha)			Area actually irrigated (ha)
	total	with groundwater	with surface water	
Baden-Württemberg	20 000	13 953	6 047	9 965
Bayern	35 000	30 811	4 189	6 350
Berlin	250	249	1	234
Brandenburg	25 000	17 623	7 377	11 509
Bremen	53	24	29	13
Hamburg	1 010	228	782	840
Hessen	45 000	40 872	4 128	28 007
Mecklenburg-Vorpommern	15 000	6 016	8 984	5 473
Niedersachsen	242 218	222 688	19 530	92 727
Nordrhein-Westfalen	35 000	31 671	3 329	15 043
Rheinland-Pfalz	35 000	13 763	21 237	28 571
Saarland	250	202	48	204



Sachsen	5 000	2 967	2 033	2 307
Sachsen-Anhalt	45 000	36 697	8 303	28 660
Schleswig-Holstein	5 450	4 930	520	2 726
Thüringen	6 500	784	5 716	1 965
Germany total	515 731	423 479	92 252	234 594

The irrigated area was assigned to cultivated land derived from the Corine 2000 land cover database for Europe located within the digitized polygons. Therefore, the irrigated area was also assigned to arable land on coarse soils.

Diseases, pests and plant protection

Table 3.11: Diseases, pests and plant protection

Crop	Harmful organism	Species names	Plant protection practices
Barley	Pest	Cereal leaf beetle; saddle gall midge; aphids; leafhoppers; cereal cyst nematode; thrips; frit fly; corn ground beetle; wheat bulb fly; orange wheat blossom midge; yellow wheat blossom midge; barley leaf miner; barley gout fly; click beet; <i>Heterodera hordecalis</i> ; barley root-knot nematode.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	Powdery mildew, rusts, Ramularia leaf spot of barley, net blotch of barley, leaf stripe of barley, scald of barley, head blight, eyespot, take-all; Barley yellow dwarf virus; Wheat dwarf virus.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	Winter cereals - <i>Bromus sp.</i> , <i>Fallopia convolvulus</i> , <i>Tripleurospermum inodorum</i> , <i>Chenopodium album</i> , <i>Polygonum aviculare</i> , <i>Galium aparine</i> , <i>Cirsium</i>	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.

		<i>arvense</i>, <i>Viola arvensis</i>, <i>Stellaria media</i>, <i>Elytrigia repens</i> spring cereals - <i>Fallopia convolvulus</i>, <i>Chenopodium album</i>, <i>Polygonum aviculare</i>, <i>Viola arvensis</i>, <i>Cirsium arvense</i>, <i>Tripleurospermum inodorum</i>, <i>Thlaspi arvense</i>, <i>Galium aparine</i>, <i>Anagallis arvensis</i>, <i>Capsella bursa-pastoris</i>, <i>Elytrigia repens</i>.	
Raspberry strawberry	Pest	Chrysanthemum leaf nematode; <i>Aphelenchoides fragariae</i> ; stem and bulb nematode; strawberry blossom weevil; strawberry mite; raspberry beetle.	Certified transplants; locality selection; adequate fertility management, residue management, removing dead or infected plant material; use of insecticides; use of bio pesticides.
	Disease	Botrytis fruit rot (<i>Botrytis cinerea</i>); spur canker of raspberry (<i>Xenodidymella applanata</i>); Phytophthora crown and root rot of strawberry (<i>Phytophthora cactorum</i>).	Preventing excess moisture in the field (plant density, locality selection, avoiding poorly drained soils, improving air circulation), pathogen-free planting stock, certified planting stock, adequate fertility management, residue management, removing dead or infected plant material, using mulches, sanitation practices, cultivar selection, soil solarisation, fungicide application.
	Weed	Annual and perennial weeds	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.
	Pest	Cereal leaf beetle; aphids; leafhoppers; cereal cyst nematode; thrips; frit fly; corn ground beetle; click beetle; barley root-knot nematode; grain nematode.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	Loose smut (<i>Ustilago avenae</i>); head blight (<i>Fusarium spp.</i>); rust (<i>Puccinia coronata</i>).	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess

Oat			moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	<i>Chenopodium album</i> , <i>Fallopia convolvulus</i> , <i>Chenopodium album</i> , <i>Polygonum aviculare</i> , <i>Viola arvensis</i> , <i>Cirsium arvense</i> , <i>Thlaspi arvense</i> , <i>Galium aparine</i> , <i>Anagallis arvensis</i> , <i>Capsella bursa-pastoris</i> , <i>Elytrigia repens</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.
Rapeseed	Pest	Brassica pod midge; rape beetle; cabbage flea beetle; rape stem weevil; cabbage seed weevil; cabbage stem weevil; cabbage gall weevil; aphids; black cutworm; turnip sawfly.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	Phoma stem canker = blackleg, Sclerotinia stem rot; club root; Verticillium stem stripping.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application
	Weed	<i>Stellaria media</i> , <i>Capsella bursa pastoris</i> , <i>Chenopodium album</i> , <i>Cirsium arvense</i> , <i>Elytrigia repens</i> , <i>Galium aparine</i> , <i>Lamium sp.</i> , <i>Tripleurospermum inodorum</i> , <i>Papaver rhoeas</i> , <i>Poa annua</i> , <i>Sisymbrium officinale</i> , <i>Veronica sp.</i>	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.
Mushroom	Pest	Fungus gnats; Shore fly; Springtails; Mushroom flies; Beetle larvae	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides; Sanitation

	Disease	Green mold; Brown blotch; Dry bubble disease; Wet bubble disease; Slugs and snails; Mites	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application, pasteurization or sterilization of growing medium, Fungicides and insecticides
	Weed	Mosses; Algae; Grasses; Broadleaf weeds	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.

Soil - Most of Germany has temperate brown and deep brown soils. Their formation depends on relief, hydrological conditions, vegetation and human intervention. Germany's finest soils are found on the loess of the northern flank of the Central German Uplands, the Magdeburg Plain, the Thuringian Basin and adjacent areas, the Rhine Valley and the foothills of the Alps. The soils range from black to extremely fertile brown and are mostly arable. The till (ground moraine) of the North German Plain and Alpine foothills has heavy but fertile soils. Luvisols or gleysols predominate, while cambisols, podzol-cambisols or podzols predominate on sandy soils. The transition from lowland to hilly and mountainous areas is characterised by a loess belt where luvisols, podzoluvisols and gleysols predominate. Chernozems and (ludic) phaeozems developed instead of luvisols in the dry basin landscapes on the lee side of the mountains, especially in the fertile loess plains and in the Upper Rhine area. Loess soils are also very common in hilly and mountainous areas. The soil pH of both types of land use showed a bimodal distribution, with peaks at pH 6.1 and 7.3 for arable land and pH 5.0 and 7.1 for grassland. Soils with pH <5 were mainly found on sandy soils in northern Germany and on acidic parent material in southern Germany. The parent material of the soils in the North German lowlands and in the Alpine foothills consists mainly of Pleistocene deposits (in old and young moraine landscapes) and in the Alpine foothills also of gravel and various Tertiary sediments of the northern Alpine foothills. Threats include high levels of nutrients, heavy metals and organic pollutants.



3.4.2 IPCC projections on climate change indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:

3.4.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

In 2022, Germany recorded an annual mean surface air temperature of 10.83°C, up from 9.49°C in 2021. Climate projections based on the SSPs suggest that by 2030, the mean surface air temperature will be 10.05°C under the SSP1-1.9 scenario (best-case) and 10.40°C under the SSP5-8.5 scenario (worst-case). By 2050, the projections indicate that the mean surface air temperature will be 10.30°C in the best-case scenario and 11.50°C in the worst-case scenario. These projections highlight the potential range of temperature increases depending on future greenhouse gas emissions and global climate policies.



Projected Average Mean Surface Air Temperature Germany; (Ref. Period: 1995-2014), Multi-Model Ensemble

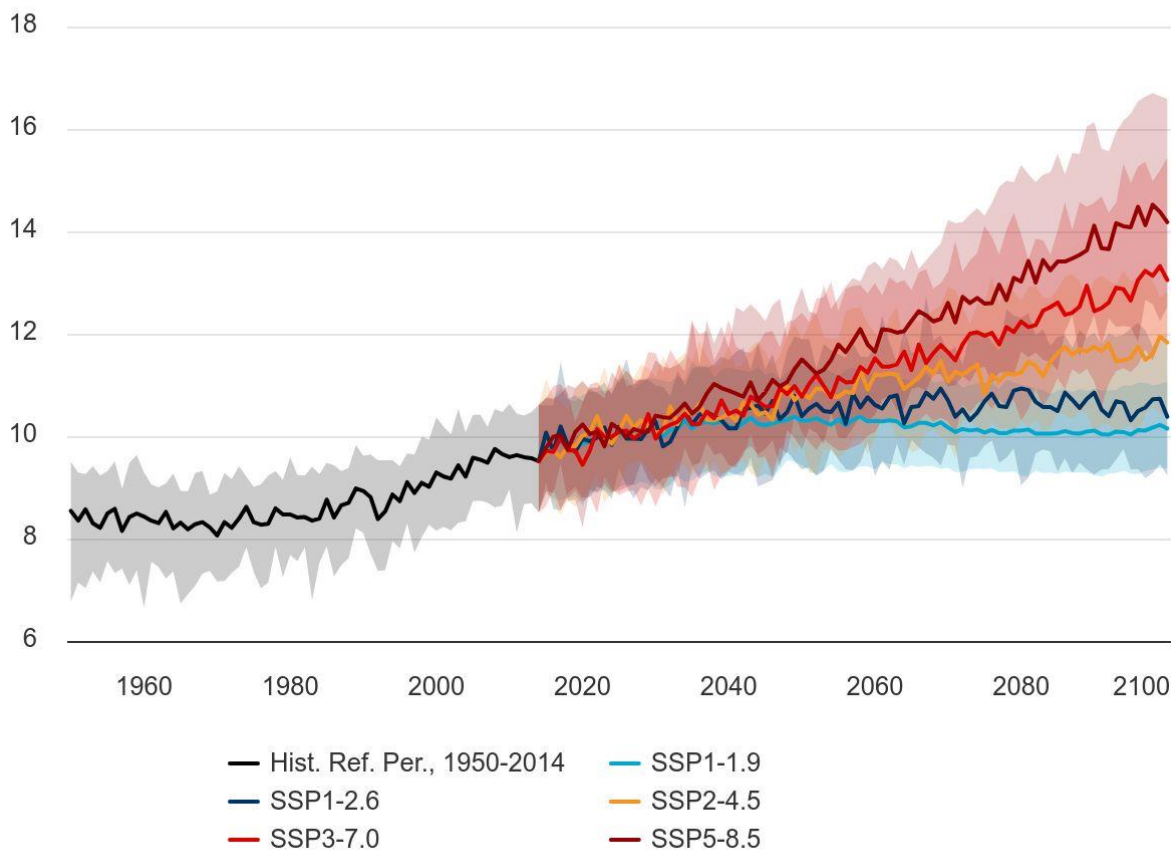


Figure 3-11: Projected average mean surface air temperature for Germany

The living lab in Germany focuses on the state of North Rhine-Westphalia. Projections for this region indicate that by 2030, the mean surface air temperature will range between 10.40°C and 10.81°C. By 2050, the mean surface air temperature is expected to range from 10.64°C to 11.84°C.

3.4.2.2 Precipitation pattern

Climate change has significantly affected precipitation patterns in Germany, causing shifts in seasonal precipitation and overall annual precipitation patterns. Winter precipitation has increased, while summer precipitation has decreased, particularly in the southwestern part of the country. Annual precipitation decreased from 772.97 mm in 2021 to 612.51 mm in 2022. Projections for annual precipitation in 2030 range between 900.23 mm and 927.64 mm across the SSP scenarios. By 2050, annual



precipitation patterns are projected to fall between 880.89 mm and 877.64 mm across all scenarios.

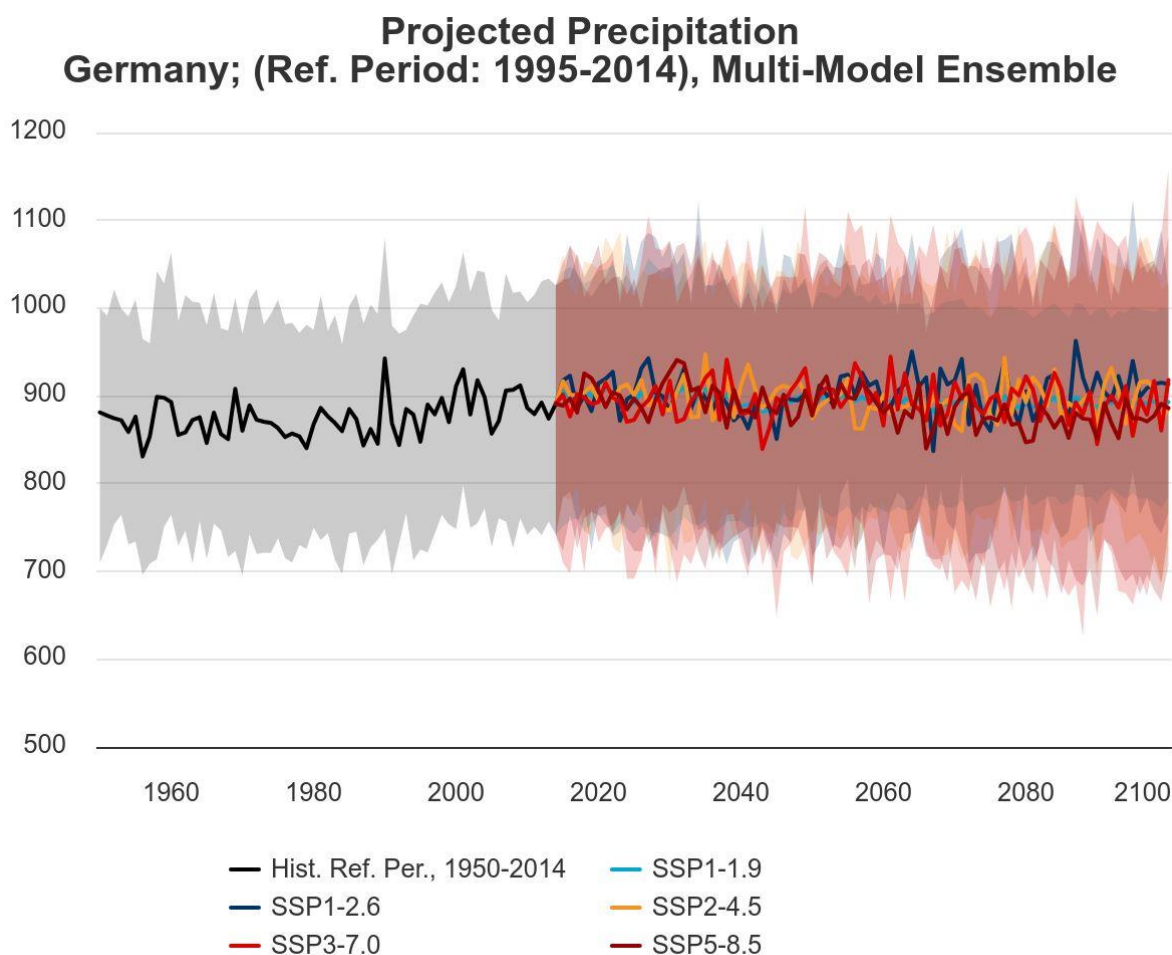


Figure 3-12: Projected precipitation patterns in Germany

The annual precipitation projected for North Rhine-Westphalia in 2030 is 965.10 mm under the SSP1-2.6 scenario and 983.13 mm under the SSP5-8.5 scenario. For 2050, projections indicate annual precipitation will range between 941.49 mm under the SSP1-1.9 scenario and 952.33 mm under the SSP5-8.5 scenario.

3.4.2.3 Sea level rise

Sea level measurements for Germany are complex due to its extensive coastlines along both the North Sea and the Baltic Sea. According to sea level data from the Helmholtz-

Zentrum Geesthacht, sea levels on the North German coast have risen by approximately 0.15 to 0.20 meters over the past hundred years.

The living lab in Germany focuses on the state of North Rhine-Westphalia, which is closer to the North Sea and monitored by the Delfzijl gauge. Projections indicate that by 2030, sea level changes in this region will range from 0.12 meters to 0.13 meters across all SSP scenarios. By 2050, the sea level change is projected to increase to a range of 0.21 meters to 0.27 meters.

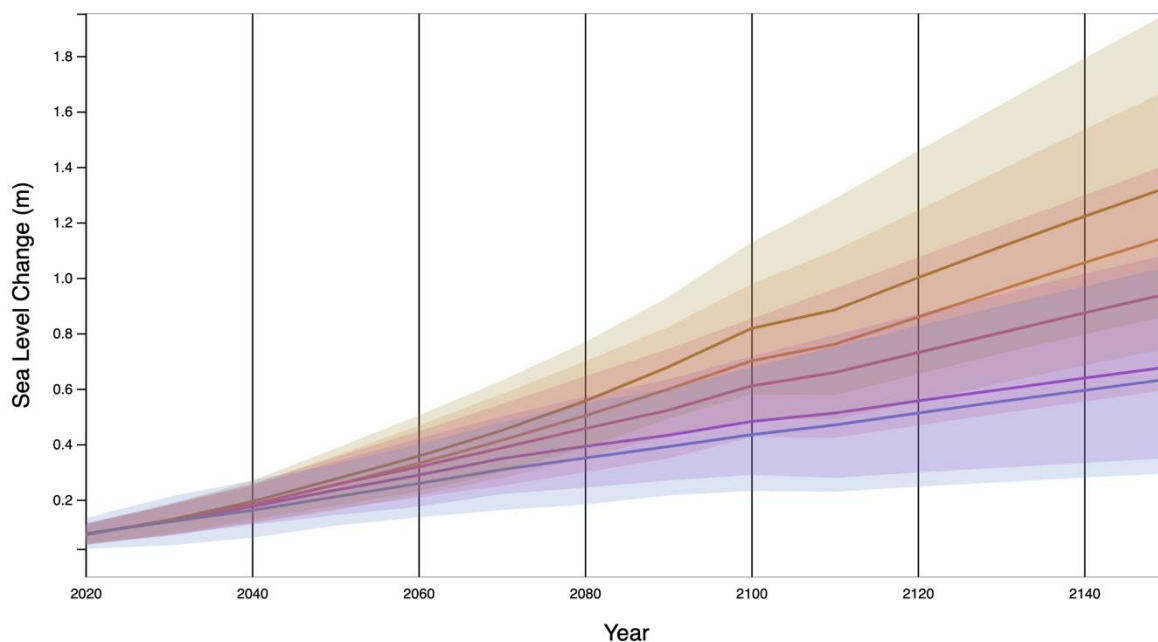


Figure 27. Projected sea level changes in Germany

3.4.2.4 *Extreme weather events*

Climate change is bringing more extreme weather to Germany. The average annual temperature has risen 1.7 degrees Celsius since 1881, exceeding the global average. Heatwaves are becoming more frequent, with the number of days exceeding 30 degrees Celsius tripling since the 1950s. Droughts are also a growing concern, with drier springs and summers leading to faster soil drying. While the number of heavy rain days hasn't significantly changed overall, some regions are experiencing more frequent extreme precipitation events. Winters are seeing a 27% increase in precipitation, and rising sea levels pose a future threat to coastal areas.



3.4.2.5 *Ecosystem and biodiversity impacts*

Climate change is expected to alter the distribution and composition of vegetation in Germany, with a shift towards more Mediterranean and arid vegetation types. The loss of biodiversity is a significant concern, with many species expected to decline or become extinct due to climate change. Changes in precipitation patterns and increased evaporation due to warmer temperatures will alter water cycles, leading to droughts and water scarcity in some areas. Many species are expected to shift their distributions northward or to higher elevations in response to changing temperatures and precipitation patterns. Changes in temperature and precipitation patterns will alter the timing of seasonal events, such as flowering and migration, which can disrupt species interactions and ecosystem function. Climate change increases the risk of extinction for many species, particularly those with limited ranges or specialized habitats. Mountain ecosystems are particularly vulnerable to climate change, with changes in snow cover and glacier extent affecting plant and animal species that depend on these habitats. Coastal ecosystems are also vulnerable, with sea level rise and increased storminess threatening habitats and species that depend on them.

3.4.2.6 *Socioeconomic impacts*

Agriculture and Food Security: Declining yields and damage to agricultural infrastructure due to extreme weather events.

Economic Losses: The total economic losses in Germany due to climate change are estimated to be around €145 billion since 2000, with more than €80 billion of these losses occurring in the past five years alone.

Health: Impact on health system due to heatwaves, floods and other extreme weather events.

3.4.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food



production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Germany and their specific focus on different products.

Table 3.12: Drivers of products for Germany

Products - Germany					
	Barley	Strawberries/Rasb erries	Oats	Mushrooms	Rapeseed
Drivers	1. Increased air temperature 2. Pathogens 3. NPKS (Nitrogen, Phosphorus, Potassium, Sulphur) 4. Crop rotation 5. Nutritional quality	1. Soil moisture 2. Precipitation changes 3. Seasonal variation 4. Fungi 5. Nutritional quality	1. Increased air temperature 2. Pathogens 3. NPKS (Nitrogen, Phosphorus, Potassium, Sulphur) 4. Crop rotation 5. Nutritional quality	1. Wood availability 2. Wheat straw availability 3. Fungi	1. Increased air temperature 2. Precipitation changes 3. Fauna 4. NPKS (Nitrogen, Phosphorus, Potassium, Sulphur) 5. Crop rotation

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.4.4 Living lab scenarios

ESAPPIN

The ESAPPIN Living Lab (LL) addresses food security in the German state of North Rhine-Westphalia (NRW). Despite a high population density and relatively urbanised landscape, agriculture plays a key role in NRW with 43,2% of the total land in the state used for agricultural purposes. This, combined with a strong scientific and industrial base, has led to NRW becoming an innovation leader in the agricultural and food sectors. It has also led to an increased role of the food processing industry in NRW as a means to maximise the utilisation of the crops and food produced within the state, with food processing accounting for 35% of the overall workforce in the agricultural industry in NRW.

Products \ Scenarios	Barley	Oat	Rapeseed	Strawberries & Raspberries	Mushrooms
1. Status quo for 2030 - 2050	X	X	X	X	X

2. Climatic shock 1: drought	X	X	X		
3. Climatic shock 2: heavy rain				X	
4. Biocontrol	X	X	X		
5. Reduction in nutrient losses of at least 50% by 2050, while ensuring no deterioration in soil fertility	X	X	X	X	

Scenario 1: Business as usual (2030 and 2050)

To construct the "Business as Usual" (BAU) scenarios for 2030 and 2050 for each of the production systems (barley, oats, rapeseed, strawberries & raspberries, and mushrooms) in North Rhine-Westphalia, we must consider the current agricultural practices, climate challenges, and technological adoption rates. The BAU scenarios will assume minimal changes in these areas, projecting forward the current trends without significant innovations or adaptations to emerging climate stressors. Here's how these scenarios might look for each crop:

Barley production:

- **2030:** Traditional farming practices with moderate use of fertilizers continue. Water scarcity starts to affect yields more significantly, but the adoption of water-efficient practices is limited. The market demand remains stable, encouraging a business-as-usual approach.
- **2050:** Climate change impacts, including longer drought periods and irregular rainfall, lead to reduced yields and increased production costs. Efforts to adopt climate-resilient varieties are noted, but widespread change is limited, affecting the economic viability of small-scale farmers.

Oats production:

- **2030:** Continued reliance on conventional farming methods with moderate input use. Occasional yield fluctuations due to increasing weather variability. There is a slow uptake of precision agriculture technologies.
- **2050:** Increased frequency of extreme weather events, such as heatwaves and heavy rains, result in more pronounced yield variability. Soil quality continues to



degrade due to lack of crop rotation and sustainable practices, leading to reduced overall productivity.

Rapeseed production:

- **2030:** Traditional pest management and fertilization practices persist. The crop faces increased pest pressures and occasional drought stress, but significant changes in management practices are rare.
- **2050:** Greater susceptibility to pests and diseases due to climate change, combined with inconsistent rainfall, significantly reduces yields. While some adoption of drought-resistant varieties occurs, it is not widespread enough to mitigate overall declines.

Strawberries & Raspberries production:

- **2030:** Moderate yields with continued reliance on seasonal labour. Weather-related issues, such as late frosts, heavy rain and heatwaves, impact fruit quality and yield. Adoption of smart irrigation and protective technologies is slow.
- **2050:** Significant reduction in yields due to more severe weather patterns and increased labour shortages. Higher production costs due to necessary protective measures (e.g., polytunnels, shade nets) make profitability challenging. Water scarcity, at times, with extended periods of heavy rain exacerbates production issues.

Mushroom production:

- **2030:** Stable production within a contained climate control system. However, rising energy costs and quality of substrate start to impact profitability. Minimal technological advancements in cultivation practices.
- **2050:** Production declines as energy costs for maintaining climate-controlled environments become prohibitively high. Competition from more energy-efficient production systems in other regions increases. Reliance on imported mushrooms grows as local production struggles.



3.4.4.1 Across all productions:

- *Innovation*: Gradual but insufficient adoption of advanced agricultural technologies. Lack of investment hampers widespread implementation.
- *Sustainability*: Continued reliance on chemical inputs with few systemic changes towards sustainable practices. Environmental impacts of agriculture become more pronounced.
- *Labour force*: Severe labour shortages with aging farmer population and minimal interest from younger generations. Reliance on automated solutions and migrant labour increases.
- *Policy and subsidies*: EU subsidies continue but are increasingly focused on crisis management rather than proactive support for sustainable practices.

Scenario 2: Climatic shock - drought impact on the agricultural sector, with a focus on barley, oats and rapeseed

Climatic conditions: Drought is characterized by extremely low precipitation levels, high temperatures, and persistent dry conditions. Severe water shortages affect both surface and groundwater supplies. Reservoirs and rivers run significantly below normal levels, impacting irrigation and overall water availability for agriculture.

Impact on crop production: Oats, similar to barley, are highly sensitive to drought conditions. The prolonged dry period results in poor plant establishment and early maturation, leading to suboptimal harvests. Rapeseed is particularly vulnerable to drought during its flowering and pod-filling stages. The drought leads to flower abortion and reduced pod set. Yield reductions of oats and barley vary from 45 to 60%. The drought leads to lower biomass production and grain filling, resulting in lighter, less nutritious grains. As an economic impact, farmers experience significant revenue drops. The feed industry, which relies on oats, faces higher costs, and some may turn to alternative feed sources, impacting the overall market dynamics. The price of barley increases due to scarcity, but this does not compensate for the overall economic damage. The oilseed market faces volatility as the supply of rapeseed oil plummets.



Farmers incur heavy losses, and the regional economy, which partially depends on rapeseed production, suffers.

Technological and adaptation measures:

Research and development: Investment in drought-resistant crop varieties and sustainable farming practices increases. Research institutions and agricultural universities focus on developing and disseminating new technologies.

Adoption of water-efficient practices: Farmers begin to adopt more water-efficient irrigation methods, such as drip irrigation and rainwater harvesting, though adoption rates are slow due to high initial costs.

Policy changes: Policymakers introduce incentives for sustainable water management and crop diversification to reduce dependency on vulnerable crop

Scenario 3: Climatic shock - heavy rain impact on the agricultural sector in North Rhine-Westphalia (NRW), Germany, with a focus on Strawberries & Raspberries

North Rhine-Westphalia (NRW), Germany, is a significant agricultural region known for its production of strawberries and raspberries. These crops are particularly vulnerable to heavy rainfall, which can lead to waterlogging, disease outbreaks, and direct damage to the fruits. This scenario explores the impacts of a period of intense and prolonged heavy rain on NRW's agricultural sector.

Climatic conditions: Heavy Rain is an unusual weather pattern that brings prolonged periods of heavy rain to NRW during the growing season. Rainfall levels exceed historical averages by 150%, resulting in saturated soil and flooding in low-lying areas. Drainage systems are overwhelmed, leading to waterlogging in fields. Rivers and streams overflow, causing localized flooding and further complicating water management efforts.

Impact on crop production: Heavy rains cause waterlogging in fields, suffocating plant roots and leading to root rot. Strawberries and raspberries are particularly vulnerable. The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201



raspberries suffer from poor oxygenation, resulting in stunted growth and plant death. Excess moisture promotes fungal diseases such as botrytis (gray mold) and mildew. Yield reductions are declining by 50%, to 100% loss of strawberry crops in seasons of continuous heavy rains. Fruit quality is severely affected, with many berries becoming unmarketable. The economic impact on farmers is severe, with losses compounded by the cost of disease management and crop salvage efforts. The continuous wet conditions prevent timely harvesting, further reducing the marketable yield.

Technological and adaptation measures

Research and development: Investment in disease-resistant and water-tolerant strawberry and raspberry varieties increases. Research institutions focus on developing and disseminating new technologies.

Adoption of water management practices: Farmers begin to adopt more advanced water management practices, including improved drainage systems and raised beds, though adoption rates are slow due to high initial costs.

Infrastructure improvements: Investment in water infrastructure, such as improved drainage systems and flood defences, reduces future vulnerability.

Policy Changes: Policymakers introduce incentives for sustainable water management and climate-resilient infrastructure investments.

Scenario 4: Implementation of biocontrol in the agricultural sector of North Rhine-Westphalia

North Rhine-Westphalia is a key agricultural region in Germany, producing significant amounts of barley, oats, and rapeseed. However, these crops are frequently affected by pests and diseases, leading to reduced yields and increased reliance on chemical pesticides. This scenario explores the long-term adoption of biocontrol methods in NRW's agricultural sector to combat these challenges and promote sustainable farming practices.



Overview of biocontrol implementation:

Biocontrol methods: Biocontrol involves the use of natural predators, parasites, and pathogens to manage agricultural pests and diseases. This approach reduces the reliance on chemical pesticides, promoting a more sustainable and environmentally friendly agriculture.

Adoption rate: In the future, NRW sees a substantial shift towards biocontrol methods, driven by increased awareness of environmental sustainability, governmental support, and successful pilot programs demonstrating the effectiveness of these methods.

Impact on crop production

Pest and disease management: The adoption of biocontrol significantly reduces the need for chemical pesticides. Natural predators and parasitoids, such as predatory mites, and parasitic wasps, are introduced to control aphid populations, a common pest for barley and oats.

This region faces ongoing challenges from pests that threaten crop yields and biodiversity. Practices to mitigate: Pest-Resistant Varieties, Beneficial Insects, Preventive Measures, and Biopesticides - derived from natural organisms, such as bacteria, fungi, and plant extracts. Habitat Enhancement: Creation and maintenance of habitats that support beneficial insects and wildlife, such as hedgerows, wildflower strips, and insect hotels. Crop Rotation helps to disrupt pest life cycles and reduce pest pressure. Intercropping and Polyculture enhance biodiversity and create less favourable conditions for pests. Mechanical Controls using physical barriers, traps, and manual removal techniques to reduce pest numbers. For example, using row covers, pheromone traps, and hand-picking of pests. Precision Agriculture utilizes drones, sensors, and data analytics to monitor pest populations and apply targeted treatments, minimizing the use of chemical pesticides.

Barley: in years where the spring season is too warm, problems with powdery mildew and barley yellow dwarf virus (BYDV) will become more common. Seed dressing with systemic insecticides will not be available as well as the effective N fertilisation in



spring due to fertilizer regulation §13. Some phytosanitary cultivation interventions will be used. Barley will be rotated with non-host crops to reduce the buildup of the pathogen in the soil. Barley varieties that are bred for resistance to powdery mildew will be planted. Various products based on beneficial microorganisms that antagonize or compete with the powdery mildew pathogen (such as *Bacillus subtilis*, *Trichoderma* spp., and others) will be employed.

Rapeseed: it will face cultivation problems related to climate such as the increasing infestation or insecticide tolerance of cabbage shoot weevil (*Ceutorhynchus pallidactylus*) and rapeseed beetle (*Meligethes aeneus*). Increasingly long periods of drought and heat will promote the development of pest populations while at the same time reducing the effectiveness of the insecticides used. As a practice to mitigation, introduction and supporting populations of natural predators and parasitoids to control pest populations will be used. For example, support for naturally occurring white-winged parasitoids *Phradis interstitialis*, *Phradis morionellus* and *Tersilochus heterocerus*. The degree of parasitisation will significantly be increased in non-agricultural areas close to rapeseed fields.

Strawberry/raspberry: the cultivation will be repeatedly under pressure due to summer weather extremes, such as long wet periods which will lead to increased Botrytis fruit rot (*Botrytis cinerea*). An important part of controlling Botrytis, will be the use of preventive methods such as reducing the conditions suitable for spread and reducing the susceptibility of the host to infection, like site selection, optimal plant density, balanced nutrition - over-densed, nitrogen-fertilised and older stands are more heavily infested. Any measures to exclude or reduce fruit damping-off will reduce the incidence like mulching, growing on foil, and removing infected fruit. Biopesticides will be used, for example, the effects of antagonistic microorganisms based on fungi such as *Acremonium*, *Trichoderma* spp., *Gliocladium* or *Pythium oligandrum*, bacteria *Bacillus* spp. or *Pseudomonas* spp., yeast extracts.

Fungal disease control: Biocontrol agents such as *Trichoderma* spp. and *Bacillus subtilis* are utilized to combat fungal pathogens affecting barley, oats, and rapeseed. These



biocontrol agents outcompete harmful fungi in the soil and on plant surfaces, reducing the incidence of diseases like powdery mildew and root rot.

Yield and quality improvements: With effective pest and disease management through biocontrol, the overall health of barley, oats, and rapeseed plants improves. Biocontrol methods help stabilize production levels by providing a reliable and sustainable pest management solution. Farmers experience fewer crop losses due to pest outbreaks, resulting in more predictable and consistent harvests.

Economic impact: While the initial investment in biocontrol agents and the establishment of supportive habitats for beneficial organisms can be high, long-term costs are reduced due to decreased spending on chemical pesticides and improved crop yields. The use of biocontrol methods enhances the marketability of NRW's agricultural products. Consumers and retailers increasingly prefer crops produced with sustainable practices, opening new market opportunities and potentially higher prices for biocontrol-managed produce.

Wider impact on agriculture and the environment

Environmental benefits: Biocontrol practices promote biodiversity by supporting a variety of beneficial organisms within the ecosystem. This helps to restore natural ecological balance and enhance the resilience of agricultural landscapes. The reduction in chemical pesticide use decreases the runoff of harmful substances into waterways, improving water quality and protecting aquatic ecosystems.

Social and economic consequences: Successful implementation of biocontrol requires extensive farmer training and education. Extension services and agricultural cooperatives play a crucial role in disseminating knowledge and best practices. Farmers adopting biocontrol methods gain economic resilience through reduced dependency on chemical inputs and more stable crop production. This resilience helps buffer against market fluctuations and climatic shocks.

Policy and research support: Policymakers introduce incentives for the adoption of biocontrol methods, such as subsidies for purchasing biocontrol agents and funding for



research into local pest and disease challenges. Continuous research and development ensure that biocontrol methods evolve to meet emerging pest and disease challenges. Collaboration between research institutions, farmers, and government agencies drives innovation and practical applications.

This biocontrol scenario highlights the potential for transforming NRW's agricultural sector through sustainable pest and disease management practices. It underscores the benefits of reduced chemical use, improved crop health, economic resilience, and enhanced environmental stewardship, paving the way for a more sustainable agricultural future.

Scenario 5: Reduction in nutrient Losses by 50% by 2050, maintaining soil fertility in North Rhine-Westphalia

North Rhine-Westphalia is one of Germany's key agricultural regions, known for its diverse crop production and intensive farming practices. However, nutrient loss, particularly nitrogen and phosphorus, poses a significant environmental challenge, leading to water pollution and soil degradation. This scenario explores the long-term strategies and impacts of reducing nutrient losses by at least 50% by 2050 while maintaining or enhancing soil fertility.

Strategies for reducing nutrient losses

Precision agriculture: Widespread adoption of precision agriculture technologies, including GPS-guided equipment, soil sensors, and drone-based monitoring. These technologies enable the precise application of fertilizers, reducing over-application and minimizing runoff. Farmers use variable rate technology (VRT) to apply fertilizers at the optimal rate for different parts of the field, based on real-time soil nutrient data and crop requirements.

Advanced nutrient management: Implementation of farm-specific nutrient budgets that account for all inputs and outputs, ensuring balanced nutrient application. Use of enhanced efficiency fertilizers (EEFs) that release nutrients slowly over time, matching the crop's uptake needs and reducing leaching and volatilization losses. Applying



fertilizers in multiple smaller doses rather than a single large application to match crop growth stages and minimize losses.

Cover cropping and crop rotation: Planting cover crops during off-seasons to capture residual nutrients, reduce erosion, and improve soil structure. Common cover crops include legumes, which fix atmospheric nitrogen, and deep-rooted species that capture subsoil nutrients. Implementing diverse crop rotations that include deep-rooted and nitrogen-fixing crops, improving nutrient cycling and soil health.

Organic amendments and soil health: Incorporating organic amendments, such as compost, manure, and green manures, to enhance soil organic matter content. This improves soil structure, water retention, and nutrient-holding capacity. Regular soil testing to monitor soil fertility and adjust nutrient management practices accordingly. Farmers receive subsidies for soil testing services.

Policy and education support: Government incentives for adopting sustainable nutrient management practices, including subsidies for precision agriculture equipment, cover crop seeds, and organic amendments. Extensive farmer education programs on nutrient management, soil health, and sustainable farming practices. Collaboration with agricultural universities and research institutions to provide up-to-date information and training. Implementation of regulations that limit nutrient applications based on soil tests and crop needs, reducing the risk of over-fertilization.

Impact on crop production and soil fertility

Crop yields: Despite the reduction in nutrient losses, crop yields remain stable or improve due to the efficient use of fertilizers and enhanced soil health. Precision agriculture ensures that crops receive the right amount of nutrients at the right time. Diverse crop rotations and improved soil health increase the resilience of crops to pests, diseases, and climate variability, contributing to stable yields.

Soil fertility: Regular soil testing and the use of organic amendments ensure that soil fertility is maintained or improved. Soil organic matter content increases, enhancing nutrient availability and soil structure. Improved nutrient cycling through diverse



rotations and cover cropping reduces the need for synthetic fertilizers, promoting a self-sustaining soil ecosystem.

Environmental benefits: Significant reduction in nutrient runoff leads to improved water quality in rivers, lakes, and groundwater, reducing eutrophication and protecting aquatic ecosystems. Enhanced soil health and diverse crop rotations support greater biodiversity in agricultural landscapes, including beneficial insects, microorganisms, and wildlife.

Economic impact: Farmers experience cost savings from reduced fertilizer inputs and improved efficiency. Initial investments in technology and training are offset by long-term savings and increased productivity. Sustainable farming practices enhance the marketability of NRW's agricultural products, meeting consumer demand for environmentally friendly and responsibly produced food.

Long-term outlook

Sustainable agriculture: By 2050, sustainable nutrient management practices will be widely adopted across NRW. The region is recognized as a leader in sustainable agriculture, with a strong emphasis on soil health and environmental stewardship.

Resilient systems: Agricultural systems in NRW are more resilient to climate change and environmental pressures, ensuring food security and economic stability for the region's farmers.

Ecosystem services: Sustainable practices enhance ecosystem services provided by agricultural landscapes, including carbon sequestration, water regulation, and biodiversity conservation.

Community engagement: Farmers, communities, and policymakers work together to promote and implement sustainable practices, creating a culture of environmental stewardship and collective responsibility.



3.5 Greece

3.5.1 Dossier of Living Lab- country profile

Country - Greece

Region in EU - Mediterranean and Southwest Europe

Name of living lab - Thriving Agroecology Living Lab (THALLA)

Partners - Agricultural University of Athens, Farmers Union, Union of Working Consumers of Greece, The Hellenic Agency for Local Development and Local Government.

Products - Honey, Table olives, Tomatoes (industrial), Wheat, Gilthead seabream & European seabass.





Figure 3-13: Map of Greece with products

Partner background information

Economics - The following information relates to Central Greece and covers five regional units: Boeotia, Euboea, Evrytania, Phocis, and Phthiotis. The province's Gross domestic product (GDP) was 8.8 billion € in 2018, accounting for 4.7% of the Greek economic output. GDP per capita adjusted for purchasing power was 18 900 € or 63% of the EU27 average in the same year. The GDP per employee was 81% of the EU average. Central Greece is the region in Greece with the fourth highest GDP per capita. Agricultural and livestock production is a key source of income and employment for most of the population of the Region of Central Greece.



**Funded by
the European Union**

The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201

The contribution of the Region to the agricultural production of the whole country is significant. The region's arable land corresponds to 10% of total arable land in Greece. The cultivated agricultural land is 3.6mil hectares. 33% of these areas are irrigated areas. Viotia covers 29.32% of the agricultural land, Evia 22.73%, Evritania 1.55%, Fthiotida 42.58%, and Fokida 4.6%. The Region occupies about 9.23% of the total cultivated area of arable crops. Whereas, about 15.36% of the total cultivated area of horticultural crops, 10,09% of the total cultivated area of tree crops. Moreover 7.43% of the total cultivated area is covered by vineyards.

Main agricultural products are industrial plants (cotton and processed tomatoes), cereals (wheat, etc.), olive oil, and vegetables. Regarding livestock production, the main activity focuses on sheep, poultry, and pigs. The fishing fleet of the region amounts to 1 762 vessels, which accounts for 10% of the Greek fishing fleet with a production estimated at approximately 13,000 tonnes (11% of total production). About 32,000 tonnes of fish from aquaculture are produced; accounting for about 34% of the total domestic production (95 000 tons), with a production value amounting to € 160 million (2011 prices), 80% of this production is exported (25 600 tonnes).

Greece has a diverse economic landscape that is primed for sustainable development. Its strategic geographical location, particularly its proximity to Athens, offers logistical advantages. The country is blessed with fertile agricultural land and a rich heritage of agricultural and livestock expertise. The country also has a significant concentration in fisheries and aquaculture, further diversifying its economic base. In addition to its natural resources, Greece is rich in cultural treasures. Iconic sites such as Delphi and Thermopylae bear witness to its historical importance. Looking to the future, Greece has significant renewable energy capacity (solar, wind and hydro). This, coupled with the potential to develop synergies between the agricultural and livestock sectors, offers exciting opportunities for sustainable growth. Besides, Greece's focus on promoting environmental and energy-saving technologies positions it well for a future-oriented economy.



Policies- Eco-schemes: Greece addresses sustainability challenges in agriculture through two main programmes: agri-environmental and agri-environmental and climate measures. Eco-schemes focus on climate resilience and environmental benefits by promoting the use of resilient crop varieties and breeds, improved nutrient management practices and reduced use of plant protection products. Agri-environment and climate measures have a broader scope and support the protection of wildlife in designated areas, the preservation of rural landscapes, the adoption of alternative pest control methods and the conservation of local biodiversity through the protection of endangered plant varieties and livestock breeds. They also support beekeepers' efforts to ensure the health of pollinators, which are vital for both ecosystem and agricultural sustainability. These programmes work together to encourage EU farmers to adopt practices that contribute to a more sustainable future.

Farming practices - Although it accounts for only 4% of employment, agriculture remains a vital sector in Greece, particularly in terms of rural cohesion. The country's agricultural landscape is diverse, with a range of production systems including conventional, organic (covering 17.56% of the total agricultural area), low-input, regenerative and no-till farming. In Central Greece, particular emphasis is placed on the conservation and re-cultivation of local and traditional crop varieties, as well as the development of varieties and seeds adapted to the specific conditions of the region and suitable for organic farming practices. Crop rotation plays a crucial role in maintaining soil health. In particular, less than a third of the land is suitable for cultivation, with the remainder being pasture, scrub and forest. Water management is a critical issue, with agricultural irrigation accounting for 80-85% of total water use.

Potential drivers

Climate - Situated at an altitude of 107 metres above sea level, Athens enjoys a warm Mediterranean climate. The average annual temperature is 17.7°C, with the warmest days in July (27°C) and the coldest in January (9.3°C). Rainfall is concentrated in the winter months, with an annual average of 377 mm. December is the wettest month (66 mm), while July is the driest (3 mm). However, this apparently mild climate poses



potential challenges for agriculture. Drought during sowing and flowering, especially during grain filling, can significantly affect crop yields. Heat stress during the growing season, especially during flowering, is another concern. In addition, Athens faces the risk of fire events, which further threaten agricultural production. Understanding these climate risks is crucial for farmers in the region to adopt resilient agricultural practices that minimise losses and ensure food security.

Food security - Greece has a long history of agriculture, with fertile land and a favourable climate for growing crops and raising livestock. The country produces a wide range of agricultural products, including cereals, fruit, vegetables, olives, olive oil, wine, dairy products and seafood. Agriculture plays an important role in Greece's economy and provides employment for rural communities. The country produces a significant proportion of its food domestically; it also relies on imports for certain commodities, such as cereals and vegetable oils. The country exports a wide range of agricultural products, including olive oil, wine, cheese, fruit and vegetables. The Greek government supports domestic farmers through subsidies, incentives and investment in agricultural infrastructure and research. Greece maintains strict quality and safety standards for food production, processing and distribution. Regulatory bodies such as the Greek Food Authority (EFET) monitor and enforce food safety regulations to ensure that food products meet high standards of hygiene, quality and safety. Regular inspections and tests help to maintain consumer confidence in the safety of the food supply. The government promotes sustainable farming practices, including organic farming, agro-ecology and biodiversity conservation, to protect natural resources, maintain rural landscapes and mitigate the effects of climate change on food production. Initiatives such as the Common Agricultural Policy (CAP) support environmentally friendly farming practices and encourage the use of renewable energy sources in agriculture.



Farming conditions

Water - In its western part there are a number of lakes, the largest of which is Iliki (19.1sq.km.). There are also several artificial lakes in the area, such as those at Kremasta, Acheloos and Mornos.

The largest river in the area is Acheloos, while the smaller ones are Agrafiotis, Gorgopotamos, Pindos, Mornos, Sperchios, etc. The reported irrigable area in Greece increased from 1 130 570 ha in 1990 to 1 235 300 ha in 1995 and 1 521 600 ha in 2003. The area under irrigation also increased from 932 980 ha in 1990 to 1 142 180 ha in 1995 and 1 294 400 ha in 2003. The area equipped for irrigation was calculated by selecting the maximum of the irrigable area reported by EUROSTAT for 13 regions and for the years 1997, 2000 and 2003. The island of Crete was further subdivided into four districts, as irrigation statistics could be obtained from the literature. The area equipped for irrigation per region calculated in this way amounts to 1,544,530 ha. This area is shown in the table below.

Table 3.13 Irrigated area in Greece

District	NUTS1-region	Area equipped for irrigation (ha)			Area irrigated (ha)
		total (max. 1997, 2000, 2003)	with groundwater	with surface water	
	Anatoliki Makedonia, Thraki	211 390	80 638	130 752	177 410
	Attiki	15 000	12 522	2 478	9 820
	Dytiki Ellada	147 520	42 648	104 872	104 587
	Dytiki Makedonia	53 360	29 049	24 311	35 710
	Ionia Nisia	5 930	3 590	2 340	2 113
	Ipeiros	50 910	8 068	42 842	38 297
	Kentriki Makedonia	347 900	108 862	239 038	292 387
Iraklion	Kriti	59 045			
Khania	Kriti	28 577			
Lasithi	Kriti	25 311			
Rethimni	Kriti	9 877			
	Kriti		103 937	18 873	86 200



Notio Aigaio	14 440	8 051	6 389	6 870
Peloponnisos	127 840	82 299	45 541	90 323
Stereia Ellada	143 830	92 415	51 415	117 793
Thessalia	294 570	169 112	125 458	238 617
Voreio Aigaio	9 030	7 345	1 685	5 890
Greece total	1 544 530	748 535	795 995	1 206 017

Olive groves are not normally irrigated in Greece, but an exception was made for the island of Crete. It is reported that more than 40 percent of olive groves there are now irrigated.

Diseases, pests and plant protection

Table 3.14 Diseases, pests and plant protection

Crop	Harmful organism	Species names	Plant protection practices
Barley,	Pest	Cyst (<i>Heterodera avenae</i>); Stubby-nematode (<i>Nanidorus minor</i>); Aphids (<i>Rhopalosiphum padi</i> , <i>Metopolophium dirhodum</i> , <i>Sitobion avena</i>); Stink bugs (<i>Aelia rostrata</i> e <i>Eurygaster maura</i>) ; Lema (<i>Oulema melanopus</i>); Humpbacked Zabro (<i>Zabrus tenebrioides</i>); Culm and ear moth (<i>Ochsenheimeria bisontella</i>); Fried fly (<i>Oscinella frit</i>); Cecidomia equestre (<i>Haplodiplosis marginata</i>).	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil : Removal and disposal of not recoverable, infested plant materials; Soil disinfection (solarisations, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Ergot; Fusarium foot rot; Leaf blotch and crown rot; Red leather disease; Oat blue dwarf; Oat mosaic; Oat necrotic mottle ; Oat red leaf; Wheat leaf rust; Black sooty mold; Wheat/Barley Bunt, Dwarf Bunt of Wheat; Loose Smut of Wheat; Tritici; Barley, powdery mildew; Wheat powdery mildew; Fusarium Head Blight; Crown and Root Rot; Black Chaff; Tan Spot; Stagonospora Leaf and Glume Blotch of wheat; Root rot, leaf spot disease,	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil; Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.

wheat, oat		seedling blight, head blight, and black point of wheat and barley; Striped barley leaf spotting and Reticulated barley leaf spotting; Brown/Yellow rust of wheat/barley. Barley leaf blight; Wheat Soilborne Mosaic Virus; Wheat Streak Mosaic, Barley yellow dwarf (BYDV: Barley yellow dwarf virus: Luteovirus.	
	Weed	Annual and perennial grasses and dicotyledonous.	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (plowing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
Vetch	Pest	Beetle vetch weevil (<i>Bruchus rufipes</i> Herbst.); Beetle (<i>Sitona lineatus</i> L.); Seed Fly (<i>Delia platura</i>) (<i>Bemisia tabaci</i>); Peamoth (<i>Laspeyresia nigricana</i>); Black legume aphid (<i>Aphis craccivora</i>); green legume aphid (<i>Acyrtosiphon pisum</i>); Red spider mite (<i>Tetranychus urticae</i>); Broomrapes (<i>Orobanche</i> and <i>Phelipanche spp.</i>).	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil: Removal and disposal of not recoverable, infested plant materials; Soil disinfection (solarisations, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity; Biological control of pest (Treatment with beneficial, antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Bacterial blight (<i>Pseudomonas stizolobii</i>); Anthracnose (<i>Colletotrichum vicia</i> , <i>C.villosum</i> , <i>C.sativum</i> , <i>C.vicia-sativa</i> , <i>C.lentis</i> , <i>C.spinaciae</i>); Artichoke Yellow Ring spot Virus (AYRSV: Nepovirusgenus).	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil (: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.

	Weed	Annual and perennial grasses and dicotyledonous.	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (plowing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
Tomato (industrial)	Pest	Root-Knot Nematodes (RKN) (genus <i>Meloidogyne</i>: <i>M. incognita</i>, <i>M. javanica</i>, <i>M. hapla</i>, and <i>M. arenaria</i> species); Tomato leaf miners (<i>Liriomyza</i> spp., <i>Tuta absoluta</i> Meyrick, Lepidoptera: Gelechiidae); White fly (<i>Bemisia tabaci</i> and <i>Trialeurodes vaporariorum</i>); Black cutworm (<i>Agrotis ipsilon</i>, <i>A. segetum</i>) Broomrape (<i>Orobanche Ramos/Phelipanche ramosa</i> (L.) Pomel); Brown marmorated stink bug; Tomato bug (<i>Nezara viridula</i>); Aphids, Tomato fruit worm - TFW; Tomato russet mite Tomato red spider mite.	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil : Removal and disposal of not recoverable, infested plant materials; Soil disinfection (solarisation, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Peronospora; Alternariosis; Fusarium wilt and Fusarium crown and root rot Plant blight; Verticillium wilt, Tomato powdery mildew; Tomato Soft Rot; Tomato leaf mold; Sclerotinia stem rot, Syringae Leaf Spot; Gray Mold; Septoria leaf Spot; Gray leaf spot; Corky root rot; Pith necrosis (<i>Pseudomonas corrugata</i>, <i>P. mediterranea</i>); Bacterial Wilt; Bacterial canker; Bacterial stem rot and fruit rot; Fruit rot; Tomato Stolbur Disease (Phytoplasmas); Viruses : Mild leaf mottling virus (Potato Virus Y -PVY); Mosaic Virus (Cucumber Mosaic Virus - CMV); Tomato Spotted Wilt Virus (TSWV: transmitted by <i>Frankliniella occidentalis</i> and <i>Bemisia tabaci</i>).	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.

	Weed	Annual and perennial grasses and dicotyledonous.	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (plowing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
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Soil - Greek soils bear the marks of centuries of human activity, particularly the loss of topsoil on slopes due to vegetation removal and subsequent erosion. Despite the influence of climate and time, the underlying parent material remains a dominant factor in determining soil properties (morphological, chemical, physical and mineralogical). Fluvisols, the most common agricultural soil type, cover about 45% of the limited arable land (only 20% of the total area of Greece). However, this important resource faces challenges such as nutrient imbalances caused by unbalanced use of fertilisers and erosion in mountainous areas, exacerbated by practices such as olive cultivation. Addressing these issues is essential for the implementation of sustainable soil management strategies in Greece.

3.5.2 IPCC projections on climate change indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:

3.5.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional

Variations: Temperature increases will not be uniform.

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Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

A consistent increase in the annual mean temperature has been observed in Greece from 2001 to 2015. This is evidenced by most meteorological stations reporting higher mean yearly temperatures compared to the period between 1961 and 2000. Over the past two decades, the average rate of warming was 0.047°C per year, which is 0.011°C above the global average. It is anticipated that the rate of warming will be more pronounced in continental regions than on islands, except in autumn, when the temperature rise is expected to be more uniform across the country. In 2022, Greece's observed annual average mean surface air temperature was 15.90°C, while in 2021, it was 15.81°C. By 2030, the projected average surface air temperature is 16.29°C in an optimistic scenario and could increase to 17.05°C in a worst-case scenario. Projections for the year 2050 indicate that the annual mean surface air temperature will range between 16.30°C and 18.28°C across different scenarios.



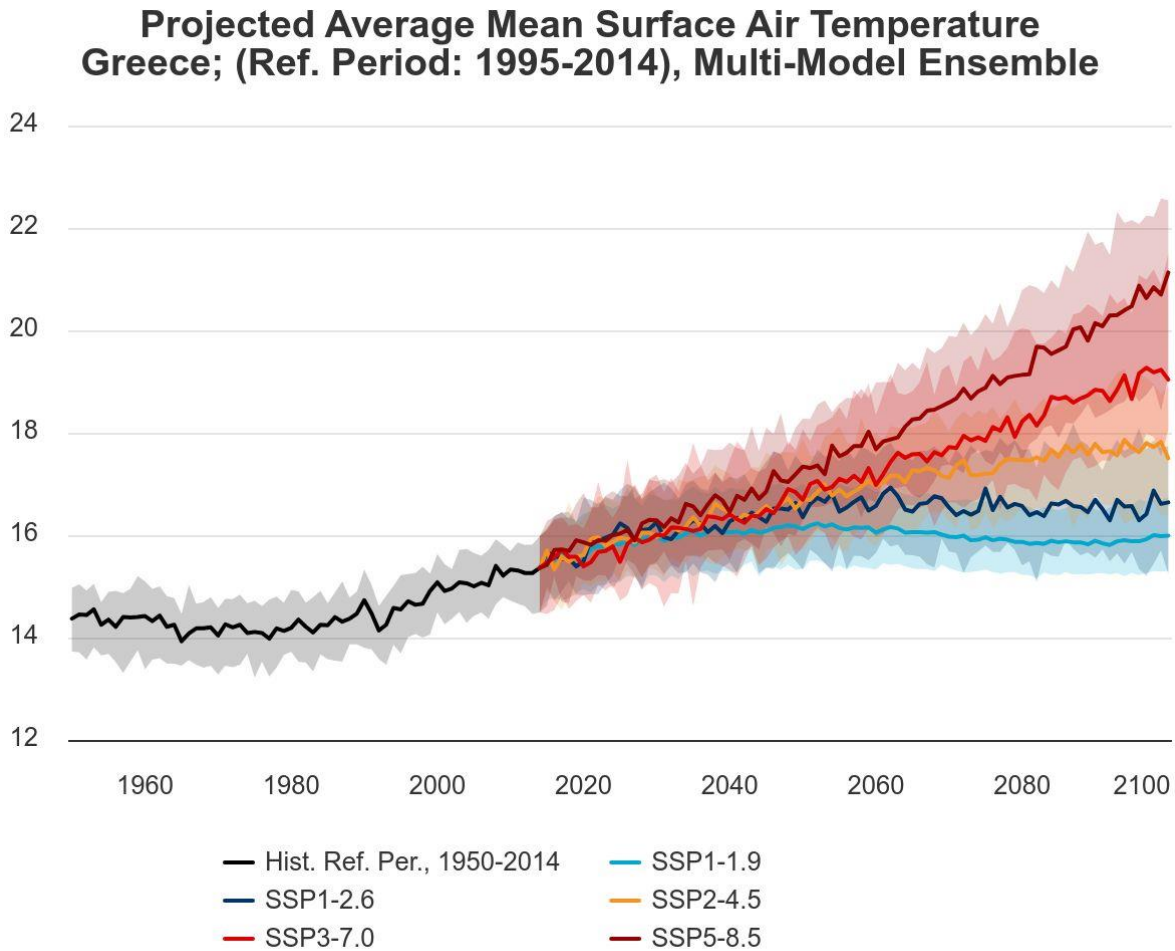


Figure 3-14: Projected average mean surface air temperature for Greece

3.5.2.2 Precipitation pattern

With regional variations across its diverse landscape, Greece experiences an average annual precipitation ranging from approximately 500 to 800 millimetres. Coastal areas typically receive less rainfall than mountainous regions, with some areas in the interior experiencing higher precipitation levels. However, projections from the Intergovernmental Panel on Climate Change (IPCC) indicate potential changes in precipitation patterns for Greece by 2030-2050 due to climate change. While specific projections for Greece may vary, the IPCC's assessments suggest a general trend towards drier conditions in the Mediterranean region, including Greece, particularly during the summer months. This decrease in precipitation could exacerbate droughts and water scarcity issues, impacting agriculture, ecosystems, and water resources.

Furthermore, extreme precipitation events may become

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more frequent, increasing the risk of flooding in specific locations. Adapting to these changing conditions will be of paramount importance for Greece, necessitating improved water management practices, cultivating drought-resistant crops, and developing resilient infrastructure.

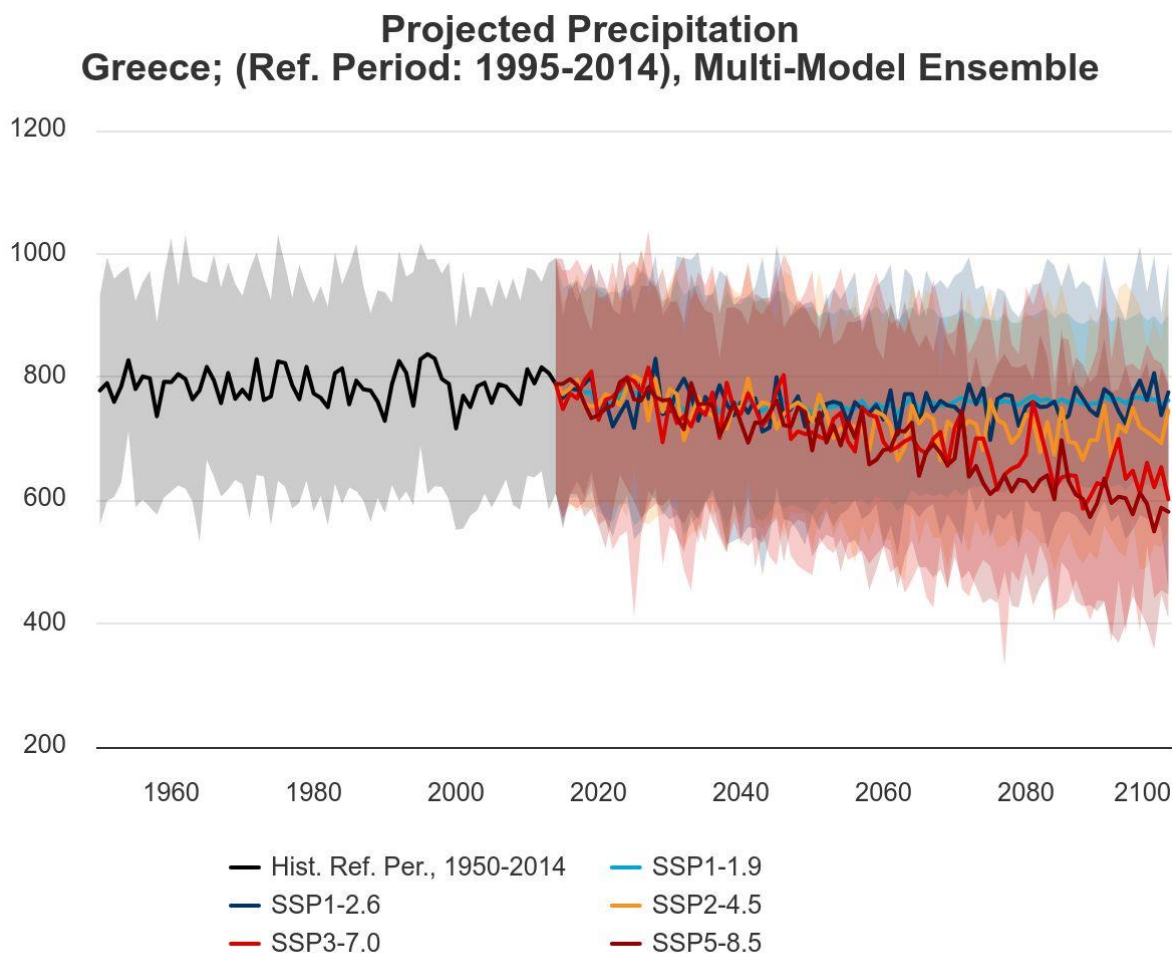


Figure 3-15: Projected precipitation patterns in Greece

3.5.2.3 Sea level rise

The IPCC projects that Greece will be significantly affected by sea level rise due to climate change, with an expected increase of about 0.1 to 0.2 metres by 2030 and 0.2 to 0.4 metres by 2050 under moderate emission scenarios (RCP4.5) and up to 0.3 to 0.5 metres under high emission scenarios (RCP8.5). This rise will exacerbate coastal flooding, erosion, affecting infrastructure, ecosystems and freshwater resources. In order to adapt to these changes and protect vulnerable coastal areas, Greece will need



to invest in coastal defences, improve land-use planning, strengthen flood management strategies and raise public awareness.

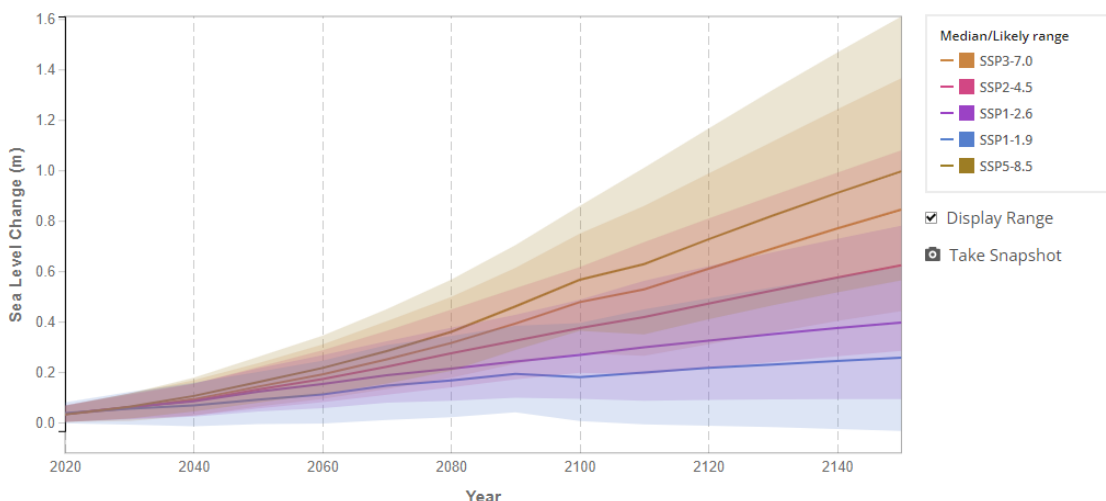


Figure 3-16: Projected Sea level changes in Denmark

3.5.2.4 Extreme weather events

By 2030, Greece is expected to experience a significant increase in the frequency and severity of extreme weather events. Heat waves are predicted to increase in frequency and severity, while droughts could increase by up to 10%, exacerbating water scarcity problems and affecting the agricultural sector. Heavy rainfall events, known to cause flash floods, are expected to increase by around 5-10%, increasing the risk of flooding. Looking further ahead to 2050, these trends will intensify, with heat waves becoming more intense and prolonged. Droughts are projected to become 20% more frequent and severe, further exacerbating water stress and agricultural challenges. In addition, heavy precipitation events are projected to increase by 10-20%, significantly increasing the risk of flash floods and potential damage to infrastructure and cities.

3.5.2.5 Ecosystem and biodiversity impacts

Climate change is a significant driver of ecosystem and biodiversity change in Greece. Habitat loss and fragmentation threaten the survival of many plant and animal species due to rising temperatures and changing rainfall patterns. Temperature changes affect the timing of biological events such as flowering and migration, disrupting ecological processes in the country. Water scarcity stresses freshwater ecosystems, while rising

sea levels and coastal erosion threaten coastal habitats. Invasive species are exacerbating biodiversity loss, outcompeting native species and disrupting ecosystems. These changes have far-reaching implications for ecosystem functioning and the provision of essential services.

3.5.2.6 Socioeconomic impacts

Food security: Climate change risks Greece's agricultural sector, with crop yields projected to decline. Olive oil production could fall up to 40% by 2050, affecting food exports and rural livelihoods.

Impact on tourism: Greece's tourism industry, a significant contributor to GDP, is vulnerable to climate change-related extreme weather events, such as heatwaves and wildfires, which could disrupt tourism activities and infrastructure.

Health impacts: Heat-related illnesses and air pollution exacerbate health risks, increasing healthcare costs and reducing labour productivity.

3.5.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Greece and their specific focus on different products.

Table 3.15: Drivers of products for Greece

Products- Greece					
	Honey	Tomatoes	Wheat	Farmed fish	Olives
Drivers	1. Pesticides 2. Drought 3. Summer heatwave 4. Pollination 5. Integrated agriculture	1. Water demand 2. Groundwater availability 3. Pesticides 4. Availability for fertilisers 5. Carbon footprint	1. Availability for fertilisers 2. Crop rotation 3. Weed management 4. Pesticides 5. Carbon footprint	1. Feed 2. Pathogens 3. Sea surface temperature 4. Heat stress	1. Pest invasion 2. Weed management 3. Integrated agriculture 4. Precision farming 5. Bio pesticide



Note: 1 represents the most important drivers, 5 represents the least important drivers

3.5.4 Living lab scenarios

THALLA

The preliminary scenario drafts outlined for THALLA Living Lab in Greece encompass the evolution of agricultural and aquacultural practices under various climate change impacts, focusing on wheat, tomato, fish, olives, and honey production. These scenarios range from business-as-usual approaches to innovative adaptations and the transition to organic practices.

Products Scenarios	Durum wheat	Industrial tomato	Table olives	Fish	Honey
1. Status quo for 2030 - 2050	X	X	X	X	X
2. Climate shock 1: Floods & flash floods	X		X	X	
3. Climate shock 2: Drought		X			X
4. Genetic biodiversity and wild flora richness loss	X	X			X
5. Addressing the challenges in adoption of organic practices			X	X	

Scenario 1: Business as usual (2030 and 2050)

Under a business-as-usual scenario, production of the food commodities will continue to face the current challenges as reflected in the last 3-4 years (e.g., extreme weather events, soil degradation, pest invasion). Lacking significant adaptations or technological advancements to counteract climate change, the cultivation of tomatoes, farmed fish, table olives, durum wheat, and honey production faces major challenges by 2030 and 2050. This outlook assumes continued current practices, ignoring the worsening impacts of climate change like extreme weather, soil degradation, and pest invasions.



Tomato production

- **2030:** The sector faces increased stress due to higher water demands amidst dwindling water supplies, compounded by more frequent droughts and heat waves. These conditions lead to a decline in both yield and quality, as current cultivation practices do not adequately address the need for water-efficient or heat-tolerant varieties.
- **2050:** The situation deteriorates further, with certain areas becoming untenable for traditional tomato farming due to exacerbated water scarcity and elevated temperatures. Mechanized cultivation practices, while increasing efficiency, contribute to environmental pollution. The interplay between these factors necessitates a shift towards more sustainable cultivation methods.

Farmed fish

- **2030:** The aquaculture sector grapples with the consequences of rising sea surface temperatures, which impact fish health and productivity. Decreases in oxygen levels and an uptick in disease prevalence begin to affect yields. Adaptation strategies are considered but not widely implemented. Production growth is estimated through the establishment of Allocated Zones for Aquaculture.
- **2050:** Some fish species become unviable for farming in their traditional locales due to the ongoing rise in temperatures and changing sea conditions.

Honey production

- **2030:** Bee populations, essential for pollination, face significant challenges as droughts and heatwaves diminish the availability of forage plants. Honey production dips, and bee colonies experience heightened stress, testing the resilience of these crucial pollinators.
- **2050:** Without measures to mitigate the impacts of climate change on bee habitats, there is a notable decline in bee diversity and numbers. This decline



has a cascading effect on crops dependent on bee pollination, threatening food security and ecosystem health.

Table olives

- **2030:** Heat stress and water deficit can affect many stages of the reproductive growth and development of olives as well as oil quality at harvest. These abiotic stresses induce a decline in the photosynthetic capacity and the carbon efficiency of olive trees by damaging part of the photosystem mechanism and reducing stomatal conductance.
- **2050>** Heat stress can also lead to some severe pest outbreaks in olive trees and mycotoxin contamination of olive drupes and oil.

Wheat

- **2030:** The high fertilizer prices and the extensive needs for chemical inputs pressure farmers who reduce their use. This will have a positive impact on the environment, yet without efficient alternatives to synthetic fertilization the yields will be significantly reduced.
- **2050:** As the cost of chemical inputs will continue rising, more and more farmers will seek to adopt sustainable practices for crop management. Precision agriculture, adoption of new cultivars or crops, and crop rotations could be proposed.

Scenario 2: Increasing number and intensity of floods

Floods and flash floods similar to the ones that took place in the focus region in the last 5 years will become more frequent, significantly affecting wheat and olive production, as well as aquaculture.

Wheat

- Seasonal heavy rainfalls could cause floods and flash floods that will diminish the yields. The high moisture following the floods will promote pest infestations, thus further reducing the yields. Rainfalls and floods in the crucial stages of the



crop will constantly negatively affect wheat farmers and degrade farm soils. Changes in the sowing dates and adoption of early maturing crop varieties could improve the resilience to such phenomena.

Table olives

- Floods and flash floods can severely lead to biotic and abiotic stresses in olive groves. Flooding may cause direct damage to trees by changing soil conditions, interrupting normal oxygen and carbon dioxide exchange between trees and their environment, sedimentation and physical damage. Flooding also can weaken trees, making them more susceptible to damage from insects and diseases leading often to the tree death.
- Need for suitable extensive drainage systems of olive orchards in combination with smart farming technologies (GPS mapping and remote sensing) to create field maps that can determine the variability in soil quality, moisture, and nutrient content. Best agricultural practices for olive trees based on smart farming technologies.

Fish

- Floods may increase contamination risks with pathogens (bacteria, parasites etc.). Site selection is important with areas less prone to flooding.
- Floods lead to the introduction of pollutants, sediments, excessive nutrients into fish farms, affecting water quality, fish welfare and health.

Scenario 3: Climatic shocks

In a future scenario characterized by increasing frequency and severity of heatwaves, tomato production faces significant challenges. Based on the RCP 8.5 model droughts will become more frequent and extensive, hindering tomato and honey production. The direct impacts of these extreme heat events include:



Tomato

- **Water stress:** Tomatoes are particularly sensitive to water availability, and heatwaves exacerbate water stress by increasing evaporation and transpiration rates. This can lead to inadequate water supply for optimal tomato growth, affecting plant health and reducing yields.
- **Heat damage:** Extreme temperatures can cause physiological damage to tomato plants, including sunscald on fruits, blossom drop, and inhibited fruit set. Pests and pathogen risk increases. These conditions directly impact the quality and quantity of the tomato harvest.
- **Pollination issues:** High temperatures can affect the viability of pollen, leading to poor pollination and subsequently lower fruit set. This issue is compounded in varieties that are less heat-tolerant.

In the immediate future, growers may attempt to manage these challenges through increased irrigation to combat water stress and the use of shade cloths to reduce temperature extremes. However, these measures may not be sustainable or sufficient in the long term, especially in regions with limited water resources. Looking ahead, the development and adoption of heat-tolerant tomato varieties become crucial. These varieties would be bred for resilience to high temperatures and designed to maintain productivity and fruit quality under heat stress conditions.

Honey

- **Extensive drought:** Droughts directly impact wild flora, and this can have a negative effect on nectar and pollen availability. Subsequently, under extensive drought bees could have lower survival rates as their diet is based on the reduced availability of pollen and nectar
- **Heat stress:** Honeybees maintain their hive temperature between 32-35°C. Above this temperature larvae and pupae won't develop and may die. The bees distribute droplets of water around the nest, which works in parallel with the



fanning to create the equivalent of honeybee air condition. Wild bees that nest above ground in stems and twigs are more vulnerable to temperature extremes. These conditions put pollinators at risk. During a heat wave, nectar and pollen providing plants are stressed and cannot provide food for pollinators. Extreme heat events are associated with widespread local extinctions of wild bee species. As certain areas get hotter and drier due to climate change, bees will have a harder time foraging, endangering their populations.

Scenario 4: Climate resilience and biodiversity loss

Biodiversity loss in the form of genetic erosion in cultivated crops and the loss of wild flora species richness in apiculture will affect the sustainable farming of wheat and tomato, and the production and quality of honey.

- **Tomatoes:** Lower yields due to reduced pollination from declining insect populations.
- **Durum wheat:** Higher susceptibility to pests and diseases from genetic uniformity and loss of natural predators.
- **Honey production:** Decline in bee populations leading to lower honey yields and increased colony collapses.

For tomatoes, development of self-pollinating and pest-resistant varieties, though concerns about long-term sustainability remain. As regards durum wheat, shift towards agroecological practices like crop rotation and intercropping for resilience. In honey production, partial recovery of pollinator populations through habitat restoration and bee-friendly practices, albeit with continuing climate change challenges.

Scenario 5: Transition to organic and sustainable practices in response to climate change

The transition to organic practices from 2024 to 2050, driven by climate change, has reshaped agriculture and aquaculture, focusing on wheat, tomato, fish, olives, and



honey. This involves addressing the challenges in adopting organic farming practices by policy strategy reframing. Key drivers include rising consumer demand for organics, significant expansion of organic farming and aquaculture, supply chain adaptations for better access to organic foods, and visible environmental benefits like improved soil health and biodiversity. This shift has resulted in a sustainable, resilient food system benefiting the environment, producers, and consumers.

With regard to the conventional sector, sustainable practices and policies are promoted, agricultural school educational programmes and sustainable farm advisory are established. Mitigation practices/policies that would enable slowing down on some of the shocks in the scenarios in conventional production are taken up by farmers. Based on the assessment of the effectiveness of Eco-schemes 2023-2027, more appropriate eco-schemes are elaborated and promoted in the farming sector etc.



3.6 Hungary

3.6.1 Dossier of living lab- country profile

Country - Hungary

Region in EU - Eastern Central Europe

Name of Living Lab - Elevating sustainability for climate and biodiversity conservation through vertical farming living lab (EcoVitaLL).

Partners - Csillagváros Kft, Budapest University of Technology and Economics, Tudatos Vásárlók Egyesülete

Products - Wheatgrass, Baby-leaf salad, Millet, Red clover, Sunflower, Amaranth



Figure 3-17: Map of Hungary with products



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The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201

Partner background information

Economics: The Balatonfüred region boasts fertile lands that support diverse agricultural activities, primarily focusing on viticulture (grape cultivation) and fruit cultivation. Viticulture has a long and distinguished history here, particularly within the Balatonfüred-Csopak wine region. The unique microclimate around Lake Balaton, characterized by slopes with good sun exposure and volcanic soils, creates ideal conditions for growing various grape varieties such as Olaszrizling, Sauvignon Blanc, Chardonnay, and Szürkebarát (Pinot Gris). In addition to grapes, the region is also conducive to cultivating fruits like apples, pears, sour cherries, and apricots. While these are the main agricultural activities, the area also supports smaller-scale operations, including cereal cultivation of wheat, barley, and other small grains, as well as animal husbandry with poultry and cattle. The region's popularity as a tourist destination further encourages tourism-related agriculture, including agritourism experiences like pick-your-own orchards, farm visits, and farm-to-table dining. Although sunflowers and red clover can be grown in Hungary, they are not primary crops in the Balatonfüred region due to less emphasis on large-scale livestock farming, reducing the need for extensive red clover, and the region's inconsistent provision of the optimal warm and dry conditions sunflowers require.

Policies: *Eco-scheme s* include the climate, the environment, and animal welfare systems: Agroecological program that mandates the implementation of at least two soil practices at the farm level. Under *Agri-environment-climate* there are AEKO Environmental protection, climate and other management commitments including Agri-environment payment. For organic farming there are Agro-ecological land-use change incentive payments, vegetables genetic resources and microorganism's ex-situ conservation as well as vegetable genetic resources in situ conservation.

Farming practices: The Balatonfüred region employs diverse production systems, including conventional, organic, low input, regenerative, and no-till farming, while actively transitioning to precision farming. Soil conservation practices and an increase in organic farming are prioritized, alongside the implementation of alley cropping



systems. Crop rotation plays a significant role, with cereal grains being the leading crop. Various crops are grown for different purposes: grains for food production, silage for livestock feed, and biomass for energy. Some crops are used internally within farms, and cover crops are planted to enhance soil health. The region also sees an expansion in the total irrigated area to support these diverse agricultural activities.

Potential drivers

Climate: Located at 130 meters above sea level, Budapest experiences a temperate oceanic climate with an annual long-term mean temperature of 10.4 °C and an annual long-term precipitation of 518 mm. January is the coldest month, with a long-term daily mean temperature of -1.6 °C, while July is the warmest, averaging 21.7 °C. June is the wettest month, receiving 69 mm of precipitation, and January is the driest, with 32 mm. The region faces several climate risks, including drought during the sowing and flowering periods, which has the highest impact during grain filling, and heat stress during the growing season, particularly affecting the flowering period. Other risks include black frost in winter, fire events, flooding, hail, and winter which pose a high risk to crops.

Food security: Food security is a crucial aspect of the country's economic and social policies, encompassing various factors such as agricultural production, trade, food safety regulations, social welfare programs, and environmental sustainability. This country has a rich agricultural tradition and fertile land suitable for cultivating a wide range of crops, including grains, fruits, vegetables, and sunflower seeds. Livestock farming, particularly pork and poultry production, is also significant. The agricultural sector contributes to domestic food production, but Hungary relies on imports for certain commodities such as fruits, vegetables, and grains. The government supports domestic farmers through subsidies, agricultural policies, and investments in agricultural infrastructure. However, achieving complete self-sufficiency is challenging due to factors such as limited arable land and climate conditions. Hungary places a strong emphasis on ensuring the quality and safety of its food products. Regulatory agencies such as the National Food Chain Safety Office (NEBIH) enforce strict standards



and regulations to ensure that food products meet high levels of hygiene, quality, and safety. Regular inspections of food establishments, food processing facilities, and distribution channels help maintain consumer confidence in the safety of the food supply. Hungary recognizes the importance of environmental sustainability in ensuring long-term food security. Sustainable agricultural practices, including organic farming, agroecology, and conservation agriculture, help protect natural resources, promote biodiversity, and mitigate the impacts of climate change on food production.

Farming conditions

Water: The area equipped for irrigation reached its maximum in 1974 at 451 000 ha when the barrage at Kisköre and a dam in Békés were put into operation [HU01]. The area still equipped for irrigation is lower today, but the statistics differ significantly depending on the reference year and the source of information. The irrigable area of the country as reported by EUROSTAT or the Central Statistics Office was 308 110 ha in 2000 and about 242,170 ha in 2003, while statistics of the National Water Authority indicate an area equipped for irrigation of 235 500 ha in 2000 and 208 400 ha in 2003. According to the latter statistics, the area equipped for irrigation declined each year within the period 1998 (264 300 ha) to 2004 (159 100 ha). Differences also exist in the statistics referring to the area irrigated. EUROSTAT reported an area irrigated of 67,100 ha in 2000 and 148 690 ha in 2003. In contrast, the National Water Authority reported actual irrigation areas of 125 300 ha in 2000 and 115 200 ha in 2003. Because of the given uncertainties area equipped for irrigation was estimated for this study by selecting for each county the maximum of the areas reported as irrigable (Central Statistics Office, year 2003) or equipped for irrigation (National Water Authority, years 2001, 2002 and 2004). The total area equipped for irrigation estimated that way is summing up to 292 147 ha and it is visible in the table below.

Table 3.16: Irrigation area in Hungary per district

District	Region	Area equipped for irrigation (ha)	Area actually irrigated (AAI) (ha)
Budapest	Central Hungary	3 117	1 300
Pest	Central Hungary	8 122	4 822
Fejér	Central Transdanubia	12 492	1 847



Komárom-Esztergom	Central Transdanubia	1 790	1 053
Veszprém	Central Transdanubia	4 276	1 020
Hajdú-Bihar	Northern Great Plain	36 254	12 366
Jász-Nagykun-Szolnok	Northern Great Plain	43 084	21 643
Szalolcs-Szatmár-Bereg	Northern Great Plain	11 963	5 188
Borsod-Abaúji-Zemplén	Northern Hungary	6 963	1 583
Heves	Northern Hungary	6 820	933
Nógrád	Northern Hungary	360	97
Bács-Kiskun	Southern Great Plain	25 179	10 221
Békés	Southern Great Plain	37 545	18 782
Csongrád	Southern Great Plain	31 888	14 676
Baranya	Southern Transdanubia	23 709	1 301
Somogy	Southern Transdanubia	4 972	2 110
Tolna	Southern Transdanubia	4 524	909
Győr-Moson-Sopron	Western Transdanubia	26 123	3 676
Vas	Western Transdanubia	1 593	186
Zala	Western Transdanubia	1 373	702
Hungary total		292 147	104 415

The area irrigated per county was computed as the average of AAI reported for the period 2003-2009. Total AAI computed that way was summing up to 104 415 ha.

Table 3.17: Irrigation area according to region

Region	Area equipped for irrigation (ha)		
	total	with groundwater	with surface water
Central Hungary (Közép-Magyarország)	11 239	8 223	3 016
Central Transdanubia (Közép-Dunántúl)	18 558	1 651	16 907
Northern Great Plain (Észak-Alföld)	91 301	13 435	77 866
Northern Hungary (Észak-Magyarország)	14 143	2 998	11 145
Southern Great Plain (Dél-Alföld)	94 612	19 728	74 884
Southern Transdanubia (Dél-Dunántúl)	33 205	4 831	28 374
Western Transdanubia (Nyugat-Dunántúl)	29 089	12 917	16 172
Hungary total	292 147	63 784	228 363

Diseases, pests and plant protection

Table 3.18: Diseases, pests and plant protection

Crop	Harmful Organism	Species Names	Plant Protection Practices
	Pest	wheat stem sawfly, cereal cyst eelworm, carabid ground beetle, cereal leaf beetle, leafhopper, wheat-bulb flies, aphids, larvae of beetles, moth, thrips, miner fly, chloropid gout	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.



Wheat, barley		fly, bug, hessian fly. Small mammals, common vole.	
	Disease	Powdery mildew; rusts; leaf spots of cereals: Septoria leaf blotch of wheat; tan spot of wheat; Ramularia leaf spot of barley; net blotch of barley; leaf stripe of barley; scald of barley; head blight; wheat bunts; eyespot; take-all; Barley yellow dwarf virus; Wheat dwarf virus.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management.
	Weed	not relevant (vertical farming)	-
Sorghum, millet, buckwheat , rye	Pest	wheat stem sawfly, cereal cyst eelworm, carabid ground beetle, cereal leaf beetle, leafhopper, wheat-bulb flies, aphids, larvae of beetles, moth, thrips, miner fly, chloropid gout fly, bug, hessian fly. Small mammals, common vole, hare.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies; use of insecticides.
	Disease	Minor	-
	Weed	not relevant (vertical farming)	-
Red clover	Pest	Alfalfa snout beetle (<i>Otiorynchus ligustici</i>), pea aphid (<i>Acyrtosiphon pisum</i>), Curculionidae (<i>Sitona lineatus</i> , <i>Sitona macularius</i> , <i>Sitona spp.</i>), Rodents: common vole (<i>Microtus arvalis</i>).	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	-	Clean seed, certified pathogen-free seed, seed treatment, land selection, cultivar selection, crop rotation, proper time of cutting, adequate fertility management.
	Weed	not relevant (vertical farming)	-
	Pest	European maize borer, black cutworm, African cotton bollworm, Tenebrionid beetle, mirid bugs, stink bug <i>Nezara viridula</i> , larvae of beetles, aphids, cereal mite, palm thrip, burdock leaf miner, grey field slug. Aves: <i>Streptopelia decaocto</i> , <i>Serinus serinus</i> . Rodents: mouse <i>Mus musculus</i> , common vole <i>Microtus arvalis</i> .	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	<i>Sclerotinia sclerotiorum</i> (1. Sclerotinia root and basal stalk rot, and wilt; 2. Sclerotinia stem rot; and (3)	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing

Sunflower		Sclerotinia head rot and midstalk rot); gray mold; downy mildew; Alternaria blight; black stem; stem canker; charcoal rot.	excess moisture in the field (plant density), adequate fertility management.
	Weed	not relevant (vertical farming)	-

Soil: The total area of Hungary is 9 303 000 ha, of which 79 % or 7 356 000 ha is agricultural land, and 48.2% or 4 502 000 ha is arable land. The topsoil textures of Hungarian soils can be characterized as follows: sand 15%, sandy loam 12%, loam 47%, and loamy clay and clay 26%. Major soil types are Cambisols in the area between the mountains and the Hungarian Great Plain, Chernozems in lowland areas, Fluvisols developed on stratified sediments in river valleys, Arenosols developed on windblown sands deposited after the end of the last ice age, and Solonchaks and Solonetzcs resulting from evaporation of groundwater containing soluble salts.

The major limitation to agriculture in Hungary is precipitation worsening due to climate change. Major threats to soil quality and agroecosystem sustainability include soil compaction (1.9 million ha) acidification (4.55 million ha) water erosion (2.31 million ha), wind erosion (1.41 million ha), and salinization (0.946 million ha). Nitrate pollution of groundwater associated with large-scale intensive animal husbandry sites represents a threat to ecosystem sustainability.

3.6.2 IPCC projections on climate change indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:



3.6.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

The climate of Hungary is classified as continental, characterised by hot summers with low humidity levels but frequent showers and cold, snowy winters. The mean annual temperature is 9.7°C. The temperature extremes in Hungary range from approximately 42°C in the summer to -29°C in the winter. During the summer, the mean temperature ranges from 27°C to 35°C, while in the winter it varies between 0°C and -15°C. By 2030, the average mean surface air temperature is projected to be 12.49 °C (optimistic) and in the worst-case scenario, be increased to 13.83 °C. Projections suggest that the annual mean surface air temperature will range between 12.54 °C and 15.67 °C at both ends of the spectrum in 2050.



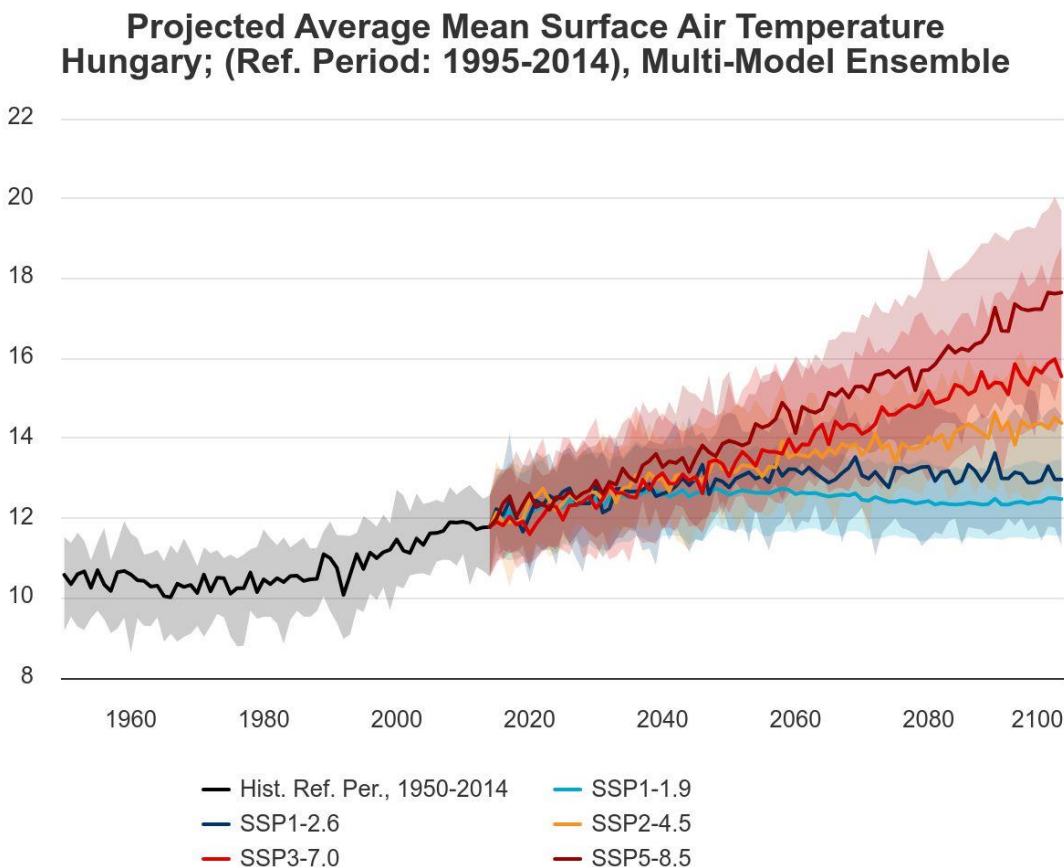


Figure 3-18: Projected average mean surface air temperature for Hungary

3.6.2.2 Precipitation pattern

The mean annual precipitation in Hungary is approximately 600 millimetres, with significant regional and seasonal variations. Projections from the IPCC indicate that by 2030-2050, Hungary may experience more intense and frequent precipitation events, particularly during the summer months. Nevertheless, the overall precipitation trends indicate a likelihood of decreasing annual totals, particularly during the summer months, which may exacerbate drought conditions. It is anticipated that winter precipitation will remain relatively stable or increase slightly. Such alterations in precipitation patterns may have a profound impact on agriculture, water resources, and the country's overall resilience to climate change.

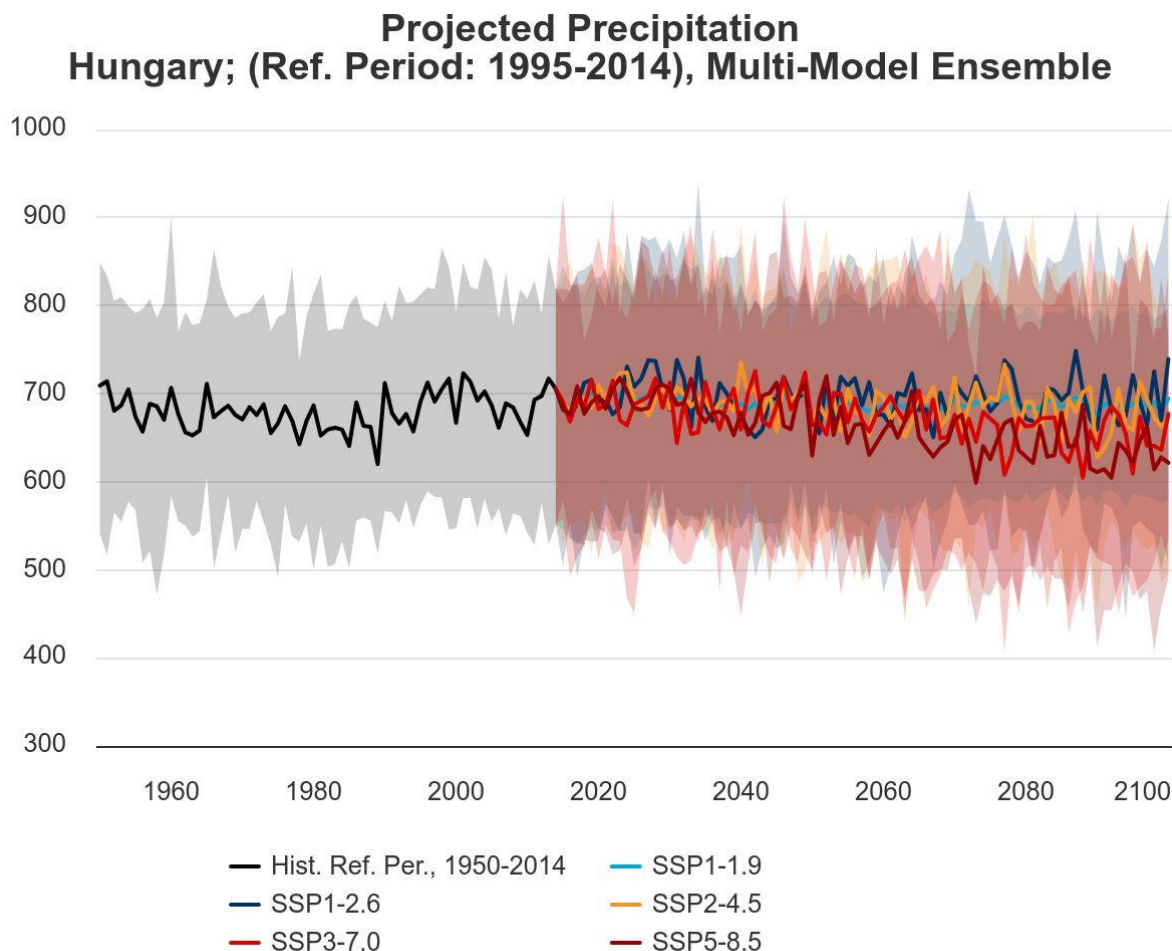


Figure 3-19: Projected precipitation patterns in Hungary

3.6.2.3 Extreme weather events

The frequency and intensity of extreme weather events such as heat waves, heavy precipitation, droughts and severe storms are projected to increase in Hungary due to climate change. By 2050, average temperatures in Hungary will increase by 1.5 to 2.5°C, with heat waves becoming more frequent and severe. The frequency and severity of droughts are also projected to grow, particularly in areas already prone to drought, exacerbating water scarcity and negatively affecting crop yields. In addition, the frequency of heavy precipitation events is expected to increase by 10-20%, leading to a greater risk of flooding and putting additional strain on infrastructure and urban planning. These changes will pose significant challenges to Hungary's agriculture, health and infrastructure.



3.6.2.4 Ecosystem and biodiversity impact

In Hungary, climate change is profoundly reshaping ecosystems and biodiversity. Climate indicators such as temperature rise, and precipitation pattern fluctuations are causing shifts in vegetation zones. Additionally, it is leading to habitat loss and changes in species distribution. Moreover, shifts in the timing of flowering and migration are disrupting ecological processes.

3.6.2.5 Socioeconomic impact

Food security: Agricultural production in Hungary is vulnerable to climate change, with crop yields projected to decline. By 2050, maize yields could fall by up to 21%, threatening food security and rural livelihoods.

Water scarcity: Rising temperatures and changing rainfall patterns increase the risk of water scarcity, affecting agricultural irrigation and industrial activities.

Economic vulnerability: Hungary's economy is vulnerable to extreme weather events due to climate change, with economic losses from floods and droughts estimated at 0.3% of GDP annually.

3.6.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Hungary and their specific focus on different products.

Table 3.19: Drivers of products for Hungary

Products- Hungary						
	Wheatgrass	Lettuce	Millet	Red clover	Sunflower	Amaranth
Drivers	1. Hydroponic 2. Water consumption	1. Hydroponic 2. Water consumption 3. Nutritional quality 4. Consumer diet	1. Hydroponic 2. Water consumption 3. Drought 4. Underutilised	1. Hydroponic 2. Water consumption	1. Hydroponic 2. Water consumption 3. Crop rotation 4. Nutritional quality	1. Hydroponic 2. Water consumption 3. Land use 4. Underutilized



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3. Land use
4. Drought
5. Feed

5. Precision
farming

crop species 5.
Nutritional quality

3. Crop
rotation
4. Feed

crop species
5. Crop rotation

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.6.4 Living lab scenarios

EcoVitaLL

EcoVitaLL consists of three partners, one growing plants on a vertical farm, one doing the analyses of the plants and the third surveying consumers about vertically grown food. Data is collected *in situ* in a controlled environment mainly focusing on water and electricity consumption. After each growth cycle is finished the biomass is analysed for nutritional value.

Products Scenarios	Wheatgrass	Baby- leaf lettuce	Millet	Red Clover	Sunflower	Amaranth
1. Status quo for 2030 - 2050	X	X	X	X	X	X
2. Vertical price tag	X	X	X	X	X	X
3. Soaring Technology, Stalling Sales	X	X	X	X	X	X
4. The Preference Pivot: Aligning Vertical Farming with Consumer Preference and Awareness	X	X	X	X	X	X
5. From Seed to Sky: Biodiversity in Vertical Farms	X	X	X	X	X	X

Scenario 1: Status quo for 2030-2050

Status quo: Hungary is expected to have more cold winters and hot and dry summers. Heavy rains are predicted to increase in intensity, coupled with heat waves lasting longer during the summer months. Flooding will be more probable, in addition to periods of water scarcity, as the overall amount of precipitation will decrease with time. EcoVitaLL, being a vertical farm in an urban setting (Budapest), will face the continued challenges of a local customer base's dietary preferences being more meat



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and less vegetables, as well as the pressures on energy prices. Vertical farming and contemporary farming practices may continue to face political and local policy pressure, as it threatens traditional farming, with the risks of geopolitical conflicts cannot be ruled out.

Scenario 1 will refer to the context of food production via conventional farming. For the remaining scenarios (2-5) they will be considered in the context of the vertical farm setting. This system relies on circulating water, which constitutes a significantly lower water demand than conventional farming. Further, there is neither of pesticides nor herbicides inputs usage. The major cost consideration in the vertical farm setting is the inputs of fertilizer into the hydroponic system and especially the energy costs associated with heating, cooling, and most importantly LED lighting. In addition, labour is one of the operating issues, up-front infrastructure costs are a big consideration, particularly without state or investor-based financing.

Wheatgrass production

- **2030:** While wheatgrass is not the most widespread crop in Hungary, high quality seed selection and provisioning remain critical. This crop will be considered for the production of fodder for animals. Wheatgrass requires moderate amounts of water to thrive. Droughts will significantly reduce yields or even cause crop failure. Temperature extremes threaten yields, while heavy rains will negatively impact harvests. Insects and fungal diseases can damage wheatgrass plants and reduce yields. New pests or diseases not currently affecting wheatgrass in Hungary could be introduced.
- **2050:** Water scarcity will be exacerbated, with extreme weather events (e.g., floods, droughts) becoming more common, causing the costs of production and for the consumer to rise. Soil erosion and desertification can be expected, reducing the overall fertility and quality of land suitable for wheatgrass cultivation. Warmer temperatures and changing weather patterns can create ideal conditions for pests and diseases to thrive. This could necessitate increased use of pesticides or fungicides, impacting production costs. Competition will be felt to find alternative crops instead of wheatgrass.



Baby-leaf lettuce production

- **2030:** The production of lettuce for the domestic market peaks during the spring months, while baby-leaf lettuce is more of a niche market produced in contained systems. Lettuce requires consistent watering, leading to increased weed growth, and will be challenging with the extended summer water scarcity. Lettuce varieties will need to be changed regularly as the threat of new pests will emerge. Consumer demand for lettuce year-round will influence a change in cultivation practices with regards to water management.
- **2050:** The long-term viability of lettuce farming via conventional farming practices will be severely threatened. This is due to water demand and scarcity, heat waves, and flooding. Unsustainable agricultural practices like intensive tillage or overuse of fertilizers can lead to soil erosion and the depletion of essential nutrients, impacting lettuce yields and quality in the long run. A decline in the agricultural workforce or rising labour costs could make it challenging for Hungarian producers to maintain efficient lettuce production. Overreliance on certain pesticides could lead to pest resistance, necessitating the development of alternative control methods.

Millet production

- **2030:** Millet is an uncommon crop for Hungary and appears to be considered experimental for this market at present. Millet's drought tolerance could make it a more attractive crop choice in the face of climate change concerns. The global demand for millets is projected to increase due to their nutritional value, gluten-free nature, and resilience to harsh climates.
- **2050:** The establishment of millet in Hungary in the long term faces several challenges: 1) Raising awareness about the benefits of millet amongst Hungarian consumers will be necessary to create a strong domestic market, 2) Hungary could face competition from established millet producers in other countries with lower production costs, and 3) the lack of dedicated processing facilities or infrastructure for millet in Hungary could pose challenges for larger-scale production. The introduction of new crops into a region are not without their risks. Like other crops, millet is susceptible to various pests and diseases. New



or more aggressive pests and diseases could emerge due to climate change, requiring constant monitoring and adaptation of control methods. Birds can be a significant threat to millet crops, especially during the ripening stage.

Red clover production

- **2030:** Red clover is not commonly consumed by humans but rather by grazing livestock. Although it is somewhat drought tolerant, the common seeded periods of early spring and fall will be shifted to avoid the higher temperature due to climate change. It has nitrogen-fixing capabilities through its symbiotic relationship with Rhizobium bacteria, so nitrogen fertilization may not be needed, although other nutrients like phosphorus and potassium are added in the form of mineral fertilizer, which will impact the cost of production.
- **2050:** As climate changes impact Hungarian agriculture, red clover will face increasing threats: 1) pests like clover weevils, stem borers, or nematodes could become more prevalent due to warmer temperatures, 2) diseases like Sclerotinia rot or clover rust could pose a greater threat under warmer and wetter conditions, resulting in yield losses and potentially forcing producers to switch to resistant varieties, 3) herbicide resistance due to overreliance on herbicides for weed control, and 4) with reduced yields of clover, its lower integration into crop rotations can decrease soil fertility. Other nitrogen-fixing legumes may be considered as a better alternative to red clover in the future.

Sunflower production

- **2030:** Hungary will continue to be a strong European producer of sunflower for both seed and oil products, as global demand for these products continue to increase. Extreme weather events, like prolonged droughts or heat waves could affect yields. New or more aggressive pests and diseases could emerge, Competition from other sunflower producers (e.g., Ukraine, Russia) can cause shifts in the commodity markets.
- **2050:** Unsustainable agricultural practices like excessive tillage or overuse of fertilizers will lead to long-term soil degradation, impacting sunflower yields and overall crop health. The monoculture farming practices currently deployed, where sunflowers are grown repeatedly on the same land, will further deplete



soil nutrients, increase pest and disease pressure, and reduce long-term productivity. Overreliance on herbicides to control weeds can lead to the development of resistant weed populations. Changes in global fat and oil markets or consumer preferences could affect the demand for sunflower products impacting Hungarian exports.

Amaranth production

- **2030:** Amaranth is an uncommon crop for Hungary and appears to be considered experimental for this market at present. Amaranth's drought tolerance could make it a more attractive crop choice in the face of climate change concerns. Amaranth is a gluten-free grain with a high protein content and a good source of dietary fibre and other essential nutrients. Certain amaranth varieties are known for their drought tolerance and adaptability to a wider range of growing conditions compared to some traditional crops.
- **2050:** The establishment of millet in Hungary in the long term faces several challenges: 1) despite its potential, consumer awareness of amaranth and its various uses might remain limited in some regions, hindering demand and market growth, 2) the global market for amaranth is still developing, and potential fluctuations in demand could create uncertainty for producers, impacting planting decisions and income, 3) Hungarian producers might face competition from established amaranth producers in other countries with lower production costs or well-developed markets, 4) a lack of dedicated processing facilities or infrastructure for amaranth in Hungary, 5) developing effective weed control strategies specifically for amaranth production systems might be necessary to avoid yield losses, and 6) access to high-quality amaranth seeds, especially

For the remaining scenarios (2-5) they will be considered in the context of the vertical farm setting. This system relies on circulating water, which constitutes a significantly lower water demand than conventional farming. Further, neither pesticides nor herbicides are commonly used in this system. The major cost consideration in the vertical farm setting is the inputs of fertilizer into the hydroponic system and the energy costs associated with heating, cooling, and most importantly LED lighting. In addition, labour is one of the operating issues, Up-front infrastructure costs are a big consideration, particularly without state or investor-based financing.

varieties suited to the Hungarian climate and growing conditions, could be a challenge for some producers.

Scenario 2: Vertical price tag

Energy management (energy crisis): energy prices are not stable due to trade imbalance, political issues, war, etc. The energy is required for functioning of vertical farm, like automation, climate control, and fertigation. In addition, vertical farms rely on LED lighting which has a high demand for energy. All products would be affected by the high cost of operations, as it is considering the general viability of vertical farming in Hungary.

Shock: Isolation/exit of Hungary from EU would lead to major trade challenges. Germany, Italy, Romania, Austria and Poland collectively accounted for over half (53%) of Hungary's agricultural exports in 2023. The shock of a Hungarian exit from the EU would have extreme consequences to the food supply chain, and drive prices of operations up due to imported energy, fertilizer and seed costs.

2030: For a vertical farm to operate efficiently, maintaining a controlled environment 24/7 is, required a lot of manual labour. The demand for qualified personnel in operating a high-tech farm are confronted by a deficient in skilled labour. Labour in vertical farm is needed for preparing planting containers, sowing seeds, cleaning facilities, and packaging. Further, the aging population may show a lower interest in farming practices generally. Further, restrictive migration policies may limit the incorporation of skilled labour from abroad. This may be presents as an opportunity to develop new education programmes to enable these new careers in vertical farming.

2050: Management of a vertical farm requires a different skill set that with conventional farming. Additionally, depending on the season, the extreme temperature fluctuation in Hungary may require added power to heat or cool facilities in order to optimize production. This impacts the bottom line on output of food products, and which is reflected in consumer prices and hence customer demand. Customers on the lower end of the economic spectrum are unable to access food products.



Scenario 3: Soaring technology, stalling sales

Currently, vertical farming is struggling to survive economically. Unlike conventional farming, vertical farms, generally, and in Hungary specifically, receive no government subsidies. Moreover, the customer preference for the food products such as leafy greens are not in high demand locally. Moreover, the average Hungarian consumer is very price conscious, which does not bode well for slightly higher vertically-farmed food products.

EcoVitaLL has considering a strategy to address niche market where demand is high, given the price premium. These include fodder for elite race horses, food products for exploratory space station, and recently niche Asian products such as wasabi for selective consumers.

Shock: No customer demand for vertically-farmed products.

Scenario 4: The reference pivot: aligning vertical farming with consumer preference and awareness

This scenario intervention aims to address an evolving customer preference, as well as enhancing the nutritional properties of vertically-farmed foods. Customer preference will change with time, and vertical farming products needs to stay relevant. Coupling consumer awareness based on data-informed nutritional advancement with closer to on-demand production of nutritionally-rich and balanced food products would provide an advancement in food supply chains.

Addressing customer preferences:

- Surveys, focus groups, and social media listening can reveal what customers are looking for in vertically farmed products. Are they concerned about taste, variety, sustainability, or price?
- Design and run surveys on consumer beliefs and preferences about food and nutrition. The results of these surveys can point to common misconceptions or ideas not based on nutritional science that could be partially addressed through education campaigns and “in-farm” science & education events.”



- Attract aspiring young farmers to experience vertical farming through mentorship and apprenticeship opportunities. This provides hands-on learning and addresses the technological future within the agricultural sector.
- Stay informed about emerging trends in food consumption, such as plant-based alternatives, locally sourced produce, and interest in specific nutrients.
- The farm utilizes real-time data on consumer preferences and aligns these data with current health recommendations backed by scientific evidence.
- Offer a wider range of vertically farmed products beyond leafy greens. Consider fruits, herbs, or even niche vegetables.
- Invest in research and development to ensure vertically farmed products have excellent taste and texture that rivals traditionally grown produce.
- Clearly communicate the benefits of vertical farming, such as reduced water usage and pesticide use. Educate customers about the freshness and safety of your products.
- Let customers experience the quality of your vertically farmed products firsthand by offering free samples.
- Increase accessibility by partnering with stores and restaurants that share your values and can showcase your products.
- Consider offering subscriptions or online ordering for vertically farmed products, catering to a convenience-focused audience.

Enhancing nutritional quality:

- The vertical farm employs a team of agricultural scientists who meticulously control light spectrums and nutrient delivery systems. This allows them to optimize the nutritional content of each crop, maximizing vitamin and mineral levels.
- Consider the recommended daily allowance (%RDA) of micronutrients in developing novel crops/products in the living lab. This can be of particular significance during the winter months when fresh vegetables are not readily available and sunlight levels are low.



- An effective campaign, promotion, to stimulate discussion of policy shift to encourage an incentive scheme by the local government to promote increased consumption of nutrient-dense leafy greens by a broader segment of society.
- Analysis of the general nutritional contents of products (i.e., , both macro and micronutrients).
- Protein-alternatives to supplement or replace meat-based products in the future. Look at which products in the living lab would provide significant amounts of proteins with quantitative data to support.
- Customize the living lab to the Hungarian market to address the micronutrient deficiencies. Essential micronutrients like iron and folate (vitamin B9) could be looked at. Based on this information, growing conditions could be adjusted to enhance the specific nutrients most desired by customers, like focusing on vitamin C during flu season or other specific nutrients.
- Also worth considering are mushrooms like oyster mushrooms and shiitake which are a rich source of micronutrients including vitamin D, iron and folate (vitamin B9), if they are grown under certain conditions (require some light exposure).
- The farm collaborates with nutritionists to develop "functional foods" - crops enriched with specific health benefits. For example, they might offer lettuce varieties with higher levels of antioxidants or kale grown with increased calcium content.
- Inoculation of nutrient solutions with different bacterial strains to study their effect on the nutritional composition and overall yield. For this particular scenario, nutrient solutions will be inoculated with various beneficial bacteria. The nutritional composition and the yield of the different microbes can be assessed.

Scenario 5: From seed to sky: Biodiversity in vertical farms

No longer confined to leafy greens and herbs, vertical farms have become biodiversity hotspots. Advancements in artificial intelligence, robotics, and genetic engineering have allowed for the cultivation of a staggering variety of crops. Diversification of crops - as consumer demand for new food/feed products emerges, a scheme for crop rotations



and expansion of offerings would be envisioned. Additionally, the broader, external markets should be examined as potential new customers, such as in areas of the world where agriculture is no longer possible due to desertification. Diversification can be accomplished by adding a new crop species or different cultivars, or by adjusting the cropping system currently in use. For vertical agriculture to be successful and achieve broader goals, it ought to be able to accommodate a variety of crops. Diversification could also be seen from the perspective of a new value crops added to existing cropping system with the main aim of increasing the farm's overall productivity. Further, diversification of crop varieties can be a reflexive strategy to mitigate heating costs, as some crops are more sensitive to heating and cooling temperatures, depending on the time of year.

- From ancient grains like quinoa and amaranth to exotic fruits like dragon fruit and guava, to specialised products for Asian diets such as wasabi, to fodder for racehorses, vertical farms are cultivating a global pantry. The focus is on nutrient-dense, climate-resilient varieties.
- Vertical farms can now simulate diverse microclimates within a single structure, allowing for the cultivation of crops from different regions. This has led to year-round availability of fresh, seasonal produce.
- Farmers are exploring symbiotic relationships between different plant species, mimicking natural ecosystems. For instance, nitrogen-fixing legumes might be grown alongside nutrient-hungry crops, reducing the need for external fertilizers.
- Vertical farms are incorporating insect habitats and pollinator-friendly plants. This not only contributes to biodiversity but also aids in natural pest control and crop pollination.

Some vertical farms have evolved into "food forests." These multi-story structures are designed to mimic the structure and function of natural forests. They incorporate trees, shrubs, vines, and understory plants, creating complex ecosystems that produce a wide range of food, fibre, and medicine.



2030: Consumers and other stakeholders in the Hungarian supply chain would need to be aware of the environmental, economic, and food safety benefits of vertical farming before they could be accepted by the wider public. Support for vertical farming through governmental funding for research, capital access, infrastructure for energy and water will provide a critical boost to such activities.

2050: By 2050, the earth's population is expected to rise to 10 billion, while natural resources on the planet continue to shrink. One of the regional solutions for food security will be vertical farming, since production is completely protected from seasonal weather, thereby providing a consistent supply for communities year-round.



3.7 Italy

3.7.1 Dossier of Living Lab- country profile

Country - Italy

Region in EU - Mediterranean and Southwest Europe

Name of living lab - AI system for detection of abiotic/biotic stress in Mediterranean crops (AideMec)

Partners - Agenzia Lucana di Sviluppo e di Innovazione in Agricoltura, SMASP AGILE SL, OP AGORA' Società Cooperativa Agricola.

Products - Barley, Tomatoes, Durum wheat, Local beans, Mono varietal field-
"Coratina" olives.





Figure 3-20: Map of Italy with products

Partner background information

Economics: The living lab is situated in the Basilicata region of Southern Italy, within the Mediterranean area. This region spans a significant portion of the southern Apennine Mountains, between the Ofanto River in the north and the Pollino massif in the south. It is bordered on the east by the Bradano River depression and has coastal plains on the Ionian Sea, as well as a short coastline on the Tyrrhenian Sea. In 2018, Basilicata's GDP was 12.6 billion euros, representing 0.7% of Italy's economic output, with a GDP per capita adjusted for purchasing power at 22 200 euros or 74% of the EU27 average. The GDP per employee was 95% of the EU average, and the unemployment rate was 8.6% in 2020, the lowest in South Italy. Agriculturally, the region dedicates 46% of its land to



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The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201

wheat cultivation. Potatoes and maize are grown in the mountainous areas, while olives and wine production, although relatively small, cover about 31 000 hectares. Bread wheat is a primary crop used for flour and bread making, while barley is mainly used for animal feed. Durum wheat is significant for pasta production. The coastal areas favour the cultivation of citrus fruits like oranges, lemons, and mandarins. Grapes are grown for wine production, contributing to several Denominazione di Origine Controllata e Garantita (DOCG) and Denominazione di Origine Controllata (DOC) regions. Olive oil, particularly from Protected Designation of Origin (PDO) olives, is a notable product. Tomatoes are widely cultivated for fresh consumption and processed into tomato paste. Other fruits and vegetables such as apples, cherries, apricots, peaches, potatoes, onions, and peppers are grown in smaller quantities. In addition to these, the region produces sugar beets for sugar, almonds as a cash crop in Matera, and legumes like lentils, chickpeas, and beans for both human consumption and animal feed. Notably, Coratina olive oil, a distinguished extra virgin olive oil, originates from the nearby Puglia region. The industrial sector in Basilicata is diverse, with the manufacturing sector accounting for 64% of the gross value added in the secondary sector and the building sector contributing 24%. Key activities in the services sector include business activities, distributive trade, education, and public administration. Recently, new sectors like manufacturing, automotive, and oil extraction have seen growth, further diversifying the region's economic landscape

Policies: Italy's strategic plan for agriculture includes several measures aimed at improving sustainability. The eco-scheme component comprises five distinct elements: supporting pollinator populations through habitat creation, promoting extensive forage systems, safeguarding olive trees of exceptional landscape value, integrating grasses into tree crops, and tackling antimicrobial resistance while improving animal welfare. Complementing these eco-schemes, the plan outlines thirty-one agri-environment-climate measures to support sustainable agriculture and environmental protection.

Farming practices: In Basilicata, the agricultural production system is diverse, encompassing conventional, organic, low input, regenerative, and no-till farming



practices. Organic farming accounts for 17.91% of the total agricultural area. Nearly 35% of the agricultural area is devoted to cereals, predominantly durum wheat, which makes up over 70% of cereal cultivation. The main cereal-growing areas are located in the Vulture-Melfese district in the north and the Hills of Matera in the southeast. Irrigation plays a crucial role in the cultivation of vegetable crops in Basilicata.

Potential drivers

Climate: Located at an elevation of 49 meters above sea level, Basilicata has a warm Mediterranean climate with an annual long-term mean temperature of 15.7°C and annual long-term precipitation of 586 millimetres. January is the coldest month, with a long-term daily mean temperature of 8.6°C, while July is the warmest month, with a long-term daily mean temperature of 23.8°C. October is the wettest month, receiving 65 mm of precipitation, and July is the driest, with just 27 mm of precipitation. The region faces several climate risks, including drought during the sowing and flowering periods, with the highest impact during grain filling. Heat stress during the growing season also significantly affects crops, particularly during the flowering period.

Food security: Italy has a diverse agricultural sector, with a wide variety of crops grown across the country's varied landscapes and climates. The country produces a significant portion of its food domestically, including staples such as grains, fruits, vegetables, olive oil, wine, and dairy products. At the same time, Italy exports a variety of agricultural products, including wine, cheese, pasta, and processed foods, to global markets. Italy's agricultural production benefits from centuries of farming traditions, modern techniques, and technological advancements. The Italian government aims to maintain a level of self-sufficiency in key agricultural products to enhance food security and reduce dependence on imports. Policies and programs support domestic farmers through subsidies, incentives, and investments in agricultural research and development. They are focused on quality and safety standards in food production, processing, and distribution. Regulatory agencies, such as the Italian Ministry of Health and the Italian Food Safety Authority (EFSA), monitor and enforce food safety regulations to ensure that food products meet high standards of hygiene, quality, and safety. The government promotes sustainable agricultural practices, including organic



farming, agroecology, and biodiversity conservation, to protect natural resources, preserve rural landscapes, and mitigate the impacts of climate change on food production. Initiatives such as the Common Agricultural Policy (CAP) support environmentally friendly farming practices and encourage the use of renewable energy sources in agriculture.

Farming conditions

Water: Based on EUROSTAT data, the irrigable area in Italy increased from 3 854 910 ha in 2000 to 3 977 210 ha in 2003, while the area actually irrigated grew from 2 453 120 ha in 2000 to 2 732 730 ha in 2003. Summing up these figures, the total irrigable area amounts to 3 892 202 ha, and the total area used for irrigation is 2 471 379 ha. The assumption is that the irrigable area reported by the agricultural census represents the area equipped for irrigation. According to EUROSTAT the irrigable area of Italy was 3 854 910 ha in 2000 and 3 977 210 ha in 2003, while the area irrigated was 2 453 120 ha in 2000 and 2 732 730 ha in 2003. The irrigated areas by province are shown in the Table below. The area irrigated was derived from the database of the agricultural census 2000.

Figure 3-21: Irrigated areas in Italy by province

Province	Area equipped for irrigation (ha)		
	Total	with groundwater	with surface water
ABRUZZO	59 358	8 077	51 281
BASILICATA	80 640	17 529	63 111
CALABRIA	117 247	64 148	53 099
CAMPANIA	125 305	72 499	52 806
EMILIA-ROMAGNA	565 573	159 981	405 592
FRIULI-VENEZIA GIULIA	91 876	30 886	60 991
LAZIO	150 088	92 602	57 486
LIGURIA	11 391	2 707	8 684
LOMBARDIA	704 517	105 037	599 480
MARCHE	49 559	23 967	25 591
MOLISE	20 881	687	20 194
PIEMONTE	449 047	101 878	347 169
PUGLIA	389 617	308 116	81 501
SARDEGNA	165 707	49 937	115 770
SICILIA	209 035	101 725	107 310
TOSCANA	111 603	41 133	70 469
TRENTINO-ALTO ADIGE	61 774	15 610	46 164
UMBRIA	66 927	17 825	49 103
VALLE D'AOSTA	26 212	506	25 707



VENETO	435 845	70 931	364 914
Italy total	3 892 202	1 285 783	2 606 419

Diseases, pests and plant protection

In Italy, agriculture is challenged by various plant diseases and pests. The main concerns are the significant threats posed by specific diseases and a range of pests affecting crops and fruit production.

Table 3.20: Diseases, pests and plant protection

Crop	Harmful organism	Species names	Plant protection practices
Barley, wheat	Pest	Aphids (<i>Rhopalosiphum padi</i> , <i>Metopolophium dirhodum</i> , <i>Sitobion avena</i>); Septoria Aphids (<i>Sitobion avenae</i> , <i>Rhopalosiphum padi</i>); Stink bugs (<i>Aelia rostrat</i> , <i>Eurygaster maura</i>) ; Lema (<i>Oulema elanopus</i>); Humpbacked Zabro (<i>Zabrus tenebrioides</i>); Culm and ear moth (<i>Ochsenheimeria bisontella</i>); Fried fly (<i>Oscinella frit</i>); Cecidomia equestre (<i>Haplodiplosis marginata</i>)	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops): Removal and disposal of not recoverable, infested plant materials; Soil disinfestation (solarisation, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Wheat leaf rust, Black sooty mild; Wheat/Barley Bunt, Dwarf Bunt of Wheat; Loose Smut of Wheat. Tritici; Barley, powdery mildew; Wheat powdery mildew; Fusarium Head Blights, Crown and Root Rot; Black Chaff; Tan Spot; Ergot; Stagonospora Leaf and Glume Blotch of wheat; Root rot, leaf spot disease, seedling blight, head blight, and black point of wheat and barley, Striped barley leaf spotting and Reticulated barley leaf spotting; Brown/Yellow rust of wheat/barley; Barley leaf blight; Wheat Soilborne Mosaic Virus; Wheat Streak Mosaic Virus; Barley yellow dwarf (BYDV: Barley yellow dwarf virus:	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.
	Weed	Annual and perennial grasses and dicotyledons: <i>Alopecurus myosuroides</i> L., <i>Apera spica-venti</i> L.; <i>Avena fatua</i> L.; <i>Bromus sterilis</i> L.; <i>Lolium</i> spp.; <i>Phalaris</i> spp. L.; <i>Poa annua</i> L.; <i>Matricaria chamomilla</i> ; <i>Cirsium arvense</i> ; <i>Convolvulus arvensis</i> ; <i>Fumaria officinalis</i> ; <i>Galium</i>	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (plowing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.

		<i>aparine; Papaver rhoeas; Polygonum aviculare; Polygonum persicaria; Capsella bursa-pastoris.</i>	
Tomato	Pest	Root-Knot Nematodes (RKN) (genus <i>Meloidogyne</i> : <i>M. incognita</i> , <i>M. javanica</i> , <i>M. hapla</i> , and <i>M. arenaria</i> spp); Tomato leaf miners; White fly; Black cutworm; Broomrape <i>Orobancha Ramos/Phelipanche ramosa</i> ; Brown marmorated stink bug; Tomato bug; Aphids; Tomato fruitworm - TFW; Tomato russet mite; Tomato red spider mite.	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops): Removal and disposal of not recoverable, infested plant materials; Soil disinfection (solarisation, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Peronospora; Alternariosis; Fusarium wilt (FW) and Fusarium crown and root rot (FCRR) Plant blight; Verticillium wilt, Tomato powdery mildew; Tomato Soft Rot; Tomato leaf mold; Sclerotinia stem rot, Syringae Leaf Spot; Gray; Septoria leaf Spot; Gray leaf spot; Corky root rot; Pith necrosis; Bacterial Wilt; Bacterial canker; Bacterial stem rot and fruit; Fruit; Tomato Stolbur Disease, Viruses : Mild leaf mottling virus (Potato Virus Y -PVY); Mosaic Virus (Cucumber Mosaic Virus - CMV) Tomato Spotted Wilt Virus (TSWV: transmitted by <i>Frankliniella occidentalis</i> ; Tomato Brown Rugose Fruit Virus.	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.
	Weed	<i>Amaranthus</i> spp.; <i>Chenopodium</i> spp.; <i>Polygonum</i> spp.; <i>Portulaca oleracea</i> ; <i>Convolvulus arvensis</i> ; <i>Echinochloa crus-galli</i> ; <i>Setaria</i> spp.; <i>Phalaris</i> pp.; <i>Solanum nigrum</i> ; <i>Sorghum halepense</i> ; <i>Hibiscus trionum</i> ; <i>Fumaria</i> spp.; <i>Datura stramonium</i> ; <i>Tribulus terrestris</i> ; <i>Xanthium italicum</i> .	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (plowing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
	Pest	Lepidoptera: Noctuidae (<i>Spodoptera exigua</i> , <i>Autographa gamma</i> , <i>Mamestra brassicae</i> , <i>Mamestra oleracea</i> , <i>Pieris brassicae</i> , <i>Ostrinia nubilalis</i> , <i>Heliverpa armigera</i>); Lepidoptera: leaf Noctuidae (<i>Agrotis</i> spp); Aphids, Aphids green/black; Fly (<i>Delia Platura</i>); Spider mite ; Pea weevil; Bean weevil.	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops): Removal and disposal of not recoverable, infested plant materials; Soil disinfection (solarisation, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.

Beans	Disease	Anthracnose; Gray mold, Powdery mildew: legumes; Downy mildew: legumes; Rust; Rhizoctonia Root Rot; Bacterial wilt; Halo Blight; Verticillium wilt; Bacterial Blight; Fusarium Root Rot; Fusarium Yellows Wilt (<i>Fusarium oxysporum</i> . Subspecies are specific to the crop. Mosaic virus (Common Bean Mosaic Virus, Common Bean Mosaic Necrosis Virus, Pea seed-borne mosaic virus); Other virus (Broad Bean Wilt Virus, Broad bean stain virus, Faba Bean Necrotic Yellows Virus)	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.
	Weed	<i>Alopecurus myosuroides</i> ; <i>Cornus sanguinea</i> ; <i>Chinchocha crus-galli</i> ; <i>Abutilon theophrasti</i> ; <i>Solanum nigrum</i> ; <i>Amaranthus</i> spp.; <i>Chenopodium album</i> ; <i>Datura stramonium</i> ; <i>Raphanus raphanistrum</i>	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (ploughing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
Olive trees	Pest	Olive tree beetle (<i>Otiorynchus cribricollis gyllenhaal</i>); Olive moth (<i>Prays oleae</i>); Olive fly, (<i>Bactrocera oleae</i>); Wood leopard moth (<i>Zeuzera pyrina</i>); Cochineal half a grain of pepper (<i>Saissetia oleae</i>); Spittlebug (<i>Philaenus spumarius</i> : responsible for the spread, in Salento, of a particular bacterial strain of <i>Xylella fastidiosa</i> spp. pauca, associated with the Rapid Olive Desiccation Complex (CoDiRO). ;Olive bark beetle, (<i>Phloeotribus scarabaeoides</i>); Olive tree borer; Olive weevil.	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops): Removal and disposal of not recoverable, infested plant materials; Soil disinfection (solarisations, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Olive Branch and Twig Dieback (BTD) (<i>Neofusicoccum mediterraneum</i>); Verticillium Wilt (<i>Verticillium dahliae</i> Kleb.); 'Olive tree leprosy' (<i>Colletotrichum gloeosporioides</i> , <i>Gloeosporium olivarum</i>); Olive peacock eye leaf (<i>Venturia oleaginea</i> - the anamorph: <i>Spilocaea oleagina</i>); Cercosporiosis, <i>Mycocentrospora cladosporioides</i> ; Sooty Mould; Olive Knot; Wood decay; Olive Quick Decline Syndrome.	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil (essential for organic crops: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.
	Weed	<i>Amaranthus</i> spp.; <i>Chenopodium album</i> ; <i>Conyza canadensis</i> ; , <i>Diplotaxis erucoides</i> ; <i>Lolium multiflorum</i> ; <i>Malva</i> spp.; <i>Portulaca oleracea</i> ; <i>Senecio vulgaris</i> .	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (ploughing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.

Soil: The soils of Italy exhibit considerable diversity, reflecting the country's varied climates and landscapes. They originate from a range of parent materials and are influenced by different soil temperatures and moisture regimes. Major soil types include alluvial soils, such as Calcaric Cambisols, Fluvisols, and Gleysols, which are often found with shallow water tables. There are also soils with clay accumulation, including Chromic, Calcic, Gleyic, Haplic, and Vertic Luvisols. Additionally, soils with vertical properties and reorganization of carbonates are present, such as Vertic Cambisols and Eutric, Calcaric, and Calcic Cambisols. Soil types vary significantly across regions, from friable acidic sands in the Dolomite Mountains in the north to nearly unworkable clay loams around Bologna and in Tuscany, and poor, dry calcareous crusts along the coastline. The Po Valley stands out as the most fertile area, benefiting from relatively evenly distributed precipitation throughout the year, although rainfall decreases towards the south. Soil regions are often defined by their specific climate and parent material, with common soil degradation processes including erosion and contamination, which vary according to different soil regions.

3.7.2 IPCC projections on climate change indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:

3.7.2.1 *Temperature*

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional



Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

In Italy, the observed annual mean surface air temperature was 14.38°C in 2022, up from 14.10°C in 2021, indicating an approximate 2% increase. Climate projections suggest that by 2030, the annual mean surface air temperature will range between 13.88°C and 14.20°C, depending on different emission scenarios. By 2050, the temperature is projected to be 14.12°C under an optimistic scenario, while a worst-case scenario predicts an increase to 15.29°C.

Climate change has regional impacts and local adaptation strategies must be followed. The living lab for Italy is in Basilicata, where the projected annual mean surface air temperature for 2030 is expected to range between 15.06°C and 15.34°C. By 2050, projections indicate that the temperature in Basilicata will range between 15.28°C in the best-case scenario and 16.50°C in the worst-case scenario.



Projected Average Mean Surface Air Temperature Italy; (Ref. Period: 1995-2014), Multi-Model Ensemble

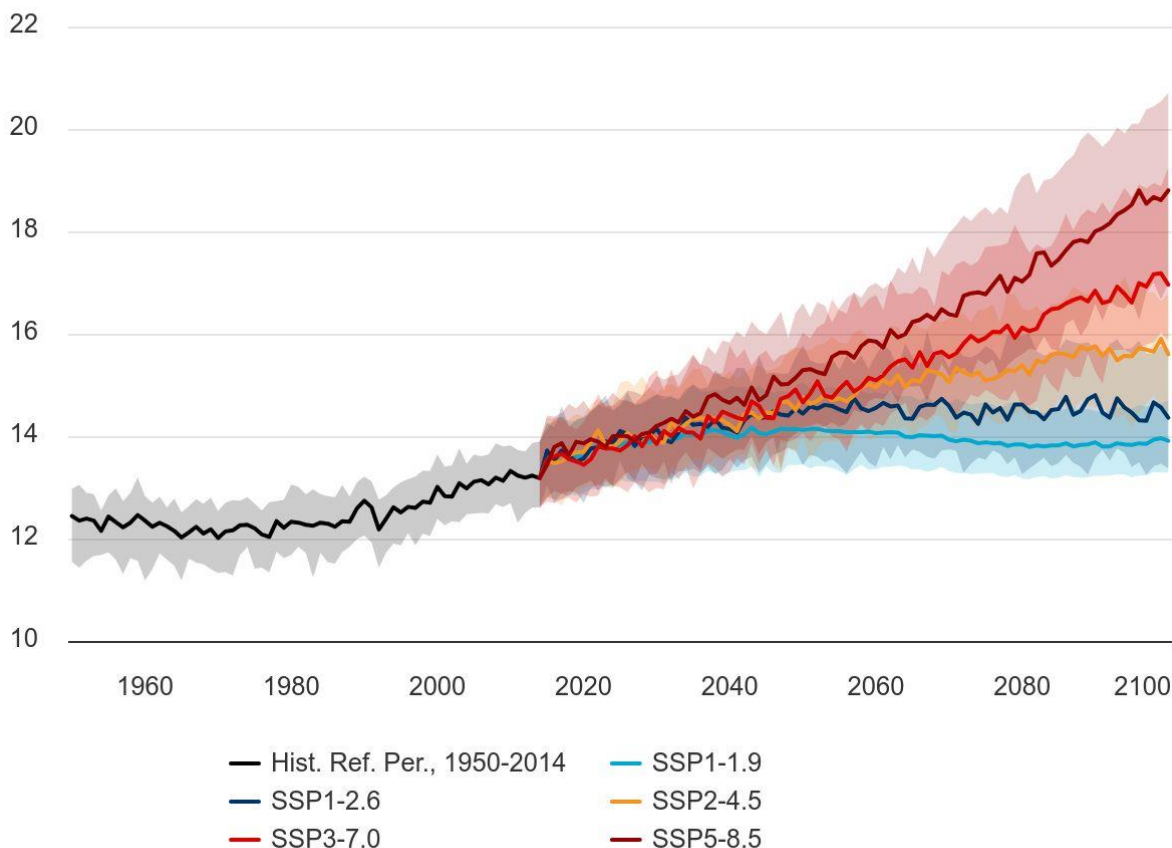


Figure 3-22: Projected average mean surface air temperature for Italy

3.7.2.2 Precipitation pattern

Italy has experienced a decrease in precipitation characterized by less frequent but more intense rain patterns over the years. For instance, mean annual precipitation was 734.18 mm in 2021, whereas it dropped to 601.08 mm in 2022. Seasonal average precipitation values since 1901 indicate that precipitation has decreased in the winter and spring seasons from 1991 to 2020 compared to the period from 1901 to 1990. Projections for 2030 suggest that annual precipitation will range from 1003.32 mm to 1037.66 mm. By 2050, annual precipitation is projected to range between 997.92 mm and 973.82 mm.

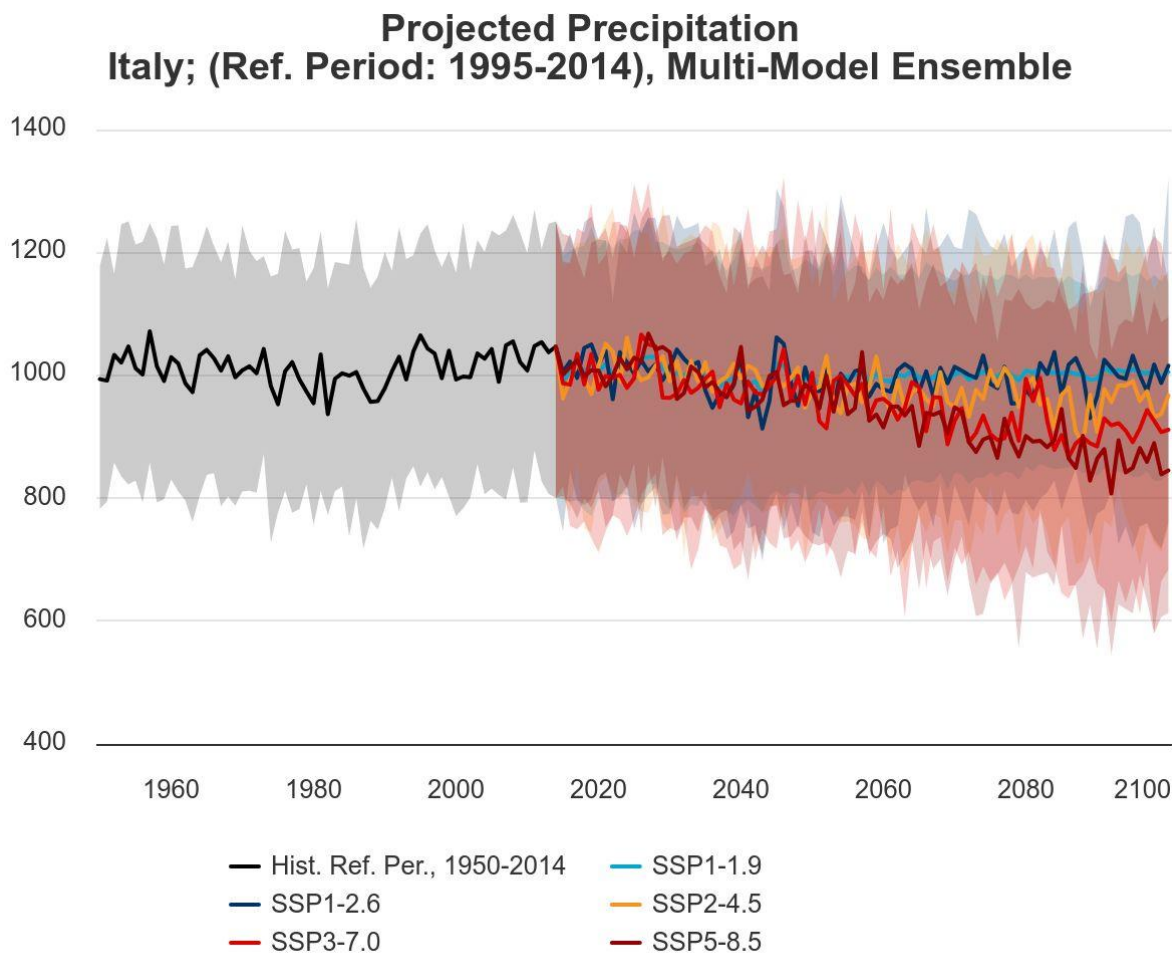


Figure 3-23: Figure 17. Projected precipitation patterns in Italy

The projected annual precipitation for Basilicata in 2030 is 685.02 mm under the SSP1 - 2.6 scenario and 682.01 mm under the SSP5-8.5 scenario. By 2050, precipitation in Basilicata is expected to range between 668.27 mm and 615.16 mm. These projections indicate a potential decline in annual precipitation, reflecting the impact of climate change on regional precipitation patterns.

3.7.2.3 Sea level rise

Sea level rise for Italy has been estimated at 1.64 mm per year since 1903. By 2050, under a low-emissions scenario, sea levels in Italy may rise by 0.18 meters, and by as much as 0.23 meters under a high-emissions scenario.

For Basilicata, the region of focus in the living lab, projections are based on data from

the Napoli (Mandrachio) gauge. Projections indicate that

The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201



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by 2030, changes in sea levels will range between 0.09 meters and 0.10 meters across all scenarios. By 2050, sea level changes are expected to be between 0.16 meters and 0.22 meters. These projections highlight the importance of addressing sea level rise in coastal areas of Italy to mitigate potential impacts on infrastructure and ecosystems.

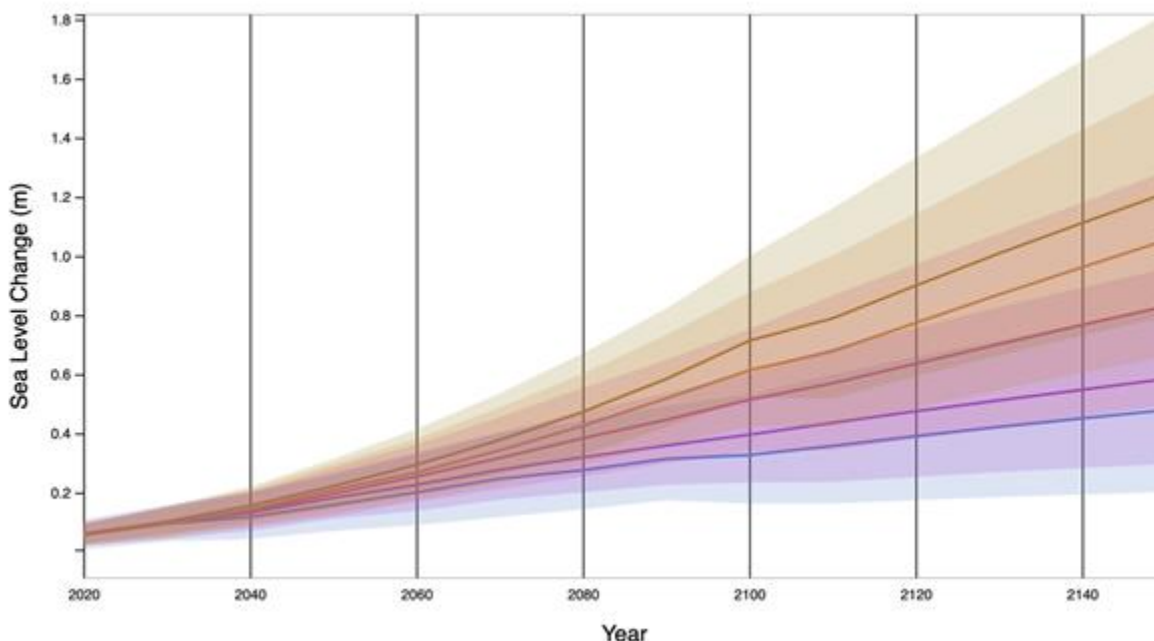


Figure 3-24: Figure 26. Projected sea level changes in Italy

3.7.2.4 Extreme weather events

Italy has been hit hard by extreme weather events since 1990, with a sharp rise in frequency in the last decade (G20 Climate Risk Atlas-Italy). Cities like Milan and Rome have seen a surge in flash floods, while northern regions like Emilia-Romagna experienced devastating downpours in May 2023. This erratic weather pattern, including intense heatwaves, hailstorms, and droughts, has caused widespread damage to life, property, and economic activities like agriculture and manufacturing. Research suggests that these trends will worsen, putting 70% of Italy's strategic assets and nearly 30% of its population at risk by 2050. Proactive measures are needed to address this growing threat and protect Italy's people, infrastructure, and economy.

3.7.2.5 Ecosystem and biodiversity impacts

Italy boasts incredible biodiversity, with the highest number and density of both animal and plant species in the European Union, and a high rate of endemism. The country is



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home to over 58 000 faunal species, including 1 268 species of vertebrates, 1 812 species of protozoans, and a vast majority of invertebrates making up the remaining 95%. Additionally, Italy hosts more than 6,700 vascular plant species, 1 156 species of bryophytes, and around 20 000 known fungi species, including 2 328 lichen taxa.

Climate change is drastically transforming the Italian mountain landscape, leading to shifts in species composition, the disappearance of certain species, and their migration to higher altitudes. Italian forests, which cover about 10 million hectares (30% of the national area) and represent 5% of Europe's total forested area, are crucial for the landscape, biodiversity, environmental balance, and economy.

However, increasing aridity in central-southern Italy is making these forests more vulnerable to disturbances, both biotic and abiotic, reducing their resistance and resilience. On average, 55 000 hectares of woodlands are significantly damaged by fires each year. About 30% of animal species and 15% of vascular plant species in Italy are endemic, with Sicily and Sardinia being particularly notable for their unique species.

The IUCN Red List of Italian Flora and other threatened species (2013) indicates that 42% of "policy species" are at various levels of threat. The Red List of Italian Dragonflies (2014) shows that among the 93 species assessed, one has become regionally extinct, and 10.9% are threatened. Similarly, the Red List of Italian Saproxyllic Beetles (2014) reveals that 21% of the 1 986 assessed species are threatened.

3.7.2.6 Socioeconomic impacts

Agriculture and food security: Climate change will impact agricultural productivity, with yields of major crops like corn, durum wheat, and grapes potentially declining in the coming decades as temperatures rise above optimal thresholds.

Infrastructure: Rising sea levels, coastal erosion and changing storm patterns could expose 0.48 million people to devastating floods by 2050 in a high carbon scenario, damaging coastal infrastructure



Energy: Higher temperatures and more severe heatwaves will affect Italy's energy system and change the profile of its energy demand. Droughts could reduce hydropower generation and water availability for cooling power plants.

3.7.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Italy and their specific focus on different products.

Table 3.21: Drivers of products for Italy

Products- Italy					
	Barley	Tomatoes	Wheat durum	Olives	Beans
Drivers	1. Drought 2. Precision farming 3. Integrated agriculture 4. Availability for fertilisers 5. Crop genetic diversity	1. Extreme weather event 2. Heat stress 3. Integrated agriculture 4. Precision farming 5. Resistant cultivar	1. Drought 2. Precision farming 3. Integrated agriculture 4. Availability for fertilisers 5. Crop genetic diversity	1. Pathogens 2. Resistant cultivar 3. Tillage 4. Crop genetic diversity 5. Integrated agriculture	1. Heat stress 2. Precision farming 3. Crop genetic diversity 4. Nutritional quality 5. Integrated agriculture

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.7.4 Living lab scenarios

AideMec

The establishment of a living lab in Southern Italy, specifically within the Mediterranean ambience of the Basilicata region, marks a significant step towards innovative agricultural and environmental management. This initiative is poised to become a beacon of research, development, and demonstration where the convergence of tradition, technology, and sustainability shapes the future of agriculture and community resilience in the face of climate change. The LL in Basilicata is not just a



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research facility but a dynamic ecosystem that engages local communities, researchers, policymakers, and industry stakeholders in co-creating and testing innovative solutions that address real-world challenges.

Products Scenarios	Wheat	Barley	Tomato	Beans	Olives
1. Business as Usual 2030 - 2050	X	X	X	X	X
2. Climatic shocks: drought and heatwaves.			X		X
3. Climate Change Impacts and Integrated Resilience Strategies	X	X			
4. Intervention to combat <i>Xylella fastidiosa</i> in olive orchards in the Basilicata region.					X
5. Addressing the lack of labour force in the agricultural sector of Basilicata.			X		X

Scenario 1: Business as usual (2030 and 2050)

To construct the "Business as Usual" (BAU) scenarios for 2030 and 2050 for each of the production systems (tomato, barley, durum wheat, olive, and bean) outlined in the Living Lab (LL) initiative in Basilicata, we must consider the current agricultural practices, climate challenges, and technological adoption rates. The BAU scenarios will assume minimal changes in these areas, projecting the current trends without significant innovations or adaptations to emerging climate stressors. Here's how these scenarios might look for each crop:

Tomato production:

- **2030:** Traditional irrigation and pest management practices continue with minor improvements. The yield fluctuates due to increasing drought and salt stress episodes, with occasional losses from new pest invasions. The adoption of smart irrigation systems is slow, and most farmers still rely on conventional methods. Genetic improvement focuses on yield rather than resilience to climate stressors.



- **2050:** The lack of significant adaptation strategies leads to more pronounced yield variability and quality issues. Soil salinization and water scarcity have become more severe, impacting the production areas significantly. Efforts to introduce drought-resistant varieties are underway but are not widespread.

Barley and durum wheat:

- **2030:** Continued reliance on traditional farming practices with moderate fertilizer use. Water scarcity begins to affect yield more significantly, but the adoption of water-efficient practices is limited. The market demand remains stable, encouraging a business-as-usual approach.
- **2050:** Climate change impacts, including longer drought periods and irregular rainfall, lead to reduced yields and increased production costs. Some efforts to adopt climate-resilient varieties are noted, but widespread change is limited, affecting the economic viability of small-scale farmers.

Olive production:

- **2030:** Olive groves continue to be managed traditionally, with little change in tillage, pest management, or water use efficiency. Yields are increasingly affected by erratic weather patterns, including heatwaves and droughts.
- **2050:** The olive oil industry faces significant challenges as older trees struggle to adapt to changing conditions, and new plantings are slow to mature. The lack of significant innovation in pest management leads to increased losses.

Bean cultivation:

- **2030:** Water management practices remain largely unchanged, leading to stress during dry periods. The genetic diversity of local varieties provides some resilience, but not enough to counteract the increasing frequency of climate extremes.
- **2050:** Continued water stress and emerging pests reduce yield and quality. Efforts to introduce smart irrigation are implemented by a minority of farmers, leading to a patchwork of productivity across the region.

Across all productions:

- *Technological Adoption:* Slow adoption of smart technologies and precision agriculture limits the potential for efficiency gains. Digital and smart



technologies are available but not fully integrated into the agricultural practices of most farmers.

- *Climate Change Impacts:* The effects of climate change become more pronounced, with increased frequency and severity of extreme weather events. Soil degradation and water scarcity have become critical issues, affecting the sustainability of agricultural production.
- *Socio-Economic Dynamics:* Labour shortages become more acute, with an aging farmer population and continued emigration of young people. The agricultural sector struggles to attract new workers, and the adoption of labour-saving technologies is slow.

Scenario 2: Climatic shocks

Scenario 2 underscores the critical importance of preparing for and adapting to climatic shocks in agricultural systems. This scenario highlights the need for a multifaceted approach that combines technological innovation, policy support, and community engagement to enhance the resilience of agricultural practices in the face of climatic uncertainties.

Drought and heatwave shock:

- *Experimental impact:* An unexpected severe drought coupled with a prolonged heatwave occurs, intensifying water stress beyond the planned drought protocol, challenging both the standard and smart irrigation systems. The extreme conditions accelerate water loss, pushing the plants to their physiological limits.
- *Adaptation strategies:* The experiment adapts by implementing emergency water conservation measures and adjusting the smart irrigation system to optimize the reduced water supply. The resilience of the two tomato varieties to these compounded stresses is closely monitored, with a focus on identifying physiological traits that confer survival advantages.
- *Outcomes:* The experiment provides invaluable data on the threshold limits of tomato varieties under extreme water and heat stress, informing future breeding and management strategies aimed at enhancing crop resilience.



Scenario 3: Advanced climate change impacts and integrated resilience strategies for barley and durum wheat

Scenario 3 aims to address the long-term impacts of climate change on barley and durum wheat resilience and adaptability. This scenario broadens the scope to encompass a wider array of climatic stressors, including extreme weather events, evolving pest and disease pressures, and the interplay of these factors with diverse agricultural practices. It seeks to harness both cutting-edge technological advancements and the wisdom of traditional knowledge to fortify crop resilience against the backdrop of a changing climate. Emphasizing a collaborative ethos, Scenario 3 underscores the imperative of bridging the divide between science, policy, and practice to navigate the challenges and seize the opportunities presented by climate change.

Experimental design enhancements

- *Extended monitoring:* To capture the nuanced effects of climate variability, this scenario advocates for longitudinal studies spanning multiple growth cycles. This approach will illuminate the crops' responses to inter-annual climatic fluctuations, offering a richer, data-driven understanding of resilience over time.
- *Enhanced stressors:* The introduction of simulated extreme weather events—ranging from hailstorms and severe heatwaves to unexpected frost—aims to test the resilience thresholds of barley and durum wheat. This facet of the design is critical for assessing the robustness of these crops under acute and unpredictable climatic conditions.
- *Pest and disease pressures:* As climate change is likely to alter the landscape of pest and disease risks, this scenario incorporates an evaluation of how emerging and intensified threats could impact crop health and yield, depending on the variety and fertilization level.

Technological and traditional integration

- *Precision agriculture:* The deployment of sensors and IoT devices for real-time crop health, soil moisture, and nutrient status monitoring exemplifies the scenario's commitment to precision agriculture. Such technologies enable



tailored irrigation and fertilization, optimizing resource use and bolstering crop resilience.

- *Genetic advances*: Exploring genetic editing to introduce or enhance traits such as drought tolerance, heat resistance, and resistance to pests and diseases represents a forward-looking strategy to future-proof these essential crops.
- *Traditional practices*: Integrating time-honoured agricultural practices—like crop rotation, intercropping, and the use of cover crops—aims to improve soil health, promote biodiversity, and manage pests naturally. This blend of old and new encapsulates the scenario's holistic approach to agricultural resilience.

Outcomes and strategies

- *Comprehensive resilience assessment*: Through detailed analysis, this scenario will pinpoint the most resilient barley and durum wheat varieties and optimal agricultural practices against a backdrop of climate change. This assessment is pivotal for guiding future breeding programs and agricultural strategies.
- *Adaptive capacity enhancement*: By identifying effective resilience-building practices, Scenario 4 will lay the groundwork for enhancing these crops' adaptive capacities. This includes breeding for resilience, refining agricultural practices to align with climatic shifts, and leveraging technology for smarter farming.
- *Policy and community engagement*: Recommendations will extend beyond the field, advocating for policy reforms that support sustainable agriculture and resilience-building. Equally, engaging with farming communities to disseminate knowledge and practices will be key to fostering grassroots resilience.

Scenario 4: Prevention of *Xylella fastidiosa* in olive orchards in the Basilicata region

Xylella fastidiosa is a devastating bacterial pathogen that affects various plant species, with olive trees being particularly susceptible. In the Basilicata region of South Italy, olive orchards are a critical part of the local economy and culture. The emergence of *Xylella fastidiosa* poses a severe threat to olive production, necessitating immediate and comprehensive intervention strategies.



Climatic Conditions: The first signs of *Xylella fastidiosa* appear in several olive orchards in Basilicata. Symptoms include leaf scorch, twig dieback, and tree decline. The pathogen spreads rapidly due to the movement of insect vectors, particularly the meadow spittlebug (*Philaenus spumarius*). The warm and humid climate of the region accelerates the spread of the disease.

Interventions: Research and development resistant varieties: Invest in research to develop and propagate *Xylella*-resistant olive tree varieties. Collaborate with agricultural research institutions and universities to accelerate breeding programs. Conduct in-depth studies on *Xylella fastidiosa* to understand its biology, transmission mechanisms, and potential weaknesses that could be targeted for control. Promote agronomic practices that reduce the risk of infection. This includes maintaining proper tree spacing, pruning to improve air circulation, and removing weeds that may harbour vectors. Improve soil health through organic amendments and soil conservation practices, enhancing the overall resilience of olive trees to disease. Encourage crop diversification within olive orchards to reduce economic reliance on a single crop and enhance ecological resilience. Promote integrated pest management practices that combine biological, cultural, and chemical controls to manage vector populations sustainably. Maintain continuous monitoring and surveillance programs to detect and respond to new outbreaks promptly. Offer financial assistance to farmers affected by tree removal and reduced yields. Support could include subsidies, low-interest loans, and compensation for lost income. Strengthen farmer cooperatives to facilitate knowledge exchange, collective action, and access to resources. Cooperatives can play a vital role in implementing large-scale interventions and monitoring efforts.

This intervention scenario outlines a comprehensive approach to managing *Xylella fastidiosa* in the olive orchards of Basilicata. It highlights the importance of early detection, containment, vector control, research, and sustainable practices in combating the disease while ensuring the long-term resilience and productivity of the region's olive industry.



Scenario 5: Addressing the lack of labour force in the agricultural sector of Basilicata

The Basilicata region of Italy is known for its rich agricultural heritage, producing a variety of crops such as tomatoes, olives, grapes, and wheat. However, in recent years, the region has faced a significant shortage of labour in the agricultural sector. Factors contributing to this issue include ageing farmer populations, urban migration of younger generations, and the seasonal nature of agricultural work. This scenario outlines strategies to address the labour shortage and ensure the sustainability of agriculture in Basilicata.

Current situation. The agricultural sector in Basilicata is experiencing a severe labour shortage. Many farms are struggling to find enough workers to plant, tend, and harvest crops. The rural population is ageing, and younger individuals are moving to urban areas in search of better opportunities, leaving a gap in the agricultural workforce. The seasonal nature of agricultural work makes it difficult to retain a stable workforce, as many workers prefer more consistent year-round employment.

Interventions: Increasing wages and providing better working conditions to make agricultural jobs more attractive. Offering bonuses for peak seasons to attract temporary workers. Providing affordable housing and transportation for seasonal workers to reduce the logistical challenges they face. Launching recruitment campaigns targeting local youth and unemployed individuals, highlighting the benefits and importance of agricultural work. Collaboration with national and international agencies to create seasonal worker programs, allowing migrant workers to fill labour gaps during peak seasons. Advocation for more flexible visa policies to enable the easier entry and exit of seasonal workers. Investments in mechanization to reduce the dependency on manual labour. Use machinery for planting, weeding, and harvesting where possible. Providing subsidies and grants to farmers for investing in mechanization and improving working conditions. Investments in advanced robotics for tasks such as harvesting, pruning, and monitoring crop health. Autonomous machines can significantly reduce the need for manual labour. In the Basilicata region is it possible to build a resilient



agricultural workforce and ensure the sustainability of its farming industry.



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3.8 Poland

3.8.1 Dossier of Living Lab- country profile

Country - Poland

Region in EU - Central Eastern Europe

Name of living lab - Co-creating resilient food Systems for Central and Eastern Europe (EcoReadyMasuria).

Partners - Research and Innovation Centre Pro-Akademia, University of Warsaw, Faculty of Biology, The Masurian Center for Biodiversity and Nature Education in Urwitalt, Association Local Action Group “Leader in EGO”, Agricultural Farm Mirosław Gontar.

Products - Milk, Fodder maize, Barley, Red clover, Sunflower.



Figure 3-25: Map of Poland with products



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Partner background information

Economics: In the Warmińsko-Mazurskie Voivodship, agriculture plays a crucial role in the regional economy. According to the 2020 Agricultural Census, there were 42.6 thousand agricultural holdings utilizing 1 173.5 thousand hectares of land. Compared to 2010, the number of agricultural holdings has decreased, but the total area has increased, leading to a rise in the average size of each holding. Of the total agricultural land, 1 073.2 thousand hectares were in good agricultural condition. Holdings in this region used less fertilizer per hectare than the national average, with a decrease in mineral fertilization but an increase in lime fertilization. Among animal manures, the use of slurry increased while the use of liquid, solid, and poultry manure decreased, reflecting changes in animal husbandry practices. In 2022, the sown area increased from the previous year, ranking among the top five voivodships in terms of area. Although slightly less land was allocated to cereals compared to 2021, the area for sugar beet, rape, and turnip rape grew, while the area for potatoes and horticultural crops declined. Annual harvests saw increases in cereals, sugar beet, rape, turnip rape, fruit from trees and bushes, strawberries, and wild strawberries, with a decrease in potatoes and vegetables. As of June 2022, there was an increase in cattle and sheep stock, but a decrease in pig stock. Turkeys were the most significant poultry species, representing half of the voivodship's poultry population, with chickens being the next largest. The region had one-third of Poland's turkey population. In 2021, while production of meat from various animals was lower, milk production increased, with the average annual yield per cow rising to 5,487 litres, up 7.2% from the previous year. In 2022, agricultural products from Warmińsko-Mazurskie Voivodship had a total value of PLN 6 693.3 million (excluding VAT), marking an increase from the previous year. Animal products were the primary focus, with higher procurement prices for cereals, poultry for slaughter, and milk compared to the national average, while prices for potatoes, cattle, and pigs were lower. The region's agriculture primarily centres on cereals such as wheat, rye, and barley, which are well-suited to its cooler, wetter climate. Potatoes and fodder crops are also important. Sunflower production is minimal in Masuria due to the region's climatic conditions, which are less favourable compared to the warmer and drier



eastern parts of Poland like Lublin and Podlaskie, where sunflowers grow more effectively.

Policies: Policies in the Masuria region include various *Eco-schemes* and *agri-environment-climate* measures. The *Eco-schemes* focus on carbon farming and nutrient management, water retention on permanent grasslands, integrated plant production, and biological crop protection. Agri-environment-climate initiatives emphasize the protection of valuable habitats and endangered species within Natura 2000 areas (I 8.11) and outside these areas (I 8.2). Other measures include the extensive use of meadows and pastures in Natura 2000 areas (I 8.3), preservation of endangered genetic resources of plants (I 8.5) and animals (I 8.6) in agriculture and promoting biodiversity on arable land (I 8.7). Additionally, organic farming (I 8.11) is strongly encouraged. These policies aim to ensure sustainable agricultural practices while conserving biodiversity and protecting the environment

Farming practices: Farming practices in the Masuria region encompass a range of production systems, including conventional, organic, low input, regenerative, agroforestry, and no-till farming. The region is characterized by mostly small farms, with a predominance of conventional farming systems, although there is a growing trend towards organic farming, which currently occupies 3.50% of the total agricultural area. Crop rotation is practiced, with rye being a common crop grown in rotation. Farmers primarily sow cereals, which are used for grain, silage, and biomass, with some crops being internally used and covering crops being implemented. Despite the environmental and agricultural benefits of new farming methods, including crop rotation and after-crop sowing, farmers often view these practices negatively. Irrigation is mainly ascent irrigation, and fertilization practices vary, with a focus on maintaining soil health and productivity.

Potential drivers

Biodiversity: New breeding objectives aim to enhance genetic diversity and reduce inbreeding within livestock breeds, ensuring effective population sizes and robust animal health. Land use changes tailored for breeding, such as the implementation of seasonal grazing, promote habitat diversity and ecological balance. Efforts to maintain



genetic diversity within breeds are crucial for sustaining effective population sizes, which contribute to the resilience of livestock populations. Additionally, managing predator abundance is essential for maintaining a balanced ecosystem, further supporting the region's biodiversity and sustainable agricultural practices

Climate: Located at an elevation of 107 meters above sea level, Warsaw experiences a temperate continental climate. The annual long-term mean temperature is 7.8°C, with annual precipitation averaging 519 mm. January is the coldest month, with a long-term daily mean temperature of -3.3°C, while July is the warmest, with a long-term daily mean temperature of 17.9°C. The wettest month is June, receiving 72 mm of precipitation, and the driest is February, with 21 mm. Climate risks in Warsaw include low temperatures, frost days, excess water, black frost, and hail. These factors affect diet and feed quality, as well as manure management. Additionally, Poland is home to the top 10 largest methane-emitting coal mines in Europe, which together released approximately 282 300 tons of methane into the atmosphere in 2020, contributing significantly to greenhouse gas emissions.

Food security: Food security in Poland is a multifaceted issue that involves various aspects of agriculture, trade, policy, and social welfare. The country produces a wide range of agricultural products, including grains, potatoes, fruits, vegetables, dairy, and meats. Agricultural production plays a crucial role in ensuring a stable and sufficient food supply for the population. Poland aims to maintain a level of self-sufficiency in food production to reduce reliance on imports and ensure food security. The government implements policies and programs to support domestic farmers and promote agricultural productivity. However, Poland still imports certain food items, especially fruits, vegetables, and specialty products that are not easily grown in the country's climate. They are applying quality and safety standards in food production and processing. Regulatory agencies, such as the Chief Sanitary Inspectorate (GIS) and the Main Inspectorate of Plant Health and Seed Inspection (PIORiN), monitor and inspect food establishments to ensure compliance with hygiene and safety regulations. This oversight helps maintain consumer confidence in the safety and quality of food products. Trade agreements and partnerships facilitate the importation of food items



while also promoting exports of Polish agricultural products to global markets. The Polish government implements social welfare programs to ensure access to food for all citizens, particularly those in vulnerable or low-income groups. Welfare programs, such as social assistance benefits and food aid initiatives, provide support to individuals and families facing food insecurity. Poland faces challenges related to climate change, including extreme weather events, changing precipitation patterns, and temperature fluctuations. These factors can affect agricultural productivity and food security. The government works to promote climate-resilient agriculture through research, technology adoption, and adaptation strategies aimed at mitigating the impacts of climate change on food production. Food security and biodiversity are influenced by a range of factors, including advancements in vaccination and therapeutic treatments, which enhance animal health and productivity. Improved monitoring and recording systems, supported by AI methods, enable more precise management and early detection of issues, contributing to both food security and biodiversity conservation. New breeding techniques and targeted breeding goal traits help in developing resilient and efficient livestock and crop varieties. The price of animal feed affects the cost of production and the sustainability of farming practices. Water availability is crucial for maintaining crop yields and livestock health, directly impacting food security. Additionally, changes in consumer diets can shift demand patterns, influencing agricultural practices and biodiversity outcomes.

Farming conditions

Water: In Poland, the extent of irrigated land reached its peak in 1975 at 408 700 ha but has since declined significantly. By 1990, this area had decreased to 301 500 ha, and further reduced to 201 100 ha in 1995 and 83 292 ha in 2003. Sub-surface irrigation, particularly in wetlands and inland valley bottoms within combined drainage/irrigation schemes, is the dominant method of irrigation in the country. The area of ameliorated grasslands is approximately 1 931 000 ha, with about 25 percent equipped with hydraulic structures that could theoretically support irrigation. However, as of 2004, only 89 000 ha of grasslands were classified as irrigable, with arable land totaling only 5 300 ha, mostly under micro-irrigation. Recent statistics from EUROSTAT indicate a resurgence in both irrigable and irrigated areas. By 2005, the irrigable area had increased to 124 200 ha, and the irrigated area had expanded to 70 450 ha. Given the



data uncertainties, areas equipped for irrigation were estimated by using the maximum values from 2003 and 2005, resulting in a total of 134 050 ha equipped for irrigation across Poland. The detailed breakdown of irrigated areas by province is available in the table below.

Table 3.22: Irrigated areas by province in Poland

Province	Area equipped for irrigation (ha)	Area actually irrigated(AAI) (ha)
Dolnoslaskie	5 890	3 137
Kujawsko-Pomorskie	11 810	6 870
Lodzkie	12 330	9 147
Lubuskie	6 100	1 383
Lubeiskie	4 670	1 987
Malopolske	1 140	630
Mazowieckie	25 140	13 107
Opolskie	1 170	670
Podlaskie	3 380	1 023
Podkarpackie	620	127
Pomorskie	8 300	4 957
Slaskie	960	600
Swietokrzyskie	760	373
Warminsko-Mazurskie	24 040	6 557
Wielkopolskie	16 560	9 250
Zachodnio-Pomorskie	11 180	3 320
Poland total	134 050	63 138
with groundwater	13 405	
with surface water	120 645	

To distribute irrigated areas within the provinces, pasture areas were extracted from the Corine 2000 land cover database for Europe. About 90 percent of Poland's irrigation area is irrigated with surface water and 10 percent with groundwater. The area irrigated per district was computed as the average of AAI reported by the EU farm structure surveys 2003, 2005, and 2007. Total AAI computed that way adds up to 63 138 ha.

Diseases, pests and plant protection

Agriculture in Poland is challenged by various plant diseases and pests. The main concerns are diseases affecting major crops and pests.



Table 3.23: Diseases, pest and plant protection

Crop	Harmful organism	Species names	Plant protection practices
Fodder maize	Pest	European maize borer, western corn rootworm, larvae of beetles, black cutworm, aphids, Chrysomelid beetle, black cutworm, spider mites, Mammals: <i>Sus scrofa</i> , <i>Microtus arvalis</i> , <i>Mus musculus</i> , Aves.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Common smut; <i>Fusarium</i> spp.(1. <i>Fusarium</i> ear and kernel rot, 2. <i>Fusarium</i> head blight, 3. <i>Fusarium</i> stalk rot, 4. <i>Fusarium</i> Root and Crown Rot); <i>Giberella</i> stalk and ear rot.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	<i>Amaranthus retroflexus</i> , <i>Echinochloa crus-gali</i> , <i>Capsella bursa pastoris</i> , <i>Thlaspi arvense</i> , <i>Stellaria media</i> , <i>Tripleurospermum inodorum</i> , <i>Cirsium arvense</i> , <i>Elytrigia repens</i> , <i>Setaria</i> sp., <i>Alopecurus myosuroides</i>	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management.
Barley	Pest	Wheat stem sawfly , cereal cyst eelworm, <i>Pratylenchus neglectus</i> , carabid ground beetles, cereal leaf beetle, , wheat-bulb flies, aphids, larvae of beetles, moth, thrips, miner fly, chloropid gout fly, bug, hessian fly.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Powdery mildew; rusts; <i>Ramularia</i> leaf spot of barley; net blotch of barley; leaf stripe of barley; scald of barley; head blight; eyespot; take-all; Barley yellow dwarf virus; Wheat dwarf virus.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, removal of volunteer plants and weeds, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	<i>Capsella bursa pastoris</i> , <i>Centaurea cyanus</i> , <i>Chenopodium album</i> , <i>Cirsium arvense</i> , <i>Elytrigia repens</i> , <i>Galium aparine</i> , <i>Lamium</i> sp., <i>Poa annua</i> , <i>Polygonum aviculare</i> , <i>Stellaria media</i> , <i>Thlaspi arvense</i> , <i>Tripleurospermum inodorum</i> , <i>Veronica</i> sp., <i>Polygonum aviculare</i> , <i>Alopecurus myosuroides</i> , <i>Convolvulus arvensis</i> , <i>Avena fatua</i> , <i>Apera spica-venti</i> .	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.

Red clover	Pest	Alfalfa snout beetle, pea aphid, Curculionidae, Small mammals, common vole.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	Root and crown rot (different causal agents).	Clean seed, certified pathogen-free seed, seed treatment, land selection, cultivar selection, crop rotation, proper time of cutting, adequate fertility management.
	Weed	<i>Elytrigia repens</i> , <i>Capsella bursa pastoris</i> , <i>Tripleurospermum inodorum</i> , <i>Stellaria media</i> , <i>Lamium purpureum</i> , <i>Galium aparine</i> , <i>Chenopodium album</i> , <i>Polygonum</i> sp., <i>Rumex</i> sp. <i>Anthemis arvensis</i> , <i>Taraxacum</i> sp.	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management.
Sunflower	Pest	European maize borer, black cutworm, African cotton bollworm, Tenebrionid beetle, mirid bugs, stink bug <i>Nezara viridula</i> , larvae of beetles, aphids, palm thrips, burdock leaf miner, grey field slug. Aves: <i>Streptopelia decaocto</i> , <i>Serinus serinus</i> . Rodents: <i>Mus musculus</i> , <i>Microtus arvalis</i> .	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.
	Disease	<i>Sclerotinia sclerotiorum</i> (1. Sclerotinia root and basal stalk rot, and wilt; 2. Sclerotinia stem rot; and (3) Sclerotinia head rot and midstalk rot); gray mold; downy mildew; <i>Alternaria</i> blight; black stem; stem canker; charcoal rot.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management, fungicide application.
	Weed	<i>Amaranthus retroflexus</i> , <i>Echinochloa crus-gali</i> , <i>Capsella bursa pastoris</i> , <i>Thlaspi arvense</i> , <i>Stellaria media</i> , <i>Tripleurospermum inodorum</i> , <i>Cirsium arvense</i> , <i>Elytrigia repens</i> , <i>Setaria</i> sp.	Mechanical and chemical weed control; preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, and clean seed); proper soil management.

Several diseases significantly impact milk production, each affecting dairy cattle in distinct ways and requiring specific control measures. Mastitis, an infection of the mammary gland, reduces milk yield and quality, and is managed through improved hygiene practices, regular milking equipment maintenance, and targeted antibiotic treatments. Lameness, which impairs mobility and grazing, is controlled by maintaining proper hoof care, providing comfortable housing, and addressing any underlying

nutritional deficiencies. Infertility disorders, affecting The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201



reproductive performance and milk output, are managed through regular veterinary check-ups, hormonal treatments, and optimizing herd management practices. Bovine viral diarrhoea (BVD) is controlled by vaccination, biosecurity measures, and culling of persistently infected animals. *Coxiella burnetii*, the cause of Q fever, is managed through vaccination and stringent hygiene practices to prevent transmission. Bovine tuberculosis (TB) and brucellosis, both serious infectious diseases, are controlled by regular testing, quarantine of infected animals, and vaccination where applicable. Johne's disease, which leads to reduced milk production due to chronic intestinal infection, is managed through maintaining good hygiene, implementing a stringent herd management plan, and culling affected animals to reduce the spread.

Soil: Poland spans an area of 312 600 square kilometres (31 million hectares), with 60% of this land dedicated to farming (18.4 million hectares) and 29% covered by woodlands. The soil cover in Poland has been shaped by a humid climate with precipitation exceeding evaporation, leading to a leaching water regime in its zonal soils. The predominant soil types include clay-illuvial soils (Luvisols or Retisols) formed from glacial tills or silt and loess deposits, which make up about 50% of the soil area. Podzolic soils (Podzols), derived from sandy materials, constitute about 12% of the soil types. Brown soils (Cambisols), primarily found on southern Poland's slopes, and rusty soils (Brunic Arenosols) prevalent in the lowlands, cover about 14% of the country. In the Masuria region, Eutric Cambisols and Luvisols are the dominant soil types, with some presence of Histosols. Polish soils are generally acidic and low in essential plant nutrients, with 50% to 65% of arable land being infertile and acidic. Soil acidity is linked to low levels of available magnesium and potassium, which are critical limiting factors for soil productivity. Major threats to soil quality include erosion, desertification, weathering, sterilization, and acidification. The extensive use of mineral fertilizers has led to nitrogen (N) and phosphorus (P) leaching, contributing to eutrophication and posing a risk to ecosystem sustainability.



Pastureland: Additionally, out of the 14.5 million hectares utilized in agriculture, 22.4% (approximately 3.25 million hectares) is dedicated to permanent grasslands and meadows.

3.8.2 IPCC projections on climate change indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:

3.8.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

The mean temperature of Poland increased by 2.1°C between 1951-1960 and 2011-2020. Over the past two decades, the country's average temperature increase (0.0586°C per year) has exceeded the global average (0.0313°C per year). In 2022, Poland's observed annual average mean surface air temperature was 9.53°C, representing a 3% increase from the previous year (2021: 9.21°C). By 2030, the projected average surface air temperature is 9.87°C in an optimistic scenario and could rise to 10.80°C in a worst-case scenario. Projections for the year 2050 indicate that the annual mean surface air temperature will range between 9.06°C and 12.38°C across different scenarios.



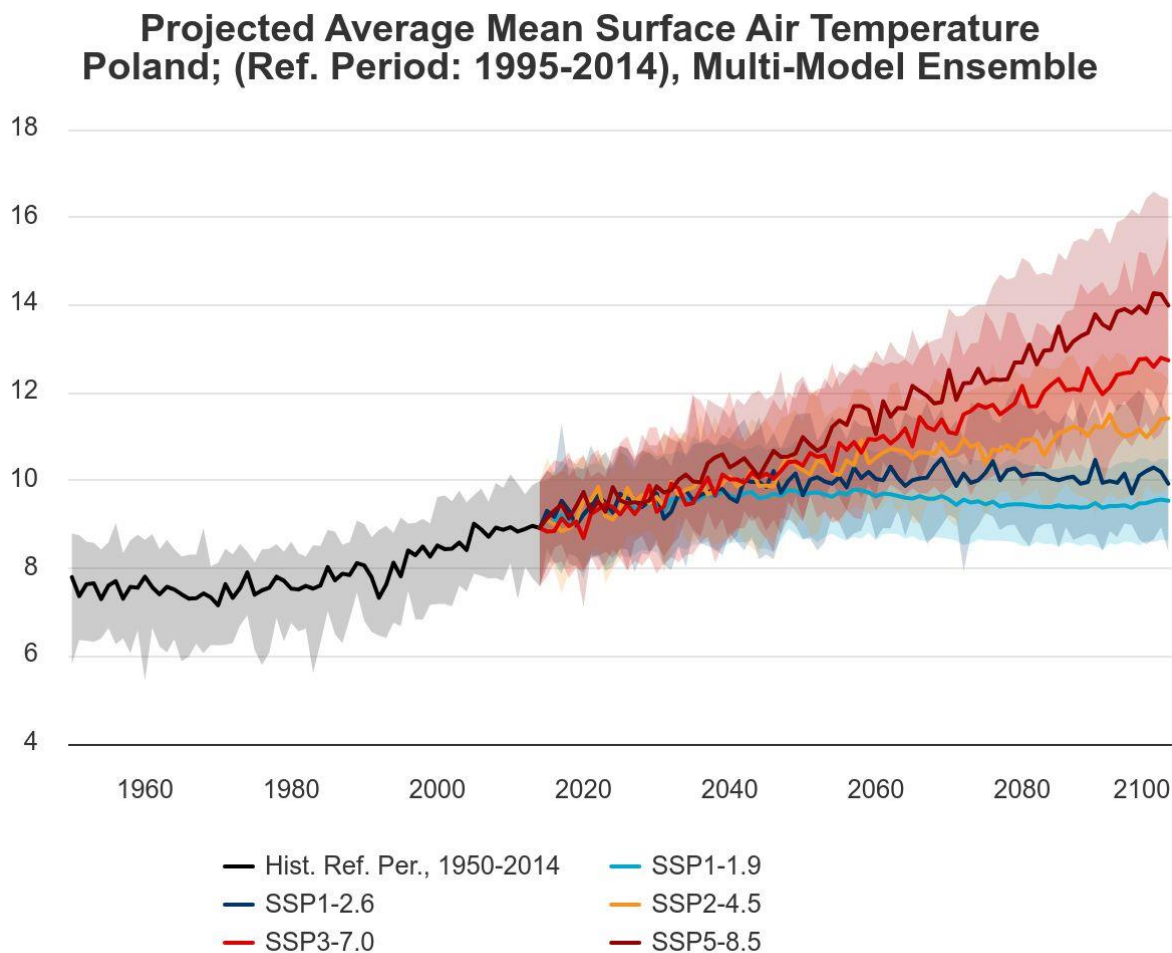


Figure 3-26: Projected average mean surface air temperature for Poland

3.8.2.2 Precipitation pattern

The annual precipitation in Poland is approximately 600-800 millimetres on average, with regional variations across the country. The eastern and southern regions tend to receive less rainfall than the western and northern areas. IPCC's assessments show a general trend towards increased precipitation variability, with more intense rainfall events likely to occur. This could lead to an elevated risk of flooding in certain regions, particularly in urban areas with inadequate drainage systems. Conversely, there may also be prolonged dry spells, posing challenges for agriculture and water resource management. Adapting to these projected changes will be of paramount importance for Poland, necessitating effective flood mitigation measures, sustainable land use practices, and resilient infrastructure to enable the country to cope with the impacts

of changing precipitation patterns.



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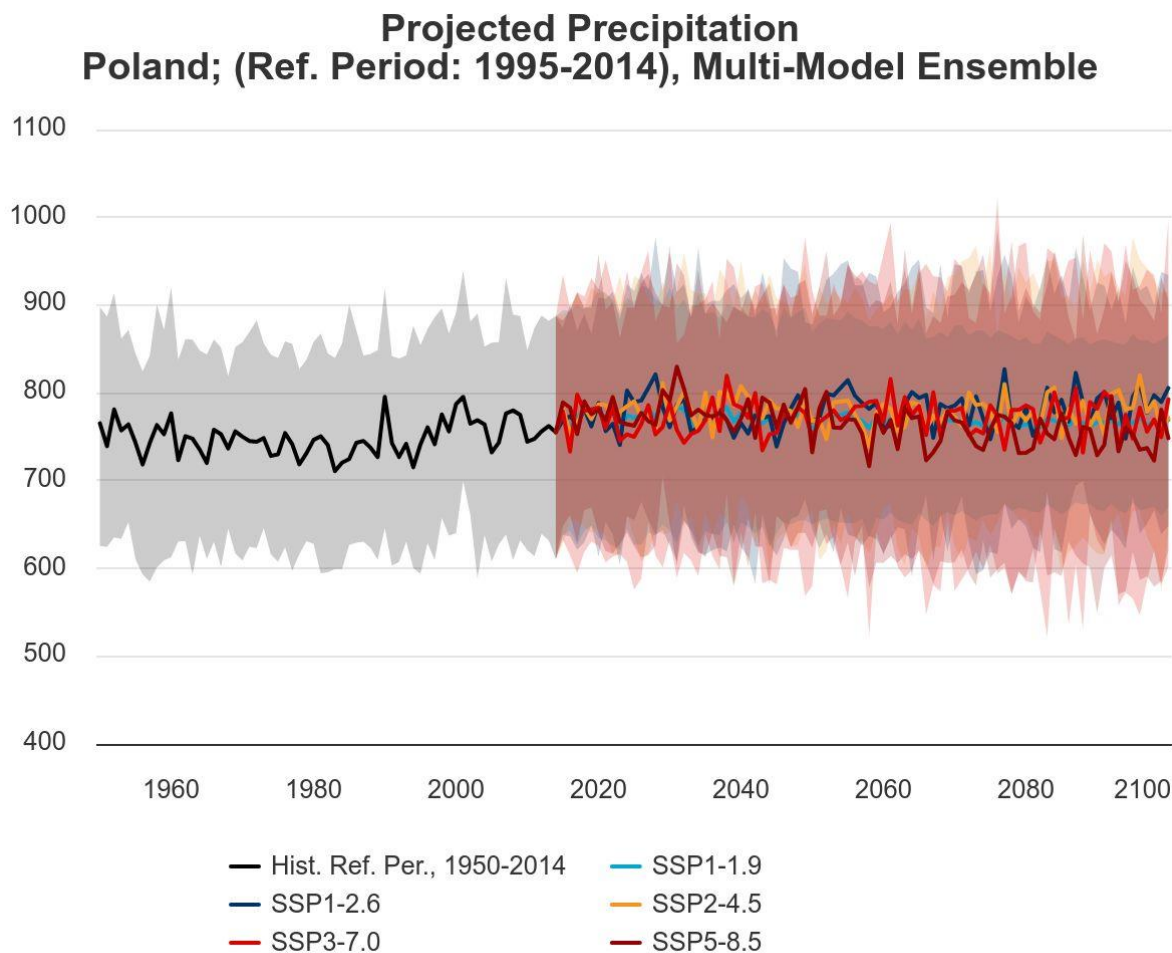


Figure 3-27: Projected precipitation patterns in Poland

3.8.2.3 Sea level rise

The IPCC projects that Poland will experience significant sea-level rise due to climate change, with an expected increase of about 0.1 to 0.2 metres by 2030 and 0.2 to 0.4 metres by 2050 under moderate emission scenarios (RCP4.5) and up to 0.3 to 0.5 metres under high emission scenarios (RCP8.5). This rise will increase the risk of coastal flooding, particularly in low-lying areas along the Baltic coast. To address these challenges, Poland must strengthen coastal defences, implement effective flood management strategies, improve urban planning and increase public awareness and preparedness for potential flood events.



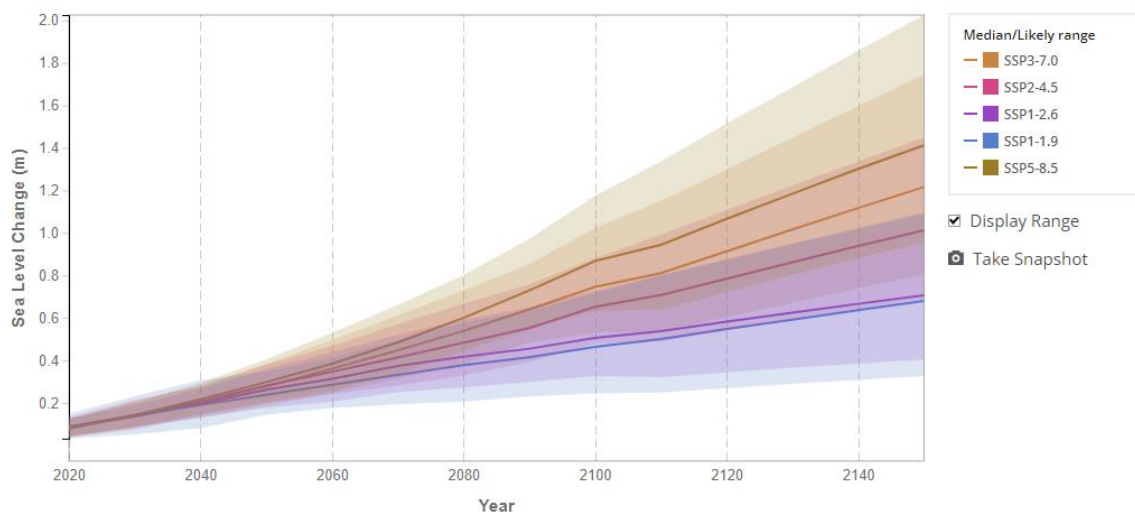


Figure 3-28: Projected sea level changes in Poland

3.8.2.4 Extreme weather events

In 2030, Poland is expected to experience a significant escalation in the frequency and severity of extreme weather events. Heatwaves are predicted to become more frequent and intense, with temperature anomalies increasing by about 1.0-1.5°C compared to historical averages. This increased heatwave intensity poses significant challenges for agriculture, public health, infrastructure and many other sectors. At the same time, the frequency of drought events may increase by up to 10%, correlating with a projected 5-10% decrease in precipitation during the summer months. Such changes raise concerns about water availability and agricultural productivity, with expected impacts on crop yields and soil moisture. In addition, heavy precipitation events, known precursors of flooding, are expected to increase by about 5-10%, accompanied by an upward trend in flood-related damages. By 2050, these climate trends are expected to worsen, with heat waves increasing in severity and duration, leading to a projected 1.5-2.5°C increase in temperature anomalies. Droughts are projected to become more frequent and severe, with drought events expected to increase by up to 20%. In comparison, heavy precipitation events are expected to increase by 10-20%, leading to an increased risk of flooding and potential damage to infrastructure and urban areas. These statistical projections underline the urgency of robust adaptation strategies and climate-resilient planning to mitigate the impacts of climate change in Poland.

3.8.2.5 *Ecosystem and biodiversity impacts*

Climate change is having a significant impact on ecosystems and biodiversity in Poland. Projections indicate a temperature increase of 1.5 to 2.5°C by 2050, leading to a shift in vegetation zones and habitat loss, disrupting species distribution. In addition, heavy precipitation events are predicted to increase by 10-20%, increasing the risk of flooding and affecting freshwater ecosystems. These changes threaten Poland's diverse biodiversity, with over 40% of species already experiencing negative impacts. Urbanisation is exacerbating these problems around Warsaw, as more impervious surfaces create heat islands and further habitat loss. The Vistula River, vital to the city's ecosystem, faces increased flood risks, affecting biodiversity and human settlements.

3.8.2.6 *Socioeconomic impacts*

Food security: Climate change threatens Poland's agricultural productivity, with crop yields projected to decline. By 2050, maize yields could fall by up to 18%, affecting food availability and prices.

Energy transition: The transition to low-carbon energy sources to mitigate climate change requires significant investment in renewable energy infrastructure but also offers opportunities for job creation and economic growth.

Infrastructure damage: Extreme weather events such as floods and storms pose risks to infrastructure, with annual damage costs estimated at between 0.2% and 0.6% of GDP by 2050.

3.8.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Poland and their specific focus on different products.



Table 3.24: Drivers of products for the Poland

Products- Poland					
	Milk	Fodder maize	Barly	Red clover	Sunflower
Drivers	1. Productivity 2. Heat stress 3. Water consumption 4. Conventional agriculture	1. Productivity 2. Drought 3. Microbial community 4. Cover crops 5. Conventional agriculture	1. Productivity 2. Drought 3. Microbial community 4. Cover crops 5. Conventional agriculture	1. Productivity 2. Drought 3. Microbial community 4. Conventional agriculture	1. Productivity 2. Drought 3. Microbial community 4. Cover crops 5. Conventional agriculture

3.8.4 Living lab scenarios

EcoReadyMasuria

The EcoReadyMasuria living lab is an open innovation initiative implemented under the umbrella of Eco-Ready project, to promote climate change adaptation solutions (agro-ecological practices and technologies) in Masuria, Poland. The region is rich in biodiversity, with deep-rooted agricultural traditions.

Products	Barley	Maize	Red Clover	Sunflower	Milk
Scenarios					
1. Status quo for 2030 - 2050	X	X	X	X	X
2. The Parched Masuria	X	X	X	X	X
3. The Broken Breadbasket	X	X	X	X	X
4. Regenerative solution for regional paradise	X	X	X	X	X
5. Masuria Mosaic: A Community Agrotourism Initiative	X		X		X

Scenario 1: Status quo for 2030-2050

Poland has experienced a dramatic increase in average surface temperature, with the trend projected to continue into the future. This is the main driver with occasional extreme drought, which results in heat stress and lack of water. Steady loss of soil microbial diversity is having impacts on food productivity creating a knock-on effect on food security. Soil erosion is a major challenge, because of the hilly topology in Masuria, heavy rainfall events, farming practices, and deforestation. Farm labour shortages are common, which impact the scale of productivity. Future the grain market has been influenced by price shocks, particularly with recent Ukraine imports.



Barley production

2030 Barley thrives in temperate climates and prefers cooler temperatures during the grain filling stage. The region also receives a decent amount of rainfall throughout the growing season, which is beneficial for barley growth. Spring barley, the dominant variety in the region, matures faster than winter barley and is less prone to winterkill. Barley for beer brewing is also cultivated in the region. Weed management is crucial for barley cultivation, as is pest management, particularly for disease like powdery mildew or rust.

2050 More frequent heatwaves and hotter summers can stress barley plants, leading to reduced yields and lower grain quality. Increased droughts will hinder barley growth and heavy rainfalls during harvest periods will damage grains. With changes in climate, new diseases pose a continued threat. Global grain price fluctuations will impact the local Masurian farms.

Maize production

- **2030:** Maize has not been a widely cultivated crop in Masuria, unlike other parts of Poland, but is increasing in cultivation. This region has a sub-optimal average summer temperature and short growing period for maximum yield of sunflower. Extreme weather events like prolonged droughts or heat waves could affect yields. Maize in Masuria is susceptible to several fungal disease (e.g., Northern Corn Leaf Blight, Fusarium, Smut) due to its relative cool and wet weather conditions.
- **2050:** Climate change will lead to more frequent and intense weather events like droughts, heatwaves, or heavy rainfall. These extremes will stress maize plants, reduce yields, and potentially increase susceptibility to diseases and pests. Overreliance on pesticides to manage existing diseases and pests will lead to the development of resistant populations. This can complicate pest and disease management and potentially increase production costs, as well as impact local biodiversity. Long-term cultivation as a monoculture, will lead to depletion in the soil, reduction in soil biodiversity, as well as erosion of topsoil, unless sustainable practices are deployed.



Red clover production

- **2030:** Red clover, a leguminous crop, is grown for forage, seed, or green manure in Masuria, Poland. It is not commonly consumed by humans, but rather by grazing livestock. Although, it is somewhat drought tolerant, the common seeded periods of early spring and fall will be shifted to avoid the higher temperature due to climate change. It has nitrogen-fixing capabilities through its symbiotic relationship with Rhizobium bacteria, so nitrogen fertilization may not be needed, although other nutrients like phosphorus and potassium are added in the form of mineral fertilizer, which will impact the cost of production.
- **2050:** As climate changes impact Polish agriculture, red clover will face increasing threats: 1) milder winters due to climate change can disrupt its dormancy, making red clover more susceptible to winterkill and reducing its overall resilience, 2) soil erosion will reduce the top soil to which this crop can thrive, 3) pests like clover weevils, stem borers, or nematodes could become more prevalent due to warmer temperatures, 4) overuse of antibiotics in livestock production can lead to antibiotic-resistant bacteria, which can complicate the treatment of red clover diseases that rely on antibiotics, and 5) with reduced yields of clover, its lower integration into crop rotations can decrease soil fertility. Other nitrogen-fixing legumes may be considered as a better alternative to red clover in the future.

Sunflower production

- **2030:** Sunflowers are not a widely cultivated crop in Masuria but are increasing in cultivation, as global demand for these products continue to increase. This region has a sub-optimal average summer temperature and short growing period for maximum yield of sunflower. Extreme weather events like prolonged droughts or heat waves could affect yields. New or more aggressive pests and diseases could emerge, Competition from other sunflower producers (e.g., Ukraine, Russia) can cause shifts in the commodity markets.
- **2050:** With the increase temperature and longer frost-free growing period sunflower may become a more productive crop in the future. However, sudden



weather shocks such as shorter frost-free periods due to climate change could further squeeze the window for sunflower maturity. Continued unsustainable agricultural practices like excessive tillage or overuse of fertilizers will lead to long-term soil degradation, impacting sunflower yields and overall crop health. The monoculture farming practices currently deployed, where sunflowers are grown repeatedly on the same land, will further deplete soil nutrients, increase pest and disease pressure, and reduce long-term productivity. Changes in global fats and oils markets or consumer preferences could affect the demand for sunflower products impacting Polish exports.

Milk production

- **2030** Milk production is typically small-scale and on family-owned farms. Herd sizes ranging from a few cows to several dozen, with traditional approaches to cow farming prevailing. Cows are pasture grazing during the warmer months, and hay and silage for the winter months. Competition from larger farms, labour shortage, and fluctuations in milk prices are some of the challenges.
- **2050** Economic factors will continue to be important drivers in milk production for the region, threatening the traditional farming approach. Climate-derived challenges include - reduced forage availability due to frequent droughts, heat stress of the animals, and an increased disease burden in livestock. Future water scarcity and manure management are among the environmental challenges emerging, and social factors such as labour shortages and rural depopulation cannot be ignored.

Scenario 2: The parched Masuria

An unprecedented heatwave grips Masuria in late June. Temperatures soar above 35°C (95°F) for several consecutive weeks. This scorching heat, far exceeding the region's average summer temperatures, disrupts the delicate balance of Masuria's agricultural ecosystem.



Shock: Heat waves are more frequent and last longer than before.

High temperatures lead to drought and water scarcity. Heat stress will impact all crops profiled in this Living Labs, as well as milk production. Evaporation rates surge due to the high temperatures, significantly increasing the water needs of crops. Soil moisture reserves rapidly deplete, putting additional stress on plants. Dairy cows experience heat stress, leading to decreased milk production and potential health problems.

Water deficiency:

The heatwave coincides with below-average rainfall, further exacerbating the water scarcity. Streams and rivers dwindle, and water tables fall, making well water extraction unreliable. Masurian farms often rely on limited irrigation systems. With increased water demand and potential restrictions due to low water levels, these systems become inadequate.

Long-term consequences:

The combined stress of heat and drought leads to significant yield reductions across various crops. Potato tubers shrink, rye harvests diminish, and pastures struggle to sustain livestock. Heat stress affects the quality of fruits and vegetables, impacting their marketability and potentially reducing farm income. Dry soil conditions accelerate wind erosion, potentially leading to a loss of valuable topsoil and reduced soil fertility. Heat and drought stress plants, making them more susceptible to pest and disease outbreaks.

Cascading effects:

Reduced crop yields and lower quality produce translate to financial losses for Masurian farmers. Milk production decline further impacts dairy farms. The regional shortage of agricultural products can lead to inflated food prices, affecting consumers across Masuria. Economic hardship caused by the agricultural shock led to social unrest, particularly among farming communities.

Scenario 3: The broken breadbasket

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Masuria's agricultural sector faces increasing pressure to boost production and compete in the global market. Young people are out-migrating to urban centre for employment. Driven by profits on the part of large corporations and pressures on local small-farm owner, land is sold for the development of large-scale agriculture holdings.

Shock: Large-scale farming and non-sustainable land-use threaten to destroy the natural habitats of Masuria.

Farming and land-use for immediate productivity threaten to destroy natural habitats. To increase the arable area, farm holding destroys natural habitats such as barks, swamps, and groves. Additionally, they are reluctant to let land lie fallow because it is economically disadvantageous and it rejuvenates the weed seed bank in the fields, which would necessitate even more intensive herbicide use in subsequent seasons.

Habitat loss and its consequences:

- Large expanses of diverse Masurian meadows are bulldozed and ploughed under to make way for vast monoculture maize fields. Meadow ecosystems are vital habitats for a variety of flora and fauna. Ground-nesting birds like lapwings and skylarks lose their breeding grounds. Small mammals like voles and field mice, the food source for many predators, disappear. Pollinator populations, crucial for the region's wildflowers and fruit production, plummet due to lack of food sources and habitat fragmentation. Increased fertilizer and pesticide use associated with intensive cultivation contaminate nearby streams and lakes. This disrupts aquatic ecosystems and harms fish populations. Monoculture cultivation depletes soil nutrients. With reduced organic matter due to the removal of hay production and minimal crop rotation, soil erosion by wind and water increases. Dust storms become more frequent, impacting air quality and reducing visibility.

Social and economic impacts:

- Local farmers who practiced sustainable hay production are forced out of business or become employees of the large farm holding, losing their traditional way of life and connection to the land. With fewer opportunities in traditional agriculture,



young people leave rural areas for cities, further straining the social fabric of Masurian communities. The focus on short-term profits leads to unsustainable agricultural practices that could harm long-term productivity. Soil degradation and declining biodiversity threaten future harvests.

Potential future:

- If left unchecked, this shock scenario could lead to a desolate landscape with vast fields devoid of wildlife. The environmental damage could impact tourism, a vital sector for Masuria's economy. This scenario highlights the importance of sustainable agricultural practices and responsible land use to protect biodiversity and ensure the long-term viability of Masuria's agricultural sector.

Scenario 4: Regenerative solution for regional paradise

This scenario envisions a collaborative effort in Masuria, Poland, to build resilience against heat stress in developing a series of regenerative agriculture practices.

The core principles place emphasis on soil health, biodiversity, and water conservation to create a more robust agricultural ecosystem. Implementation of strategies to minimize the impact of high temperatures on crops and livestock. Farmers, scientists, and local authorities work together to share knowledge and resources. Utilization of weather forecasting, soil moisture monitoring, and crop performance data to guide actions.

Soil biodiversity:

- Loss of microbial diversity results in lower productivity of crops.
- Practices to mitigate: Cover crops increase microbial diversity. Biostimulators and practices that affect microbial diversity are encouraged.
- Impact on in-field plant biodiversity: Poor soil structure resulting from low microbial diversity can create conditions that favour certain weed species over others, potentially leading to an increase in problematic weeds. A less diverse microbial community may alter the persistence of herbicides.
- Practices to mitigate: conservation tillage, organic amendments, cover crops, Integrated Weed Management, crop rotation, enhancing beneficial microbes,



reducing chemical inputs, regular soil testing for microbial diversity and health indicators to facilitate management decisions.

Weeds:

- Impact on in-field plant biodiversity: *Some* weed species may expand their ranges poleward, moving into regions previously too cold for their survival. This can potentially lead to higher increase of weed diversity in higher latitudes, but also allowing new invasive weeds to establish and spread. Some weeds may become more problematic, requiring changes in herbicide use and other control measures.
- Practices to mitigate: Integrated Weed Management (mix of mechanical, chemical, biological, and cultural weed control methods, crop rotation, cover crops), regular monitoring of weed species.

Biological predators:

- Habitat enhancement to encourage biological predator presence. Plant diverse, native flowering plants around fields and along property lines. These create corridors for beneficial insects, provide shelter, and offer a source of pollen and nectar, attracting predators like ladybugs, lacewings, and parasitic wasps. Plant small strips of wildflowers within fields. These provide a continuous food source for predators throughout the growing season. Create raised earthen mounds covered in vegetation, providing overwintering habitat for ground beetles, which prey on various pest insects.

Soil health enhancement:

- Cover cropping used to retain moisture, suppress weeds, and improve soil structure. Composting and biochar application to increase organic matter and water holding capacity. Reduced tillage practices to minimize soil disturbance and erosion.

Heat-tolerant crop selection:

- Introduction of drought-resistant crop varieties like legumes, millets, and certain heirloom grains. Experimentation with intercropping techniques to create shade and improve microclimates. Planting dates adjusted based on weather forecasts to optimize growing seasons.



Water management strategies:

- Improved irrigation systems with drip technology for targeted water delivery. Rainwater harvesting through ponds and cisterns to capture and store precipitation. Mulching with organic materials to reduce evaporation and conserve soil moisture.

Monitoring of invasive species:

- Monitor the spread of invasive species, not only in the area of the living lab, but also in neighbouring areas and countries. As climate change progresses, these dynamics will trigger changes in natural conditions which will be reflected in changes in the species composition of the fauna, including pests.

Supporting livestock:

- Providing shade structures and access to cool water for animals. Adjusting feeding times to avoid peak heat hours. Exploring heat-tolerant breeds or introducing crossbreeds with improved heat resistance.

Knowledge sharing and capacity building:

- Workshops and demonstrations on regenerative practices and heat stress mitigation. Establishment of a farmer-to-farmer network for experience exchange and peer support. Collaboration with agricultural research institutions to develop and adapt best practices.

Scenario 5: Masuria Mosaic: Smart agro-community

This scenario envisions the integration of modern services, technology, local markets, and policy frameworks designed to support agriculture and community well-being in Masuria, Poland. Its aim is to address challenges like climate change, promote sustainable agricultural practices, and importantly promote local livelihoods.

The core principles of this initiative are that there will be collaboration between local farms, villages and specialised service providers to work together to create economic opportunities for local stakeholders, through both agricultural and non-agricultural activities in rural areas. Practices focus on organisation of local markets as well as precision and organic farming techniques. Tourists interact directly with farmers, learn



traditional crafts, and experience both traditional and modern Masurian life. Profits are shared fairly among stakeholders, supporting local livelihoods and rural development.

The Masurian Smart Agro-Community is composed of farmer-friendly stakeholders working closely together with local farmers:

Specialized service providers:

- Farm services providers, who offer specialized services such as equipment rental, soil analysis, crop consulting, and organic farming support to enhance farm productivity and sustainability.
- Agrotourism providers, who develop and promote farm-based tourism activities, offering unique rural experiences that attract visitors and generate additional income for farmers.

Local agricultural advisors and distributors of precision farming solutions:

- Technology distributors as a link connecting farmers' thoughts and needs with solutions developed by agricultural technology innovators
- Training centres and agricultural advisors educate farmers on the latest precision agricultural techniques and technologies, ensuring widespread adoption and effective usage.
- Strengthening the role of agricultural advisors or a new form of advisor (local agricultural manager) to manage the service needs of local farmers and buyers of agricultural products, strengthening the policy of short supply chains.

Local developers and providers of precision agriculture solutions:

- Technology innovators: Local businesses and startups focused on developing precision agriculture tools and solutions, such as automated cow milking robots, drones for crop monitoring, automated irrigation systems, and data analytics platforms.
- Training centres educate farmers on the latest precision agriculture techniques and technologies, ensuring widespread adoption and effective usage.



Local purchasers and short supply chains:

- Local markets and shops, which create markets and retail outlets dedicated to selling locally produced goods, ensuring farmers have direct access to consumers and fair pricing.
- Crop harvest collection centres, which facilitate the aggregation, processing, and distribution of farm produce, minimizing the need for intermediaries and reducing costs.

Sustainable agricultural preservation policy makers:

- Lobby policy-makers to encourage organic farming, as well as investment in precision agriculture technologies, offering subsidies, grants, and low-interest loans to farmers adopting these innovations to ensure operational costs of farms are driven down despite the outflow of labour force from rural areas. Policies need to encourage establishment of local crop harvest collection centres, which contribute to shortening the farm-to-fork distances.
- Establish regulations to prevent the overuse of dominant positions by large buyers and agricultural holdings, protecting small-scale farmers. Regulations require supermarkets to have sections exclusively for local farmers sold at prices agreed without intermediaries, promoting local produce and reducing transportation costs.
- Restrictions on the creation of excessively large farms and the leasing of very large land areas, ensuring land remains available for small and medium-sized farms.
- Incentives and support programs for young people to enter farming, such as education grants, start-up funding, and mentorship programs.

Benefits:

The Masurian Smart Agro-Community envisions a future where small-scale farming is not only viable but also competitive and attractive. By integrating specialized services, new technologies, local markets, and supportive policies, this community aims to create a vibrant and sustainable agricultural landscape that provides economic opportunities, preserves the environment, and enhances the quality of life for all its residents. This collaborative ecosystem ensures that farming remains a respected and rewarding profession, inviting new generations to build their futures in Masuria.

Traditional crafts, food specialties, and local stories are
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shared with visitors. Collaboration fosters a sense of pride and responsibility for the region's future.

Challenges:

Funding may be needed for infrastructure improvement, marketing, and educational programmes. Fostering trust and cooperation among diverse stakeholders can take time. Ensuring effective implementation and enforcement of policies that support small-scale farmers and prevent market abuses by large entities. Balancing land use restrictions with the need for economic growth and development, ensuring that policies do not inadvertently hinder agricultural productivity. Designing fair and efficient subsidy programs that target the farmers who need them most without creating dependency or market distortions. Ensuring that precision agriculture and other technological solutions are implemented in an environmentally sustainable manner and not discourages tourism.

Success factors:

- Strong community leadership
- Collaboration with local NGOs and tourism agencies
- Investment in training and skill development for farmers and tourism operators
- Effective marketing campaigns promoting Masuria Mosaic's unique offerings
- Supportive policies that protect the interests of small-scale farmers, prevent market abuses, and encourage investment in sustainable agriculture.
- Efficient local markets and crop collection centres that prioritize local produce, ensuring farmers have direct access to consumers and fair pricing

Overall, the Masuria Mosaic scenario strives for a future where traditional agricultural practices blend with modern agriculture and sustainable tourism, creating a vibrant, economically viable region that celebrates its cultural heritage and natural beauty.

Sustainable preservation policy and subsidies incentives would help to encourage this scenario, ranging from investment in precision agriculture designed and developed locally, as well as habitat and biodiversity preservation to support for traditional live ways through government funding schemes.



3.9 Spain

3.9.1 Dossier of Living Lab- country profile

Country - Spain

Region in EU - Mediterranean and Southwest Europe

Name of living lab - Living lab for enhancing the resilience of agriculture in Catalonia (CONCAT LL)

Partners - Institute of Agrifood Research and Technology, Naked Innovations S.L, Federació de Cooperatives Agràries de Catalunya

Products - Poultry, Apples, Wheat, Flathead grey mullet, Olive trees for either olive oil or table olive production.



Figure 3-29: Map of Spain with products



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The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201

Partner background information

Economics: In Catalonia, Spain, livestock production, particularly poultry and pigs, dominates the agricultural sector, contributing over 65% to the region's total agrarian output. Besides livestock, Catalonia is renowned for its diverse agricultural products. The region is a significant producer of various fruits, including apples, pears, peaches, and citrus fruits like oranges and lemons. It also grows a wide array of vegetables such as tomatoes, peppers, onions, and lettuce. Rice cultivation is prominent in certain areas, especially within the Ebro Delta region. Olive oil production is expanding, with the industry primarily concentrated in southern Catalonia. The flathead grey mullet (*Mugil cephalus*) does not play a significant role in Catalonia's agricultural or aquaculture sectors. This species inhabits coastal waters and estuaries of the Mediterranean Sea but is not a major target for commercial fishing in Catalonia. The region's aquaculture industry is more focused on freshwater species like trout, carp, and eels, which align better with the region's inland resources and infrastructure. Additionally, the flathead grey mullet is less popular in Spain's market compared to other fish species such as cod, hake, and tuna, which further diminishes the incentive for its large-scale commercial exploitation.

Policies: The *Eco-schemes* include initiatives for extensive pastures and policies aimed at establishing biodiversity patches and sustainable cultivation. These measures are designed to enhance the environmental sustainability of farming practices. The *agri-environment-climate* strategies focus on integrated production systems and sustainable cultivation methods. They support sustainable pastures and encourage apiculture practices to boost biodiversity.

Farming practices: In Catalonia, farming practices are diverse, incorporating conventional, organic, low input, regenerative, and no-till farming systems. Organic farming now covers 10.95% of the total agricultural area and has rapidly expanded over the past decade, although it largely remains industrial in nature. Livestock production dominates the region's agrarian output, representing more than 65% of total production, with some areas exceeding 80%, reflecting a strong focus on livestock in Catalonia's



agriculture. Crop rotation in the region involves a variety of crops including cereals, legumes, and vegetables, which are used for grain, silage, and biomass, with many crops being internally utilized for local consumption and animal feed. To enhance soil health and prevent erosion, cover crops like legumes and grasses are frequently employed between main crop cycles.

Potential drivers

Biodiversity: In Catalonia, biodiversity efforts in agriculture are driven by a range of practices and goals. New breeding objectives focus on enhancing genetic diversity and resilience within livestock breeds, while land use changes for breeding aim to adapt agricultural practices to better support biodiversity. Seasonal grazing is employed to maintain diverse and healthy ecosystems in pastures, promoting the regeneration of native plant species and supporting various wildlife. Measures of genetic diversity, including monitoring inbreeding and effective population size, are crucial for maintaining robust and adaptable livestock populations. Additionally, predator abundance is managed to ensure ecological balance, which supports the overall health of the agricultural environment and its biodiversity.

Climate: Located at an elevation of just 6 meters above sea level, Barcelona experiences a Warm Mediterranean climate characterized by mild, wet winters and hot, dry summers. The annual mean temperature is 16 °C, with December being the coldest month at a daily mean of 9.7 °C and July the warmest at 24 °C. Precipitation averages 650 millimetres annually, peaking in October with 99 mm, while July is the driest month with just 22 mm. Climate risks include droughts during the sowing and flowering periods, which can significantly impact grain filling. Additionally, heat stress during the growing season is particularly severe during flowering, posing risks to crop productivity. Fire events also represent a potential threat. Although climate factors like temperature are less impactful on chicken production due to indoor breeding practices, they affect feed quality and methane emissions from manure management, and increased air conditioning costs are a concern.

Food security: Spain has a diverse and extensive agricultural sector, benefiting from a variety of climates and landscapes across the country. The agricultural production in



Spain includes a wide range of crops such as fruits, vegetables, olives, grains, and wine grapes. Livestock farming, particularly pork and poultry production, is also significant. Spain's agricultural sector is known for its modern techniques and innovative practices, contributing to high productivity levels. While Spain produces a significant portion of its food domestically, it also relies on imports for certain commodities, such as grains, vegetable oils, and tropical fruits. The Spanish government supports domestic agriculture through subsidies, incentives, and investments in research and development. Efforts are made to maintain a level of self-sufficiency in key agricultural products to enhance food security and reduce dependence on imports. Spain upholds strict quality and safety standards in food production, processing, and distribution. Regulatory agencies, such as the Spanish Agency for Food Safety and Nutrition (AESAN) and the Ministry of Agriculture, Fisheries, and Food (MAPA), monitor and enforce food safety regulations to ensure that food products meet high standards of hygiene, quality, and safety. Regular inspections and testing help maintain consumer confidence in the safety of the food supply. The government promotes sustainable agricultural practices, including organic farming, agroecology, and water management strategies, to protect natural resources, conserve biodiversity, and mitigate the impacts of climate change on food production. Initiatives such as the Common Agricultural Policy (CAP) support environmentally friendly farming practices and encourage the use of renewable energy sources in agriculture. Vaccination and therapeutic treatments are crucial for maintaining livestock health, which directly impacts food security by reducing disease outbreaks and improving productivity. Enhanced monitoring and recording systems, supported by AI methods, enable better management and early detection of issues, thereby safeguarding food supplies and promoting sustainable practices. New breeding techniques and targeted breeding goal traits contribute to the development of more resilient and productive animal breeds, which can adapt to changing environmental conditions and contribute to biodiversity. The price of animal feed affects both the cost of production and the economic viability of farming, influencing food security. Water availability is another critical factor, as it affects crop and livestock production. Lastly, changes in consumer diets can shift agricultural priorities and practices, impacting both



the demand for various products and the focus on biodiversity conservation within farming systems.

Farming conditions

Water: The area equipped for irrigation saw a significant increase from 2 540 310 ha in 1990 to 3 828 110 ha in 2003. This upward trend was mirrored in the area irrigated, which grew from 2 433 700 hectares in 1990 to 3 437 370 ha in 2003. However, the combined total area equipped for irrigation, as reported for individual municipalities, was 3 575 488 ha, suggesting a slight discrepancy compared to the global irrigation map figures. The data illustrates an overall expansion in irrigation infrastructure and usage over the period, reflecting increased efforts to enhance agricultural productivity through improved water management. The irrigated areas by region are shown in the Table below.

Table 3.25: The irrigated areas in Spain by region

Comunidades Autonomas	Area equipped for irrigation (ha)		
	Total	with groundwater	with surface water
Andalucía	861 065	336 171	524 894
Aragón	406 326	17 858	388 468
Asturias	8 417	1 256	7 161
Cantabria	1 983	67	1 916
Castilla-La Mancha	518 580	407 450	111 130
Castilla y León	492 207	181 533	310 674
Cataluña	248 321	58 559	189 762
Ceuta	0	0	0
Comunidad Valencia	304 998	114 034	190 964
Extremadura	246 010	32 987	213 023
Galicia	77 522	36 229	41 293
Islas Baleares	21 716	20 857	859
Islas Canarias	30 373	21 641	8 732
La Rioja	45 338	6 510	38 828
Madrid	27 892	3 385	24 507
Melilla	0	0	0
Murcia	185 811	73 695	112 116
Navarra	74 122	3 104	71 018
País Vasco	24 807	1 320	23 487
Spain total	3 575 488	1 316 656	2 258 832



The area irrigated for 60 provinces and regions was derived from the database of the Agricultural Census 1999 while the area equipped for irrigation with groundwater was computed for the 19 states by using the data from the EU farm structure survey 2003.

Diseases, pests and plant protection

In Spain, agriculture is challenged by plant diseases and pests, including significant threats to fruit and vegetable crops. Several diseases, pests and weeds are mentioned in the table below.

Table 3.26: Diseases, pests and plant protection

Crop	Harmful organism	Species names	Plant protection practices
Apples	Pest	San José Scale (<i>Comstockaspis pernicios</i> a-formerly <i>Quadraspidiotus perniciosus</i>); Rosy apple aphid, (<i>Dysaphis plantaginea</i>); green apple aphid (<i>Aphis pomi</i>); woolly apple aphid (<i>Eriosoma lanigerum</i>); European red spider mite (<i>Panonychus ulmi</i>); Mediterranean fruit fly (<i>Cerat</i> itis <i>capitata</i>); brown marmorated stink bug (<i>Halyomorpha halys</i>)	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil : Removal and disposal of not recoverable, infested plant materials; Soil disinfestation (solarisation, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Fire Blight; Crown, Collar and Root Rot of Apple (<i>Phytophthora spp.</i>); White Rot (<i>Botryosphaeria dothidea</i>); Blossom Blight (<i>Monilinia spp</i>); Alternaria Blotch dry rot(<i>Alternaria spp</i>); Wet core rot; Apple Scab; Powdery Mildew; white haze; Black Rot; Canker Diseases; Apple Ring Rot and Canker; European Brown Rot; Gray Mold Rot; Blue mould; Sooty blotch; Flyspeck.	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil : Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.
	Weed	Annual and perennial grasses and dicotyledonous.	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (plowing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
	Pest	Aphids (<i>Rhopalosiphum padi</i> , <i>Metopolophium dirhodum</i> , <i>Sitobion avena</i>); Septoria Aphids (<i>Sitobion avenae</i> e <i>Rhopalosiphum padi</i>); Stink bugs (<i>Aelia rostrata</i> e <i>Eurygaster maura</i>) ; Lema (<i>Oulema melanopus</i>); Humpbacked Zabro (<i>Zabrus tenebrioides</i>); Culm and	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil : Removal and disposal of not recoverable, infested plant materials; Soil disinfestation (solarisation, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest

Wheat, barley		ear moth (<i>Ochsenheimeria bisontella</i>); Fried fly (<i>Oscinella frit</i>); Cecidomia equestre (<i>Haplodiplosis marginata</i>).	(Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Wheat leaf rust; Black sooty mold, Wheat/Barley Bunt; Loose Smut of Wheat; Erysiphe graminis f. sp. Tritici; Barley, powdery mildew; Wheat powdery mildew; Fusarium Head Blight (scab), Crown and Root Rot; Black; Tan Spot; Stagonospora Leaf and Glume Blotch of wheat; Ergot; Root rot, leaf spot disease, seedling blight, head blight, and black point of wheat and barley; Brown/Yellow rust of wheat/barley; Barley leaf blight; Wheat Soilborne Mosaic Virus (WSMV: Furovirus, associated with <i>Polymyxa graminis</i>); Wheat Streak Mosaic Virus (WSMV: Potyvirus) Barley yellow dwarf (BYDV: Barley yellow dwarf virus: Luteovirus)	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.
	Weed	Annual and perennial grasses and dicotyledonous.	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (ploughing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
Olive trees	Pest	Olive weevil (<i>Rhodocytus cibripennis</i>); Olive tree beetle (<i>Otiorynchus cribricollis gyllenhaal</i>); Olive moth (<i>Prays oleae</i>); Olive fly, (<i>Bactrocera oleae</i>); Cochineal half a grain of pepper (<i>Saissetia oleae</i>); Olive bark beetle, (<i>Phloeotribus scarabaeoides</i>); Olive tree borer (<i>Hylesinus oleiperda</i> Fabr.).	Regular monitoring of plants; Use of pest-resistant plant varieties; Maintaining hygiene and healthy of soil : Removal and disposal of not recoverable, infested plant materials; Soil disinfection (solarisation, bio fumigation, use of steam); Good agricultural practices (e.g., Crop rotation); Use of traps; Maintaining microbial soil biodiversity ; Biological control of pest (Treatment with beneficial , antagonists, mites and insects/mites); Verification of the effectiveness of the defence strategy adopted.
	Disease	Verticillium Wilt (<i>Verticillium dahliae</i> Kleb.); 'Olive tree leprosy' (<i>Colletotrichum gloeosporioides</i> , <i>Gloeosporium olivarium</i>); Olive peacock eye leaf (<i>Venturia oleaginea</i> - the anamorph: <i>Spilocaea oleagina</i>); Cercosporiosis (<i>Mycocentrospora Cladosporioides</i>); Sooty Mould (<i>Alternaria</i> spp.; <i>Capnodium</i> spp.; <i>Cladosporium</i> spp.); Lupa Fomes spp., <i>Stereum</i> spp., <i>Poliporus</i> spp. e <i>Coriolus</i> spp.); Olive Knot (<i>Pseudomonas savastanoi</i> pv. <i>Oleae</i>)	Regular monitoring of plants, in order to get early diagnosis for rapid intervention; Good agricultural practices (e.g., Crop rotation); Use of disease-resistant plant varieties; Maintaining hygiene and healthy of soil: Removal and disposal of diseased plant materials; Maintaining microbial soil biodiversity ; Bio stimulants of soil fertility (plant growth promoting microorganisms); Biological control of diseases (antagonistic fungi, bacteria, natural bioactive compounds); Verification of the effectiveness of the defence strategy adopted.

	Weed	Annual and perennial grasses and dicotyledonous.	Prevention methods, good agronomic practices and direct control methods: crop rotations; soil working (ploughing, harrowing); burning of crop residues; high planting density; grazing; manual intervention; optimized use of herbicides.
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Grey mullet is susceptible to a variety of diseases that can significantly impact aquaculture production. Common ailments include bacterial infections caused by pathogens like *Vibrio*, *Aeromonas*, and *Pseudomonas*, often linked to poor water quality. Parasitic infections, such as those caused by protozoa, monogeneans, and copepods, can affect gills, skin, and internal organs. While less frequent, viral diseases like herpesvirus and nodavirus can also pose a threat. Additionally, fungal infections, primarily secondary to bacterial or parasitic infestations, can be caused by organisms such as *Saprolegnia* and *Achlya*. To mitigate these challenges, rigorous preventive measures are essential. Maintaining optimal water quality parameters, including temperature, pH, dissolved oxygen, ammonia, and nitrite levels, is paramount. Implementing strict biosecurity protocols, such as quarantine for new stock, disinfection of equipment, and controlled access to the farm, is crucial in preventing disease introduction. A balanced diet fortified with essential nutrients enhances fish health and resistance to disease. Stress reduction through proper handling, adequate space, and stable environmental conditions is vital. Early disease detection through regular monitoring allows for prompt intervention. Vaccination, when available, can provide additional protection. Furthermore, the use of probiotics and immunostimulants can strengthen the fish's natural defences.

Poultry are susceptible to various diseases including Marek's disease, avian influenza, *Salmonella*, coccidiosis, *E. coli*, fowl cholera, Newcastle disease, and *Campylobacter*. These diseases can cause significant losses in poultry production and pose risks to human health. Effective prevention involves strict biosecurity measures, vaccination programs, proper hygiene, nutrition, and early disease detection. By implementing these practices and consulting with a veterinarian, poultry farmers can significantly reduce the impact of diseases on their flocks.

Soil: In Catalonia the main soil types found are Alfisols, Calcisols, Luvisols, Gypsisols, Aridisols, Entisols, Inceptisols and Vertisols. Inceptisols are the most representative and dominant soil order in the Mediterranean area, where olive trees are grown, with the xerepts suborder their most typical. About soil organic matter. Spain is the EU country with the lowest average soil organic carbon content compared to other Mediterranean countries. Crops and pastures cover almost 50% of the Spanish landscape. The most important threats to soil in Catalonia include changes in land use, such as the transformation of agricultural land from dryland farming to irrigation farming, the increase of urban development, and forest fires, declining organic matter, desertification and soil salinity. Spain is the second country in the orography of the European Union, so it has large areas with slope gradients greater than 15% and thus, water erosion is the main problem for soils.

3.9.2 IPCC projections on climate change indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:

3.9.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Meteorological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.



The annual average surface air temperature in Spain was 15.30°C in 2022, up from 14.72°C in 2021. Climate models project that by 2030, the average temperature will be 14.88°C in an optimistic scenario, rising to 15.09°C in a worst-case scenario, reflecting ongoing climate change trends. By 2050, under varying emission scenarios, the temperature is expected to range between 15.11°C and 16.21°C. These projections are based on the SSPs used by the Intergovernmental Panel on Climate Change (IPCC), which account for different greenhouse gas concentration trajectories.

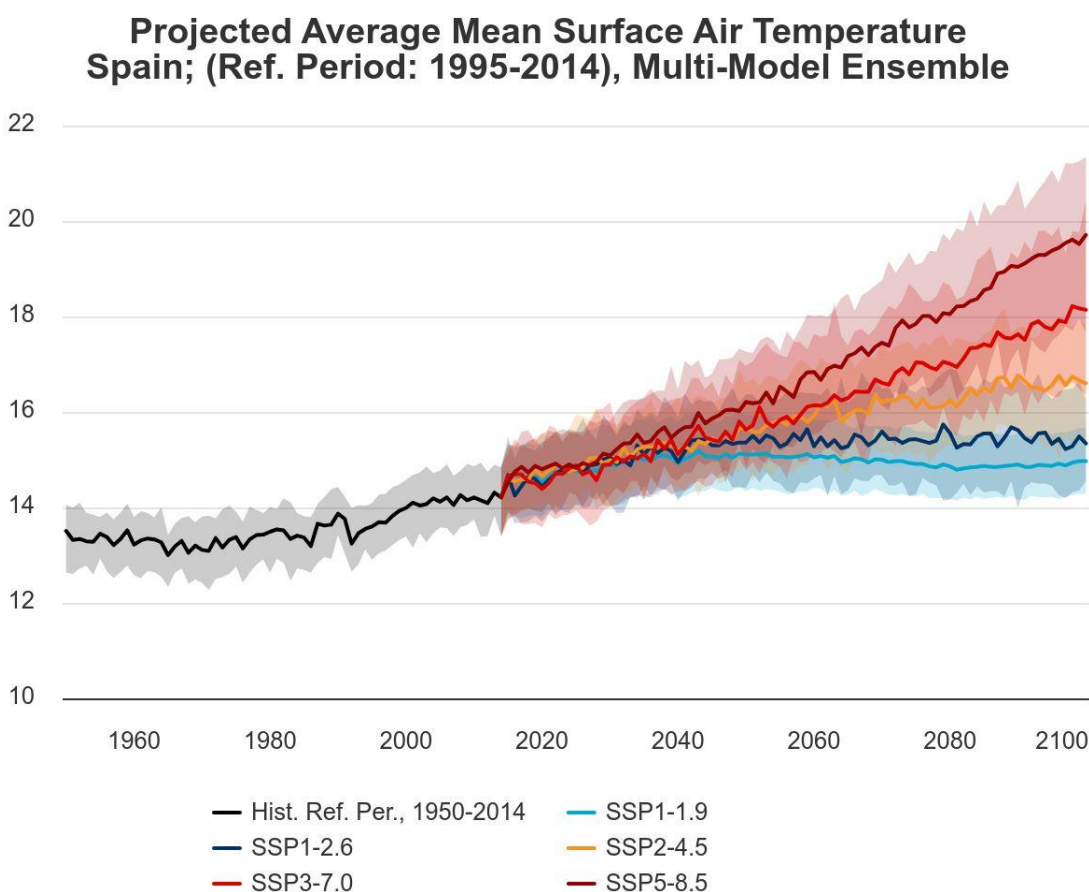


Figure 3-30: Projected average mean surface air temperature for Spain

In Catalonia, the focus of the living lab in Spain, the average air temperature in 2022 was 14.79°C, representing a 13.88% increase from the previous year. This increase shows the sensitivity of regional climates to global warming. Projections for Catalonia, using regional climate models, suggest that by 2030, the temperature will range from 13.87°C under the best-case SSP1-1.9 scenario to 14.09°C under the worst-case SSP5-

8.5 scenario. By 2050, temperatures are expected to range between 14.09°C and 15.18°C, highlighting the significant impact of continued greenhouse gas emissions on regional climate patterns.

3.9.2.2 Precipitation pattern

Data reveals that climate change has produced a decrease in annual precipitation in most of Spain. In 2021, the historical average precipitation was 628.86 mm, whereas in 2022, annual precipitation was 551.43 mm. This decrease is particularly evident in the months of March and June. Projected annual precipitation across all scenarios ranges from 636.27 mm to 658.50 mm for 2030 and from 653.64 mm to 632.18 mm for 2050. Although the changes in precipitation are gradual, more drastic variations are predicted around 2100.

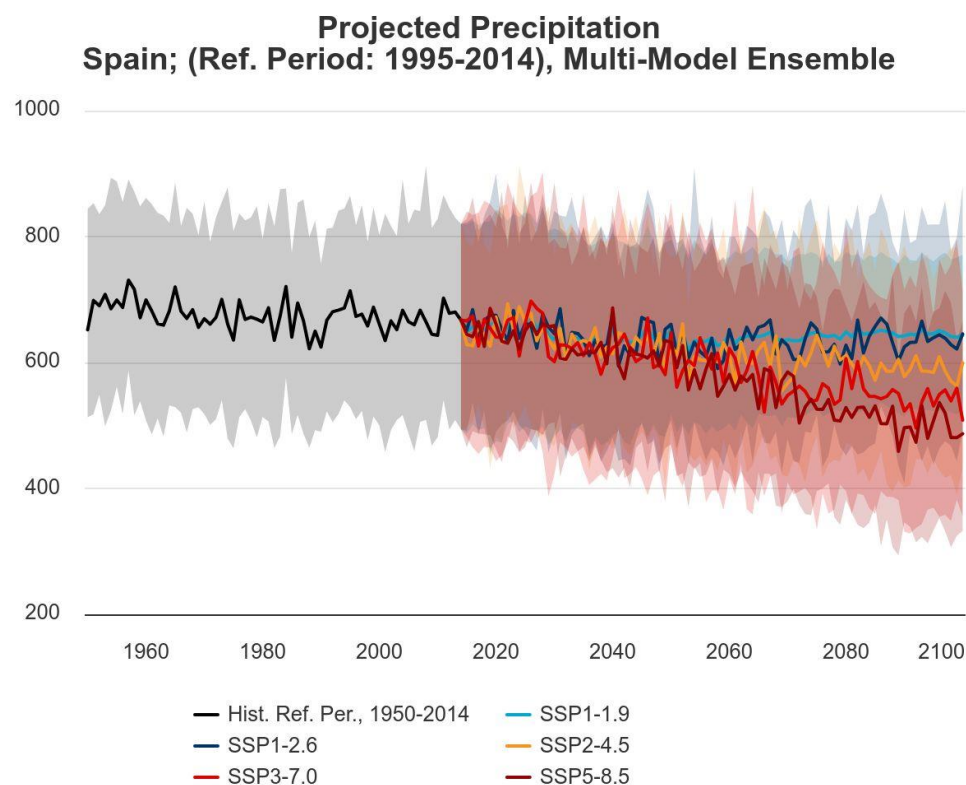


Figure 3-31: Projected precipitation patterns in Spain

Projections for annual precipitation in Catalonia in 2030 range from 771.5 mm to 804.94 mm. By 2050, precipitation in Catalonia is projected to be within the range of 789.82 mm to 786.68 mm. These projections indicate a slight variation in precipitation



patterns, reflecting the ongoing impacts of climate change on regional weather systems.

3.9.2.3 Sea level rise

Sea level rise in Spain is a significant concern due to its Mediterranean and Atlantic coastlines. The rate of sea level rise has been 0.002-0.003 meters per year along the Atlantic coast and slightly less along the Mediterranean coast.

For the living lab in Catalonia, the gauge situated at Barcelona was selected for sea level rise projections for 2030 and 2050, relative to a 1995-2014 baseline. In 2030, the total sea level change in Barcelona is projected to be between 0.13 meters and 0.14 meters under all SSP scenarios. By 2050, the sea level change is predicted to be between 0.24 meters and 0.28 meters.

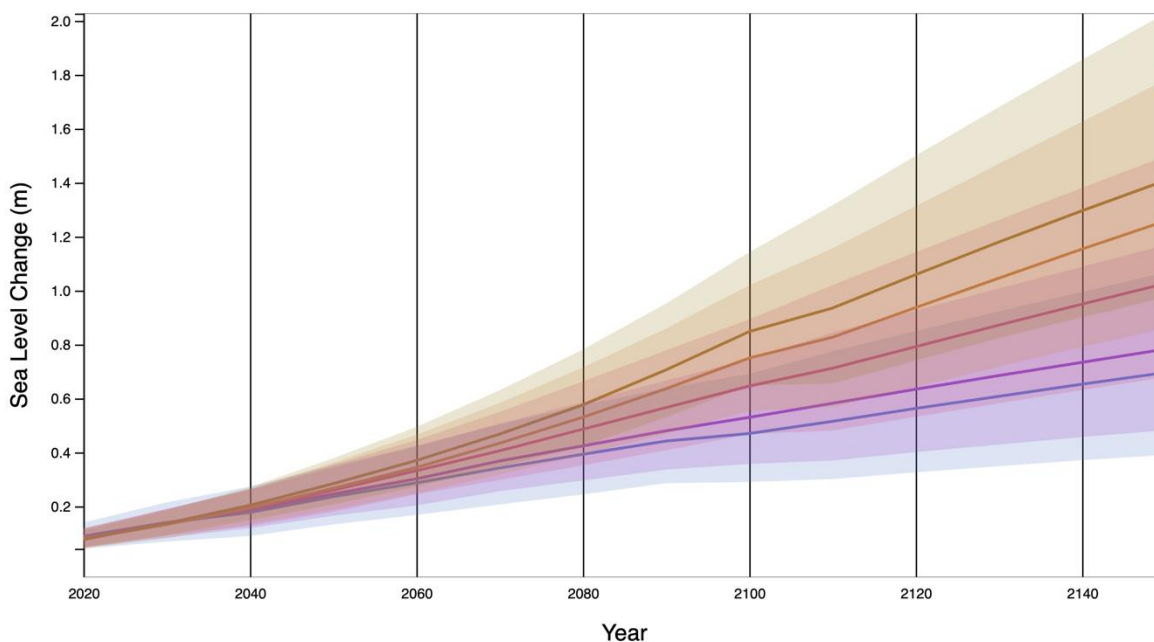


Figure 3-32: Projected Sea level changes in Spain

3.9.2.4 Erratic weather events

Spain has been grappling with increasingly erratic weather patterns in recent years. Drought has exacerbated to levels not seen since 1995. Rainfall also has plummeted to 25% of normal levels. However the few rains are characterized by heavy winds with torrential rainstorms. In recently years, a historical rainfall occurred in the interior of

the peninsula, accumulating up to 20 inches of snow in The ECO-READY project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101084201



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Madrid and in other areas of the centre and East of Spain. These extreme conditions have a crippling effect on agriculture and tourism - two pillars of the Spanish economy. Conversely, the country has witnessed devastating floods in the south and east Spain, with relentless rain causing fatalities, infrastructure damage, which indicate that rising sea levels due to global warming may have worsened the situation. These extreme events have caused economic hardship and social uneasiness.

3.9.2.5 Ecosystem and biodiversity impacts

Climate change is disrupting Spain's rich diversity. Warmer temperatures are confusing plants and animals, causing them to bloom earlier or migrate at inappropriate times. This disrupts their feeding cycles and jeopardizes their survival.

Rising sea levels and drier conditions are squeezing coastal ecosystems and forests, making these vital habitats increasingly vulnerable. Species are struggling to adapt to the rapid changes, with some potentially facing extinction, while invasive species take advantage of the upheaval. The combined impacts of habitat loss, disrupted lifecycles, and competition from newcomers threaten to significantly reduce Spain's biodiversity.

3.9.2.6 Socioeconomic impacts

Food Security: Climate change is expected to exacerbate food insecurity in Spain, particularly in rural areas. Literature suggests that climate change will lead to a decline in yields of staple crops such as wheat, maize and rice. Other studies also suggest that there will be an increase in saturated lipid and sugar levels in food intake, contributing to obesity and a decline in the Mediterranean diet.

Tourism: The peak tourist season may be altered, and water supply problems, especially on the Mediterranean coast, Balearic Islands and Canary Islands, plus coastal flooding, could hinder growth in this sector. High-emission scenarios are expected to reduce Spain's attractive tourist profile in favour of Northern destinations by the last third of the century.



3.9.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Spain and their specific focus on different products.

Table 3.27: Drivers of products for Spain

Products- Spain					
	Poultry	Apples	Wheat	Mullet	Olive oil
Drivers	1. Global warming 2. Heat stress 3. Nutritional quality 4. One health 5. Microbiome	1. Drought 2. Increased air temperature 3. Summer heatwave 4. Pest invasion 5. Pathogens	1. Drought 2. Global warming 3. Pathogens 4. Productivity 5. New breeding	1. Sustainable intensification 2. Increased freshwater and estuary temperature 3. Ocean acidification 4. Integrated agriculture 5. Hydroponic	1. Drought 2. Summer heatwave 3. Fauna 4. Increased air temperature 5. Microbial community

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.9.4 Living lab scenarios

CONCAT

CONCAT aims to establish a multidisciplinary collaborative Living Lab focused on addressing climate change challenges in the Mediterranean and Southwestern European Regions (MSWER), with Catalonia as a central focus. The overarching goals include enhancing food security, promoting climate resilience, and ensuring consistent access to essential food products, including olives, apples, wheat, poultry, and aquacultured fish.



Products Scenarios	Olives	Apples	Wheat	Poultry	Aquaponics
1. Business as Usual (2030 - 2050)	X	X	X	X	X
2. Climate shock (2030)	X	X	X	X	X
3. Climate shock (2050)	X	X	X	X	X
4. Climate Change and Policies Practices (2050)	X	X	X		
5. Integrated Scenario Up to 2050 Under Various Storylines and Emission Scenarios	X	X	X		

Scenario 1: Business as usual (2030 and 2050) for Catalonia

The purpose of this scenario is to predict the impact (by the years 2030 and 2050) of continuing the current agricultural practices without significant changes in key agricultural products. The generated knowledge will help different Catalan stakeholders, including producers, food manufacturers, and policy makers to gain a comprehensive understanding of the potential liabilities for continuing current agricultural practices without significant changes. It will advocate for the development of adaptive strategies, inform policy-making, and enhance the resilience of agricultural systems to climate change and extreme weather events.

The focus is on Olives, Apple, Wheat, Poultry, and Aquaponics.

1- Olives: production will likely be impacted by rising temperatures and reduced availability of water, leading to a noticeable decrease in yield and quality.

To adapt, stakeholders may need to invest in water-efficient irrigation systems, drought-tolerant olive varieties, pest management strategies, and explore innovative approaches to preserve the heritage and build resiliency into the future of local olive supply chains.

- Focus: 71 native Catalan varieties (for varieties assessment) and Arbequina Olive Variety (for drought assessment).



- Goal: Assess resilience to climate change, water efficiency, production quantity, and quality under different climate conditions.
- Outcome: Understand risk factors and impact of adverse climate conditions and inform the design of adaptive strategies for olive cultivation.

2- Apple varieties resilience: With changing climate conditions, some apple varieties in Catalonia may become more susceptible to changing weather patterns and rising temperatures. Stakeholders may need to focus on breeding and promoting resilient apple varieties that can withstand future climate challenges. Integrated soil conservation techniques may also be necessary to maintain healthy apple orchards.

- Focus: Over 15 apple varieties, including 6 Gala varieties, 2 Golden varieties, 2 Granny varieties, 2 Fuji varieties and 3 resistant varieties to Apple scab (Inogo, Crismon Crisp and Story Inored).
- Goal: Assess how different apple varieties cope with rising temperatures and extreme summer heat.
- Outcome: Understand biotic and abiotic risk factors and impact of adverse climate conditions and inform the design of adaptive strategies for managing orchards effectively, including the diversification of apple variety in the same orchard.

3- Wheat varieties evaluation: As temperatures rise and rain patterns are disrupted, the growth and yield of wheat in Catalonia is increasingly affected. Thus, stakeholders may need to evaluate and select drought-tolerant wheat varieties to ensure continued productivity. Improving soil health and implementing crop rotation practices can also help mitigate the impacts of climate change on cereal production.

- Focus: Recent wheat varieties.
- Goal: Assess the resilience and efficiency of different wheat varieties with respect to changing environmental conditions, and their yield and resistance to diseases and pests
- Outcome: Identification of the wheat varieties that are most resilient to climate change.

4- Poultry: Poultry farming in Catalonia may face challenges due to increasing heat stress on chickens. Stakeholders may need to invest in cooling systems, shade structures, ventilation, and change their management approach to ensure the well-being of the birds, while optimising costs. Breeding for heat-resistant chicken strains and adjusting feeding practices can also help minimise the negative effects of heat stress on poultry production.

- Focus: Poultry barns with controlled environments.
- Goal: Assess the resilience of poultry production in controlled environments (growth despite challenge) and analyse the correlation between heat stress and production.
- Outcome: Develop contingency plans for poultry farming during heat waves, including ventilation, cooling adjustments, structural changes, and adjustments in feeding practices.

5- Aquaponics: Aquaponics, a sustainable farming system that combines aquaculture and hydroponics and may become more important in Catalonia as water resources become scarcer. Stakeholders may need to invest in scaling aquaponics technology and training to increase food production while conserving water. Monitoring water quality, managing nutrient cycles, and optimising fish and plant species selection will be crucial for successful and scalable aquaponic operations in the face of climate change.

- Focus: Gray mullet and vegetable production in an aquaponics facility.
- Goal: Validate aquaponics as a scalable climate-resilient solution for aquaculture.
- Outcome: Develop sustainable fish production methods based on aquaponics as contingency for fish farming.

Scenarios 2-3: Climatic shocks (2030 and 2050)

The critical role of adaptive strategies and technological advancements in mitigating climate risks and ensuring agricultural resilience for agricultural products in Catalonia are highlighted. With projections indicating increased vulnerability to extreme



temperatures, droughts, and other climatic challenges, it becomes crucial to implement proactive measures (Magnet model).

The following scenarios focus on such extreme weather conditions, and the risk they entail to the sustainability of production, to gauge the resilience of crops under these conditions and develop mitigation and adaptation strategies. In this respect, the 2030 and 2050 scenarios will be defined according to data provided by Eco-Ready and other open data sources.

1. Olives:

- 2030: Increased vulnerability to extreme temperatures and droughts may lead to reduced olive yield and lower-quality fruit.
- 2050: Continued climate change could exacerbate these challenges, necessitating the adoption of drought-resistant olive varieties, and robust water-efficient irrigation systems.
- Mitigation: Focus on testing of drought-resistant olive varieties, water-efficient irrigation, and adaptive orchard management.

2. Apples:

- 2030: Heatwaves and irregular precipitation patterns may impact apple quality and quantity, emphasising the need to identify resilient apple varieties and optimise orchard management.
- 2050: Heightened climate variability may further stress apple cultivation, requiring enhanced irrigation strategies and management practices to maintain productivity. Mitigation: Identify resilient apple varieties, improve orchard irrigation strategies, and enhance orchard management practices.

3. Wheat:

- 2030: Rising temperatures and altered precipitation patterns might reduce wheat productivity, prompting the development of heat-tolerant and drought-resistant varieties.



- 2050: Continued climate change could intensify these conditions, necessitating advanced soil management practices and predictive modelling to sustain cereal crop yields.
- Mitigation: Develop heat-tolerant and drought-resistant varieties, optimise soil management, and utilise advanced predictive models (e.g., MAGNET) for planning.

4. Poultry:

- 2030: Heatwaves may increase chicken mortality and reduce productivity, prompting investments in barn ventilation, cooling systems, and possibly breeding heat-resistant poultry strains.
- 2050: Persistent heat stress challenges may require ongoing adaptation of poultry management practices and infrastructure to mitigate climate impacts effectively.
- Mitigation: Consider breeding heat-resistant poultry strains and upgrade the design and features of barns and production facilities, including the optimization of ventilation and cooling systems, and adjust feeding practices.

5. Aquaponics systems:

- 2030: Despite potential stability, aquaponic systems could face vulnerabilities and scaling challenges due to extreme weather events, and frequent droughts, necessitating enhanced system resilience through improved design and management practices.
- 2050: Continued climate variability may require further diversification of aquaponic species and integration of renewable energy sources to ensure scalability, environmental control and sustainable production.
- Mitigation: Enhance system resilience through improved design and management, diversify species, and integrate renewable energy for environmental control.



Scenario 4: Climate change and policies practices (2050)

In this scenario, farmers in olive, apple and wheat growing regions are facing increasingly unpredictable weather patterns and drought conditions, heavily affecting their production and stressing their orchards.

The scenario looks to identify and accelerate the adoption of mitigation strategies through policy recommendations. In order to achieve this, it follows an engagement approach that aims to build consensus among the stakeholders on a shared agenda, which acts as a key reference to policymaking. Each shared agenda is co-developed through collaboration between producers, manufacturers, consumers, and policymakers, and will address issues such as water management, sustainable practices, quarantine and mitigation, and support action.

The shared agendas will establish a long-term mitigation strategy, which includes policy-enabled holistic solutions that support sustainable farming practices. These practices will not only help to mitigate the effects of climate change on crops, but also improve soil health and biodiversity in the area.

1- Olives and apples: Develop a shared agenda that represents a consensus and an agreement between all stakeholders involved in orchard-based agriculture (olives and apples) to migrate towards a more sustainable and economically feasible production approach capable of mitigating the effects of climate change.

2- Wheat: Develop a shared agenda that includes the design and implementation of new production methods for cereals that help producers build resilience in the face of climate change, using approaches that could include efficient water management, crop variety and crop rotation, and the adoption of climate-resilient species.

Scenario 5: Integrated scenario up to 2050 under various storylines and emission scenarios

This scenario explores the potential future of sustainable and resilient agriculture for olives, apples, and wheat in the context of various storylines and emission scenarios up



to 2050. It takes into account different trajectories of global development, climate change impacts, and mitigation efforts, based on the Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs). These frameworks provide a comprehensive view of how global society, economies, and environments might evolve in the context of climate change and its mitigation.

Storylines and emission Scenarios:

1. Low emission, sustainable development (RCP2.6 & SSP1):

- **Agriculture:** Intensive efforts in sustainable agriculture are adopted early on, with significant investment in research and development of climate-resilient crop varieties. Water-saving technologies and soil conservation practices become widespread, supported by strong policy frameworks and international cooperation.
- **Outcomes for olives, apples, and wheat:** Enhanced biodiversity and ecosystem services lead to stable and increased yields despite the challenges posed by climate change. The agricultural sector becomes a model for sustainability, with minimal environmental impact.

2. Moderate emission, middle-of-the-road development (RCP4.5 & SSP2):

- **Agriculture:** Adoption of sustainable practices progresses at a moderate pace, with uneven implementation across regions. Efforts to develop and deploy climate-resilient varieties are successful but face challenges due to limited funding and policy support.
- **Outcomes for olives, apples, and wheat:** Crop yields fluctuate due to varying success in mitigating climate impacts. While some regions thrive, others struggle with adaptation, leading to moderate improvements in resilience and sustainability overall.



3. High emission, fragmented world (RCP8.5 & SSP3):

- **Agriculture:** Limited cooperation and investment in sustainable agriculture led to continued reliance on traditional practices. Efforts to adapt to climate change are fragmented and often reactive, with minimal advances in resilience or sustainability.
- **Outcomes for olives, apples, and wheat:** The agricultural sector faces significant challenges, with frequent crop failures and declining yields. Biodiversity suffers, and the environmental impact of agriculture intensifies, exacerbating the effects of climate change.



3.10 Sweden

3.10.1 Dossier of Living Lab- country profile

Country - Sweden

Region in EU - Baltic and Scandinavian

Name of living lab - Sustainable solutions for climate change resilience in food security (SECO-Collab)

Partners - SweGreen AB (SweGreen), Royal Institute of Technology (KTH Food), Mälardalen University (MDU)

Products - Leafy greens, Herbs, Microgreens, Chilli, Brassica



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Figure 3-33: Map of Sweden with products



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Partner's expertise

SweGreen AB specializes in climate-smart farming technology, focusing on in-store-grown leafy vegetables and developing controlled environment growth chambers.

Royal Institute of Technology (KTH Food) tackles challenges such as climate change, food and water security, and future energy supply through interdisciplinary research and collaborations, emphasizing sustainable food production, circular food processes, and functional food products for health.

Fotografiska Stockholm AB, known for contemporary photography, can offer unique perspectives on sustainability through visual communication and public engagement.

Mälardalen University (MDU) contributes expertise in areas like Future Energy, Healthcare and Welfare, Embedded Systems, and Industrial Engineering, supported by robust industry collaborations and a strong infrastructure for applied research and innovation.

Partner background information

Economics: In the Stockholm Region, agriculture holds minimal importance due to the region's small geographical size compared to the vast agricultural lands in southern Sweden, such as Skåne. Limited land availability restricts large-scale agricultural activities, and the region's status as the capital and a major urban centre further limits opportunities for extensive agriculture due to urban development and infrastructure. The region's economy primarily focuses on services like finance, technology, and education, and industry sectors including pharmaceuticals and telecommunications, which contribute significantly more to the region's economic output than agriculture. Potential important sectors in the Stockholm Region include Urban Agriculture, which involves various small-scale, sustainable farming practices within urban environments such as rooftop gardens, vertical farming, and community gardens. Although these practices contribute a negligible portion to the region's overall agricultural output, they promote local food production, improve environmental sustainability, and foster community engagement. Horticulture, involving the cultivation of flowers, fruits, and



vegetables in greenhouses or controlled environments, may also exist to cater to local demand for fresh produce, though on a limited scale compared to other regions in Sweden. Small-scale vegetable production, such as tomatoes, lettuce, and herbs, might be cultivated due to their higher market value and shorter growing seasons, catering to local demand and niche markets.

In contrast, Scania is the leading producer of rapeseed in Sweden, contributing significantly to the country's total production. The region's fertile soils and suitable climatic conditions make it ideal for growing rapeseed, with the area dedicated to rapeseed farms potentially reaching over 500,000 hectares in some years. Sweden's established aquaculture industry primarily focuses on open-net cage farming in coastal areas, particularly for salmon and rainbow trout, contributing significantly to the national economy and seafood exports. Some pilot projects and research initiatives exploring Urban Integrated Agriculture (UIA) concepts are emerging in Sweden, focusing on land-based recirculating aquaculture systems (RAS). These closed-loop systems raise fish in controlled environments and could be suitable for urban settings.

Policies: The *Eco-scheme* in Sweden encompasses a range of initiatives aimed at improving climate resilience, environmental health, and animal welfare. Key components include compensation for intercropping practices designed for carbon sequestration, which helps capture and store carbon dioxide from the atmosphere, and the use of catch crops and spring tillage to reduce nitrogen leakage, thereby improving soil health and water quality. Additionally, payments are offered for precision planning to optimize resource use and minimize environmental impact. Compensation is also provided for establishing protection zones against water areas and adapted protection zones to safeguard water quality and prevent pollution.

The agri-environment-climate measures include various commitments related to environmental protection, climate resilience, and sustainable management practices. These measures encompass compensation for the management of pastures and hay meadows, which includes additional supplements to support biodiversity and ecosystem services. Compensation for mountain huts ensures the preservation of traditional alpine



farming practices, while support for endangered livestock breeds helps maintain genetic diversity and heritage breeds. Furthermore, the scheme includes compensation for the management of wetlands and ponds, which are critical for water regulation, habitat provision, and biodiversity conservation.

Past farming: In Sweden, the agricultural production system encompasses a variety of approaches including conventional, organic, low input, regenerative, and no-till farming. Although the number of farms is decreasing, the size of these farms is increasing. By 2023, the organic farming area in Sweden has nearly tripled over the past 15 years, now accounting for approximately 20% of agricultural land, with a target to increase this to 30% by 2030. However, only 3.50% of the total agricultural area is currently organic. Crop rotation is practiced with various crops such as perennial grasses (timothy, fescue), red clover, alfalfa, and mixes of grasses with legumes used as catch crops in rotation. Crops are utilized for various purposes including grain, silage, and biomass, and some crops are internally used within the farm.

Regarding irrigation and fertilization, the available data is limited, but in 2003, less than 30% of areas equipped for irrigation were actually irrigated. Unlike several other European countries, Sweden does not have legal limitations on the application rates of mineral fertilizers, though the application of animal manure is restricted in vulnerable areas. Instead, Sweden has prioritized measures to reduce nutrient discharge from arable land to the surrounding environment. These measures include farming more autumn-sown crops, providing subsidies for catch crops, creating wetlands and buffer strips, and utilizing N sensors and/or crop satellite images for split nitrogen application.

Potential drivers

Climate: Located 52 meters above sea level, Stockholm experiences a temperate oceanic climate. The annual long-term mean temperature is 6.6 °C, and the annual long-term precipitation is 532 mm. January is the coldest month with a long-term daily mean temperature of -2.8 °C, while July is the warmest month with a long-term daily mean temperature of 17 °C. July is also the wettest month, receiving 71 mm of precipitation, whereas March is the driest month with just 26 mm of precipitation.



Climate risks in Stockholm include low temperatures, frost days, excess water, and snow, all of which can impact agricultural and urban activities in the region.

Food security: Sweden has a robust agricultural sector that, despite its relatively small size, produces a wide array of crops including grains, vegetables, and fruits, as well as livestock such as cattle, pigs, and poultry. While not entirely self-sufficient in food production, Sweden maintains a stable and diverse agricultural industry to support its population's nutritional needs. The Swedish Food Agency (Livsmedelsverket) ensures high standards of hygiene, nutritional content, and safety in food products by monitoring agricultural practices, food processing facilities, and distribution channels to minimize contamination and foodborne illness risks. The country invests in research and development to enhance farming techniques, improve crop yields, and reduce environmental impact. Sustainable practices like organic farming, crop rotation, and integrated pest management are promoted to foster biodiversity and preserve natural resources. Sweden's comprehensive social welfare system prioritizes access to food for all citizens, with government programs providing financial assistance and support to vulnerable populations, ensuring access to nutritious food. Food banks and charitable organizations distribute surplus food to those in need, addressing food insecurity among disadvantaged groups. Sweden exports agricultural products such as dairy, meat, and processed foods, while importing items like fruits, vegetables, and specialty goods to meet consumer demand, participating in international trade agreements to facilitate food product exchange. Recognizing the impact of climate change on its food system, Sweden actively works to enhance resilience through climate-adaptive agricultural practices, crop variety diversification, and improved water management strategies. Sustainable food production methods, renewable energy sources, and waste reduction initiatives contribute to Sweden's overall climate resilience in the context of food security.

Farming conditions

Water: Area equipped for irrigation for 8 regions was derived from the statistics of the farm structure survey 2003. AEI reported for the regions added up to 188 470 ha as shown in the table below. Since these 8 regions are still pretty large and statistics on



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areas equipped for irrigation were not available at higher resolution, statistics on irrigation water consumption were used to downscale the irrigated area statistics to counties and municipalities. This procedure likely introduced an unknown error since irrigation water use per unit area varies. However, it helped to identify the main zones of irrigation infrastructure development. The detailed breakdown of irrigated areas by province is available in the table below.

Table 3.28: Irrigated area by province in Sweden

Region	Area equipped for irrigation (ha)			Area actually irrigated (AAI) (ha)
	total	with groundwater	with surface water	
Mellersta Norrland	1 740	0	1 740	193
Norra Mellansverige	7 530	266	7 264	833
Östra Mellansverige	26 500	2 035	24 465	2 857
Övre Norrland	2 100	0	2 100	237
Småland med öarna	27 440	5 161	22 279	9 180
Stockholms Län	4 130	0	4 130	360
Sydsverige	78 340	38 057	40 283	31 750
Västsverige	40 690	5 053	35 637	6 740
Sweden total	188 470	50 571	137 899	52 150

The area irrigated for the same regions was computed as the average of the AAI reported in the farm structure surveys in 2003, 2005, and 2007 [SE01]. AAI computed this way added up to 52 150 ha.

Diseases, pests and plant protection

In Sweden, chilli and lettuce crops face challenges from specific plant diseases and pests. For chilli, problems include fungal infections and pests such as aphids and spider mites. Lettuce crops are often affected by downy mildew and pests such as aphids and leaf miners.

Table 3.29: Diseases, pests and plant protection

Crop	Harmful organism	Species names	Plant protection practices
	Pest	Brassica pod midge; rape beetle; cabbage flea beetle; rape stem weevil; cabbage seed weevil; cabbage stem weevil; cabbage gall weevil; aphids; black; turnip sawfly.	Clean seed; certified pest-free seed; seed treatment; land selection; cultivar selection; crop rotation; proper time of cutting; adequate fertility management; tillage (residue management); eradication of host weeds; use of bio pesticides based on essential oils and micro-organisms; support and introduction of natural enemies.



Rapeseed	Disease	Phoma stem canker = blackleg; Sclerotinia stem rot; club root; Verticillium stem stripping.	Clean seed, certified pathogen-free seed, seed treatment, crop rotation, tillage (residue management), cultivar selection, proper timing of sowing, preventing excess moisture in the field (plant density), adequate fertility management.
	Weed	<i>Sinapis arvensis</i> , <i>Stellaria media</i> , <i>Veronica arvensis</i> , <i>Capsella</i> <i>bursa-pastoris</i> .	Mechanical weeding: preventive methods (e.g., crop rotations, time of sowing, crop varieties selection, cover crops, clean seed); proper soil management.

Soil: Gleysols, Arenosols, and Regosols. Southern Sweden presents a more complex soil pattern, including Cambisols and Leptosols. Out of Sweden's total land area of approximately 41 million hectares, about 23.5 million hectares are under productive forestry. Other land categories include peat land, mountainous land without forests, and arable land. Notably, the southern third of Sweden encompasses about 90% of the country's agricultural land. The total agricultural land, comprising cropland and pastures, is estimated at 3.525 million hectares, with 7.6% of this area (267,990 hectares) consisting of organic peat and gyttja soils. Major threats to soil quality and agroecosystem sustainability in Sweden include acidification, with soil pH having dropped by 1-1.5 units since the 1950s, and anthropogenic contamination, particularly from mercury (Hg), cadmium (Cd), and lead (Pb) deposition. Nitrogen deposition also poses a threat, as the low carbon-to-nitrogen (C/N) ratio resulting from nitrogen deposition, especially in southwestern Sweden, increases the risk of nitrate leaching and the eutrophication of coastal marine environments.

3.10.2 IPCC projections on climate change indicators for 2030 and 2050

The Intergovernmental Panel on Climate Change (IPCC) provides the Sixth Assessment Report (AR6) which is a comprehensive assessment on climate change. The IPCC's reports include projections for future climate conditions based on various greenhouse gas (GHG) emission scenarios. Here are some key projections for the period 2030-2050 from recent IPCC reports:



3.10.2.1 Temperature

The Global Mean Surface Temperature (GMST) in 2023 was 1.45°C (World Metrological Organization, 2023). However, GMST is expected to increase to approximately 1.5°C to 1.6°C above pre-industrial levels by 2030 based on the shared socioeconomic pathway (SSP) scenarios. By 2050, if current GHG emissions trends remain unchanged, GMST will be 2.0°C, and under high-emission scenarios, could increase to about 2.5°C. Regional Variations: Temperature increases will not be uniform. Polar regions are expected to warm faster than the global average, with the Arctic potentially warming by more than 3°C by 2050.

In 2022, Sweden recorded an annual mean surface air temperature of 3.84°C, representing an increase of about 20% from the previous year. Climate projections indicate that by 2030, the average mean surface air temperature will be 4.38°C under an optimistic scenario and 4.54°C under the worst-case scenario. By 2050, the annual mean surface air temperature is projected to range between 4.62°C and 5.36°C, depending on the emission scenarios.



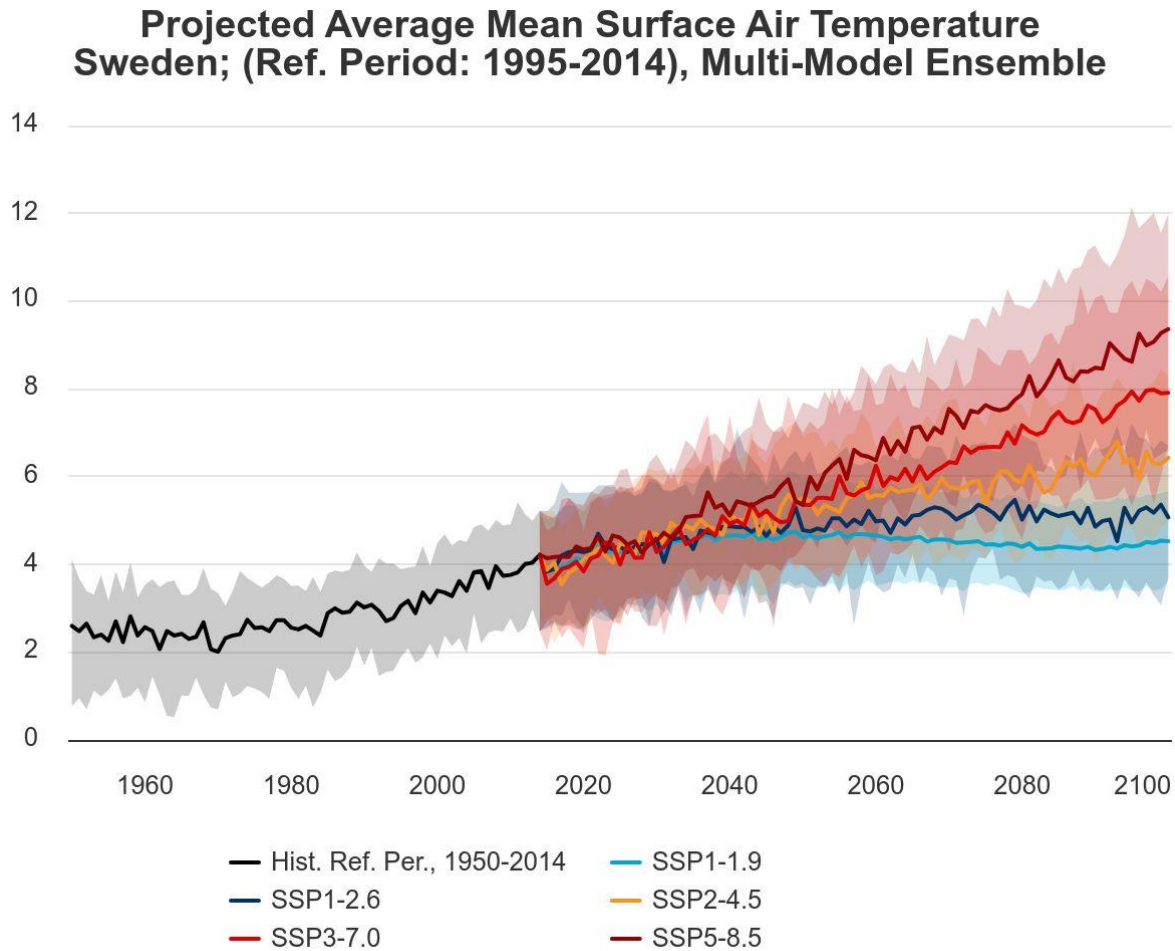


Figure 3-34: Projected average mean surface air temperature for Sweden

3.10.2.2 Precipitation patterns

Precipitation in Sweden is generally increasing, mostly in the north. Historical data indicates an increasing trend in precipitation during winter, spring, and summer since 1991. Mean annual precipitation was 607.70 mm in 2021 and 604.30 mm in 2022. Projections for 2030 show that precipitation will be 812.69 mm under the SSP1-1.9 scenario and 808.75 mm under the SSP5-8.5 scenario. For 2050, projections indicate precipitation of 799.40 mm under the SSP1-1.9 scenario and 815.49 mm under the SSP5-8.5 scenario. These increasing precipitation trends are expected to become more pronounced towards the end of the century.

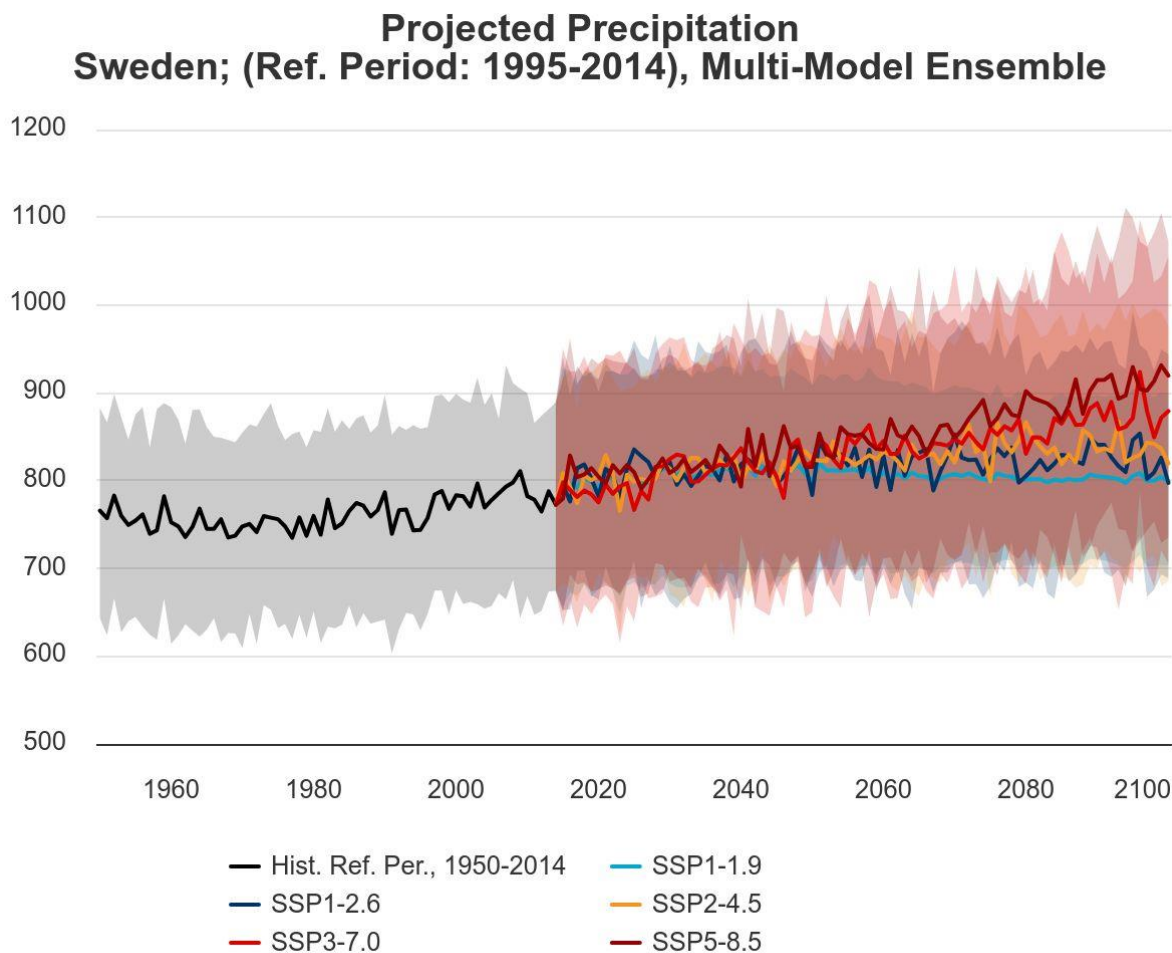


Figure 3-35: Projected precipitation patterns in Sweden

3.10.2.3 Sea level rise

Since the end of the 19th century, climate-driven sea level changes along Sweden's coast have caused an average rise of approximately 0.15 meters. Projections for 2030 suggest that sea level changes will range between -0.01 meters and 0.01 meters. By 2050, projections indicate that sea level changes will range from -0.01 meters to 0.04 meters. These relatively modest changes reflect regional factors such as land uplift counteracting sea level rise along Sweden's coast.



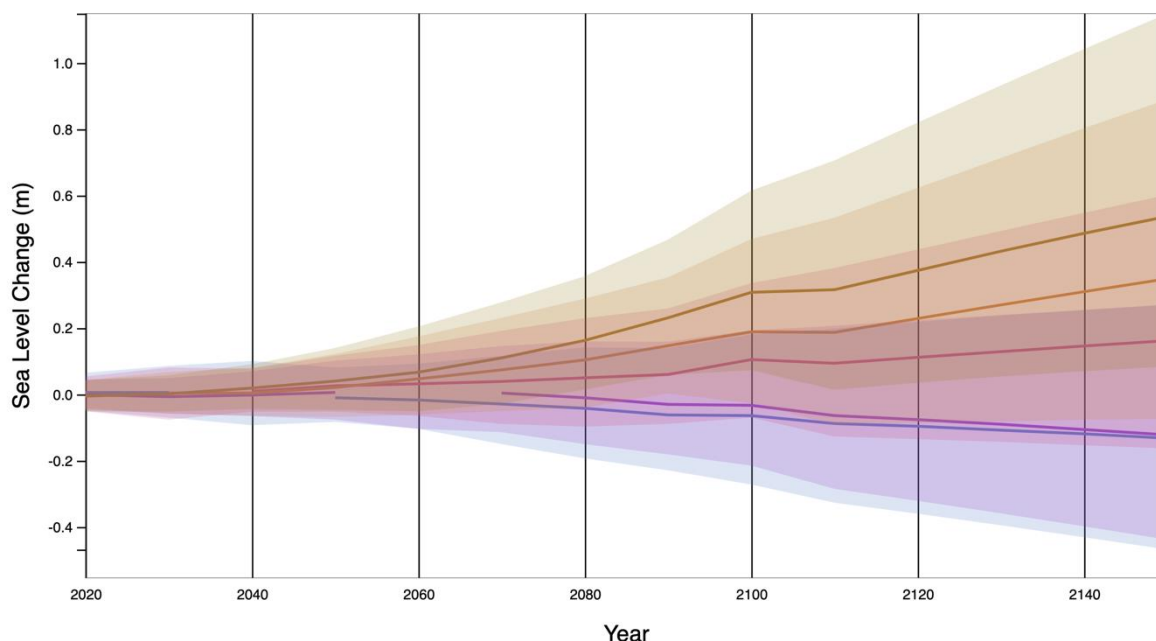


Figure 3-36: Projected Sea level changes in Sweden

3.10.2.4 Extreme weather events

Sweden's climate is expected to become more extreme. Heatwaves will become more frequent and intense, with record temperatures impacting the entire country, especially in southern and central regions. Winter and spring will see increased precipitation, leading to higher water flow and potential flooding risks, particularly in western Götaland and Svealand, as well as parts of Norrland. Conversely, summers will likely be drier, raising concerns about droughts and wildfires, especially in the south. Landslides are also expected to become more frequent, particularly in areas already prone to them. These changes highlight the need for Sweden to adapt to a more unpredictable and potentially hazardous climate.

3.10.2.5 Ecosystem and biodiversity impacts

Climate change is significantly impacting Sweden's ecosystems and biodiversity, affecting its forests, mountains, and coastal areas through changes in temperature and precipitation patterns. The treeline is shifting northward and to higher elevations, with forests encroaching on tundra and mountain vegetation experiencing a projected 40-60% loss. Increased disturbances like insect outbreaks and forest fires are facilitating



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invasions by non-native species. In the Baltic Sea, climate change is leading to more frequent and severe saltwater inflows, increased salinity, phosphate concentrations, and expanding hypoxic bottom areas. Coastal ecosystems are retreating landward but face a “coastal squeeze” where their retreat is blocked by shoreline structures. Nearly 750 species in Sweden are negatively affected by climate change, with significant impacts on almost 200 species. Northern bird species are retracting while southern species expand northward, and butterflies are advancing their flight dates. Species with limited retreat options, such as Arctic Ocean survivors in the Baltic Sea and alpine species, are at significant risk.

3.10.2.6 Socioeconomic impacts

Agriculture and food security: Climate change will impact food security in Sweden by affecting the availability and accessibility of food. The country's food security is already vulnerable due to its high reliance on imports and the limited domestic production of certain food items

Future projections: Climate change is expected to cause significant economic losses in Sweden, particularly in the agricultural sector due to extreme weather events like heatwaves, floods, and droughts.

Economic losses: Losses especially in the agricultural sector will be seen due to the extreme weather events. These losses and impact on food security are expected to increase in the future.

3.10.3 Drivers of products

A number of factors affect different crops, such as biodiversity, climate change and food security. The interlinked challenges of biodiversity loss, climate change and food security are complex. Biodiversity loss weakens key ecosystem services needed for food production, such as pollination and pest control. At the same time, climate change is disrupting agricultural systems and increasing the risk of species extinction. The table below highlights the living lab in Sweden and their specific focus on different products.



Table 3.30: Drivers of products for Sweden

Products- Sweden					
	Leafy greens	Microgreen	Herbs	Chillis	Brassica
Drivers	1. Carbon footprint	1. Carbon footprint	1. Carbon footprint	1. Carbon footprint	1. Carbon footprint
	2. Precision farming	2. Precision farming	2. Precision farming	2. Precision farming	2. Precision farming
	3. Using a diverse crop portfolio	3. Using a diverse crop portfolio	3. Using a diverse crop portfolio	3. Using a diverse crop portfolio	3. Using a diverse crop portfolio
	4. Productivity	4. Productivity	4. Productivity	4. Productivity	4. Productivity

Note: 1 represents the most important drivers, 5 represents the least important drivers

3.10.4 Living lab scenarios

SECO-Collab

Swegreen is an agritech company and a vertical farming innovation company. Offering world-unique, efficient and automated growing platforms to supermarkets, grocery stores, restaurants, hotels and property owners for production of greens onsite. This means that the crops have zero transport with minimal energy consumption and a potential minimized carbon footprint.

Products \ Scenarios	Leafy greens	Micro-greens	Herbs	Chillis	Brassica
1. Status quo for 2030 - 2050	X	X	X	X	X
2. Powering Up, Profiting Down: The Energy Drain of Vertical Farming	X	X	X		
3. From Fields to Farmscapes: A Sustainable Future	(X)	(X)	(X)	(X)	(X)
4. The Preference Pivot: Aligning Vertical Farming with Consumer Preference and Awareness	X	X	X	X	X
5. From Seed to Savings: Harvesting Value in Vertical Agriculture	X	X	X	X	X



Note: Scenario 3 does not influence the food products directly, but rather addresses farming through and land-use from a systemic perspective.

Scenario 1: Status quo for 2030-2050

Sweden is expected to have an increased average surface temperature with time, coupled with the increasing trend of more precipitation in the winter and spring months. Sweden's climate is expected to become more extreme. Heatwaves will become more frequent and intense, with record temperatures impacting the entire country, especially in southern and central regions. Although there have been sea level rises due to climate change, relatively modest changes are reflected due to regional factors such as land uplift counteracting sea level rise along Sweden's coast. SECO-Collab, being a consortium centred on vertical farm food production in an urban setting (Stockholm), will face challenges of a local customer-base's dietary preferences, as well as the pressures for energy prices. Vertical farming and newer farming practices may continue to face political and local policy pressure, as it threatens traditional farming.

Scenario 1 will refer to the context of food production via conventional farming. For the remaining scenarios (2-5) they will be considered in the context of the vertical farm setting.

This system relies on circulating water, which constitutes a significantly lower water demand than conventional farming. Further, there is no use of pesticides or herbicides. The major cost considerations in the vertical farm setting are the input of fertilizer into the hydroponic system and the energy costs associated with heating, cooling, and, most importantly, LED lighting. In addition, labour is one of the operating issues, and up-front infrastructure costs are a big consideration, particularly without state or investor-based financing.

Leafy greens production

Due to Sweden's climate, growing lettuce outdoors in southern Sweden year-round is challenging. The dominant method is within greenhouses, which provide a controlled environment where temperature, light, and humidity can be optimized for lettuce growth throughout the year. Southern Sweden has a higher concentration of greenhouses compared to the north. Conventional greenhouses use traditional heating methods like fossil fuels or wood pellets. They produce a variety of lettuces, including iceberg, romaine, and leafy greens.



Micro-green production

Microgreens are tiny vegetable and herb greens harvested at a very young stage, typically when they're just 1-3 inches tall. They're essentially seedlings, somewhere between a sprout and a baby green (e.g., arugula, beet, broccoli, kale, mustard, pea-shoots, radish). Sweden seems to be embracing vertical farming techniques for microgreens. This method allows for efficient use of space and resources, making it ideal for urban areas.

Herb production

Due to Sweden's short growing season and cool climate, outdoor cultivation of herbs is mainly limited to the summer months. Popular herbs like parsley, dill, and chives can be grown domestically during this period. Greenhouse production is the most common method for year-round production of herbs in Sweden. Greenhouses provide a controlled environment with temperature, light, and humidity regulation, allowing for consistent growth throughout the year.

Chili production

There is limited large-scale commercial production of chilis in Sweden. Household may attempt to grow chilis within their homes on sunny garden-windowsills or with the aid of grow lamps in the winter months.

Brassica production

Common types of foods products in the Brassica genus include broccoli, cauliflower, cabbage, Brussels sprouts, kale, kohlrabi, turnips, and bok choy.

2030: Sweden's climate presents some challenges for growing brassicas. The short growing season and colder temperatures can limit the types and varieties that thrive outdoors. Despite the challenges, some brassicas like cabbage, white cabbage, and kohlrabi are successfully grown outdoors in Sweden during the summer months. Greenhouse and tunnel cultivation extend the growing season and provide a more controlled environment for brassicas like broccoli, cauliflower, and Brussels sprouts. The focus will be more on the varieties for outdoor cultivation, for example, early maturing, cold-tolerant, or day-length neutral varieties to name a few.



2050: While milder winters could extend the outdoor growing season for some brassicas, it could also disrupt the natural dormancy period required by some biennial varieties. This disruption could lead to weaker plants and reduced yields. Heatwaves and droughts can stress brassica plants, leading to stunted growth, lower yields, and increased susceptibility to pests and diseases. Heavy rains can lead to waterlogging, which can damage brassica roots and promote fungal diseases. Periods of drought can stress plants and make it difficult for them to absorb nutrients. This can lead to reduced yields and poorer quality vegetables.

Scenario 2: Powering up, profiting down: The energy drains of vertical farming

Energy required for functioning of vertical farms, via automation, and climate control are a substantial cost to operations. In addition, vertical farms rely on LED lighting which has a high demand for energy. All products would be affected by the high cost of operations. This impacts the bottom line on production of food products and reduces customer demand. Customers on the lower end of the economic spectrum are unable to access food products.

Shock: Energy prices become too high to allow for the sustainable viability of vertical farms in Sweden. Food products from southern countries are far cheaper than locally produced foods to the point where customer demand for vertical farm grown products loss market share.

In this scenario, the rising prices of food and increasing inflation rates impact consumer behaviour. The economic strain forces consumers to reconsider their purchasing choices, especially when it comes to higher-priced vertically farmed products such as organic salads. Due to economic constraints, a portion of the consumer base starts to shift from purchasing organic leafy greens, microgreens, and herbs to more affordable conventional imported products. This change is driven by the need to manage household budgets more efficiently amidst rising food prices and inflation. The shift in consumer preference affects the market dynamics and influences the overall demand for organic produce.



Impacts:

- *Consumer Behaviour* - Decreased demand for vertically-farmed greens due to their higher cost. Increased demand for conventional salads as a more affordable alternative. Potential decline in the market share of organic produce.
- *Economic Factors* - Inflation leads to higher prices for all types of food, but the price gap between vertical and conventional produce becomes more significant. Rising costs of production for vertical farms, including higher wages, energy costs, and inputs, which are not equally offset by subsidies or price premiums.
- *Market Dynamics* - Supermarkets and grocery stores may reduce their stock of vertically-farmed leafy green, microgreens and herbs due to lower sales, focusing instead on conventional salads.
- Price-sensitive consumers prioritize essential goods and cheaper alternatives, further impacting the sales of vertical food products.
- *Supply Chains* - Supply chains for vertically-farmed produce may experience disruptions due to decreased demand and adjustments in production volumes.

Mitigation approaches can be seen in Scenario 5.

Scenario 3: From fields to farmscapes: A sustainable future

This scenario addresses an opportunity to both encourage appropriate land use, while maintaining food security. At present, technologies for vertical farming can facilitate only some food products. However, with greater advancements in automation, AI, and improved hydroponics, a broader variety of foods can be cultivated. A systemic assessment of land-use would be considered, balancing food production (urban - vertical) with restoration of land biodiversity. An off-setting policy becomes supported to promote urban/vertical farming where previously cultivated farmlands are “re-wilded” to enhance natural habitats and biodiversity, without threatening food security or access.

Challenge: Balancing agricultural production with ecological restoration.



Solution - A government-backed initiative that incentivizes urban vertical farming while promoting re-wilding of former agricultural lands.

Incentives for vertical farming:

- Provide financial grants to individuals and businesses interested in setting up vertical farms in urban areas.
- Offer tax breaks on property taxes, construction costs, and operational expenses for vertical farms.
- Make underutilized public land available for long-term leases at significantly reduced rates, specifically for vertical farming projects.
- Establish a knowledge-sharing network with workshops, training programs, and mentorship opportunities to connect experienced vertical farmers with newcomers.

Incentives for re-wilding: Offer financial compensation to landowners who take their land out of agricultural production and dedicate it to re-wilding initiatives. This could be a one-time payment or an annual stipend.

- Provide technical assistance and resources to landowners on best practices for re-wilding their land, including seed selection, habitat creation, and ongoing maintenance.
- Develop a program that rewards landowners for the ecosystem services their re-wilded land provides, such as carbon sequestration, water filtration, and biodiversity enhancement.

Expected outcomes:

- Vertical farms will produce fresh, local food year-round, reducing reliance on long-distance transportation and associated emissions.
- Re-wilding former agricultural land will allow native flora and fauna to return, creating a more balanced ecosystem with increased biodiversity.
- Re-wilded areas will help to filter air and water, improving overall environmental health in urban areas.



- The program will create new jobs in vertical farming, re-wilding, and related industries.
- The program will raise public awareness about the importance of sustainable food production and ecological restoration.

Pilot program in Southern Sweden:

- The program can be piloted in Southern Sweden by identifying suitable public land for vertical farm development and offering grants to interested local residents or businesses.
- Local farmers who are willing to participate in re-wilding initiatives can be identified and offered compensation and technical assistance.
- The success of the pilot program can be measured by monitoring food production in vertical farms, biodiversity increases in re-wilded areas, and public reception.
- Allowing conventional farmers to test crops in the vertical farm setting.

Long-term vision:

- This program can be a model for other regions in Europe focusing on vertical farming and biodiversity restoration.
- By promoting vertical farming and re-wilding, Southern Sweden can become a leader in sustainable food production and ecological restoration.

Additional considerations:

- Public education campaigns can highlight the benefits of locally grown food produced in vertical farms and the importance of re-wilding efforts.
- Invest in research and development of vertical farming technologies to improve efficiency and reduce costs.
- Involve local communities in the planning and implementation of the program to ensure its success and long-term sustainability.

By implementing this program, Southern Sweden can achieve a future where urban populations have access to fresh, local food while simultaneously restoring and protecting its natural environment.



Scenario 4: The preference pivot: aligning vertical farming with consumer preference and awareness

This scenario intervention aims to address an evolving customer preference, as well as enhancing the nutritional properties of vertically-farmed foods. Customer preference will change with time, and vertical farming products need to stay relevant. Coupling consumer awareness based on data-informed nutritional advancement with closer to on-demand production of nutritionally-rich and balanced food products would provide an advancement in food supply chains.

Addressing customer preferences:

- Surveys, focus groups, and social media listening can reveal what customers are looking for in vertically farmed products. Are they concerned about taste, variety, sustainability, or price?
- Design and run surveys on consumer beliefs and preferences about food and nutrition. The results of these surveys can point to common misconceptions or ideas not based on nutritional science that could be partially addressed through education campaigns and “in-farm” science & education events.”
- Stay informed about emerging trends in food consumption, such as plant-based alternatives, locally sourced produce, and interest in specific nutrients.
- The farm utilizes real-time data on consumer preferences and aligns these data with current health recommendations backed by scientific evidence.
- Offer a wider range of vertically farmed products beyond leafy greens. Consider fruits, herbs, or even niche vegetables.
- Invest in research and development to ensure vertically farmed products have excellent taste and texture that rivals traditionally grown produce.
- Clearly communicate the benefits of vertical farming, such as reduced water usage and pesticide use. Educate customers about the freshness and safety of your products.
- Let customers experience the quality of your vertically farmed products firsthand by offering free samples.



- Increase accessibility by partnering with stores and restaurants that share your values and can showcase your products.
- Consider offering subscriptions or online ordering for vertically farmed products, catering to a convenience-focused audience.

Enhancing nutritional quality:

- The vertical farm employs a team of agricultural scientists who meticulously control light spectrums and nutrient delivery systems. This allows them to optimize the nutritional content of each crop, maximizing vitamin and mineral levels.
- Consider the recommended daily allowance (%RDA) of micronutrients in developing novel crops/products in the living lab. This can be of particular significance during the winter months when fresh vegetables are not readily available and sunlight levels are low.
- Analysis of the general nutritional contents of products (i.e., , both macro and micronutrients).
- Protein-alternatives to supplement or replace meat-based products in the future. Look at which products in the living lab would provide significant amounts of proteins with quantitative data to support.
- Customize the living lab to the Swedish market to address the micronutrient deficiencies. An example is the lack of vitamin D during months which lack sunlight. Other essential micronutrients like iron and folate (vitamin B9) could be looked at. Based on this information, adjust growing conditions to enhance the specific nutrients most desired by customers, like focusing on vitamin C during flu season or other specific nutrients.
- Also worth considering are mushrooms like oyster mushrooms and shiitake which are a rich source of micronutrients including vitamin D, iron and folate (vitamin B9), if they are grown under certain conditions (require some light exposure).
- The farm collaborates with nutritionists to develop "functional foods" - crops enriched with specific health benefits. For example, they might offer lettuce



varieties with higher levels of antioxidants or kale grown with increased calcium content.

- Inoculation of nutrient solutions with different bacterial strains to study their effect on the nutritional composition and overall yield. For this particular scenario, nutrient solutions will be inoculated with various beneficial bacteria. The nutritional composition and the yield of the different microbes can be assessed.

Scenario 5: From seed to savings: harvesting value in vertical agriculture

Reducing operational costs is a big challenge for vertical farming. The following intervention scenario is intended to mitigate several of the economic challenges.

Cost reduction inputs:

- Using more sustainable energy sources which are less costly, such as locally sources solar, wind and water generated power supplies
- Sourcing more affordable avenues for seed supplies, including developing own stockpiles of seeds.
- Regenerated fertilizer sources, such as microbiologic mixtures as a supplement or substitute to mineral fertilizers. Improve nutrient cycles and water system circularity.
- Automation to reduce the labour cost. The development of AI and robotics as part of standard operations expenditure. Form cooperative agreements with local academics to enable advanced R&D in these areas, while leveraging national and EU grant opportunities.
- Employ more specialized individuals with the skills to use advanced technologies with a focus on R&D. This would complement the current model of farming within local grocery stores.
- Seek alternative growing techniques to cut costs (e.g., growing without substrate), via exchange of best practices with other vertical farms.



Mitigation strategies:

- Initiate lobbying efforts to enable policies to support a certificate of quality, or label.
- Develop a lobbying network, possibly EU wide, to encourage subsidies for vertical farming.
- Support effort to include vertical farming within the category of organic products or a novel, but similar statured label, based on the absence of added chemical and reduced water use in the production process.
- Enhance marketing campaigns to emphasize the long-term health and environmental benefits of vertically-farmed salads. Educate consumers about the true cost of food, including the hidden environmental and health costs of conventional farming.

Solution:

- Devise cost management measure - sustainable energy sources, subsidies for renewable energy sources, system automation to reduce labour costs)
- Implement supply chain optimization (through partnerships, efficient logistics).
- Focus on product diversification based on consumer demand.
- Promote marketing efforts (campaigns, promotion of health benefits, consumer engagement)
- Install dynamic pricing (seasonal promotions, loyalty programs, etc.)
- Initiate partnerships (e.g., plant-based meat alternative companies; real-time customer health monitoring - smart watch for nutrients, etc.)
- Consider alternative Sales Channels (online purchasing and E-commerce)
- Lobby policymakers to encourage including vertical farming within the agriculture subsidies schemes.



4 Discussion

The engagement with 10 living labs across different regions of Europe provides a unique opportunity to understand not only the current state of agricultural practices, climatic and biodiversity shocks, but also to compare and contrast solutions to common challenges. In assembling a team of specialists to devise future intervention strategies, discussions revealed that depending on the individual's perspective and training, they would approach a future challenge from very different lenses. Thus, highlighting the need to approach futures in food security from an inter- to trans-disciplinary approach, and accepting that creative strategies need not only to be devised, but modelled, and experimentally tested. Evident within a „real world” setting are crucial, for example in the following actions: agricultural processes, policy initiatives, or gain of farmer acceptance and customer demand.

Within this discussion section, we touch on just a few of the numerous common themes coming from these scenario design cases, but we do not attempt to exhaustively explain each of the individual topics, nor do we attempt to explore all possible topics. Here, we would like to just highlight a few areas, which could be more deeply explored in the future. The topics which follow include: sustainable farming methods, crop breeding or varieties, soil health, biodiversity in agriculture, policies in agriculture, inter-/trans-disciplinarity, and systemic change in the food production system.

Sustainable farming methods

As climate, economic, and social shocks become more frequent, there is considerable potential to improve beyond conventional farming. Innovative practices like organic, vertical, regenerative, and sustainable intensive farming are being explored, especially in Europe, which has advanced agricultural expertise and resources. These methods aim to enhance food security by boosting resilience and productivity while promoting biodiversity through diverse and healthy ecosystems. The Eco-Ready project's ten living labs across Europe are investigating these practices, focusing on organic, vertical, and



regenerative farming, to name a few. Despite their significant contributions to sustainable agriculture, these approaches face challenges:

Organic farming: Challenges include local conditions, reliance on compost, and labour impacts. EU regulations lack specific protections for water and habitats, and certification inconsistencies persist. Policies should harmonize standards, support new farmers, and fund research. See more under the sections of living lab scenarios for the Czech Republic and Denmark.

Vertical farming: While it enhances food security, mitigates climate change, and conserves biodiversity, it faces high setup costs, significant energy use, and limited crop diversity. Policies should subsidize costs, promote renewable energy, and support crop research. See more under the sections of living lab scenarios for Hungary and Sweden.

Regenerative agriculture: This practice improves soil health and biodiversity through techniques like crop rotation and reduced tillage but encounters challenges such as specialized knowledge, transition costs, and potential short-term yield losses. Policies should provide education, financial incentives, and research support to advance its adoption and sustainability. See more under the section of living lab scenarios for Poland.

Crop breeding or varieties

In principle, plant breeding results in improved or tailor-made varieties according to demand. In most cases, consumer demand influences the characteristics of food products derived from breeding for certain traits. For instance, the Green Revolution of the 1940s to 1960s focused on developing high-yielding plants, resulting in increased food supplies and eradicating starvation at the time. Somewhere along the way, consumer preferences shifted to caloric intake, favouring plants with high carbohydrate content to help feed many. In recent times, plant-based proteins have been a focus, and studies reflect that the breeding of legumes and other crops with high protein



content is on the rise. This reveals that plant breeding offers a sustainable approach that is economical and, if properly done, leads to consumer satisfaction.

Plant breeding can help mitigate challenges associated with climate change, but with a condition. By identifying the respective climate change shocks like drought, heat stress, salinity stress, incidence of pests and diseases, and low nutrient content.

In the scenarios for the Greek living lab, some of the mitigation strategies include developing self-pollinating and pest-resistant varieties. A common approach has been the strategy to develop heat and drought-tolerant varieties, which has been highlighted in the living labs of Poland, Spain, Germany, Italy, and Greece. In Italy, there is a serious concern to develop olive cultivars resistant to *Xylella fastidiosa*. In Germany, disease-resistant strawberry and raspberry varieties are also in focus. Plant breeding presents a vital opportunity to enhance agricultural resilience in the face of climate change. By focusing on developing varieties that can withstand environmental stresses and meet evolving consumer demands, we can ensure food security and sustainability for future generations. The mitigation strategies developed by living labs across Europe exemplify the potential of innovative breeding practices to address both current and future agricultural challenges.

Soil health

Healthy soils are rich in organic matter and, together with microorganisms, enhance their ability to sequester carbon. This process of carbon sequestration, reduces the amount of carbon dioxide in the atmosphere, helping to mitigate the effects of climate change. Additionally, healthy soils improve water retention, nutrient availability, and root growth, leading to increased crop yields and greater resilience against extreme weather events. Soils rich in organic matter also exhibit better structure and porosity, which reduces erosion and runoff, further protecting agricultural productivity. Diverse soil ecosystems support a wide range of organisms, from bacteria and fungi to insects and earthworms, all of which contribute to nutrient cycling and soil fertility.



The Czech living lab focuses on enhancing soil health and biodiversity for sustainable farming through various practices. Similarly, the living labs in France, Italy, Poland, and Germany advocate for crop rotations, intercropping, and cover crops to boost soil health. Furthermore, these living labs plan to introduce beneficial microorganisms and bio-stimulants, as well as incorporate organic amendments like compost and green manure, to improve microbial diversity and soil fertility.

Biodiversity in agriculture

Biodiversity is declining at an unprecedented rate globally due to overwhelmingly two factors, habitat loss and climate change. At the same time, there is a global concern for food security, also mainly driven by climate change. Interlinkages between climate change, food security and biodiversity enable practitioners and policy makers to find novel solutions where all three axes of the climate-food-biodiversity nexus benefit and support each other. However, if we are to make a real change, we need to provide evidence for the benefits of the climate-food-biodiversity nexus that goes beyond the main areas of research in agroecology. Biodiversity needs to take centre stage and receive equal attention to the other two players in the climate-food-biodiversity nexus. Our Eco-Ready report highlights opportunities where research can support practices and policies that benefit food security whilst also promoting climate mitigation and biodiversity conservation, for example through organic farming, improved soil health and animal breeding leading to reduced emissions. See scenarios of the living labs for Czech Republic, Denmark, France, Germany, Greece, Hungary, Poland and Sweden.

Policies in agriculture

Global agriculture needs to meet many challenges, and this prompts us to face uncharted territories and take unprecedented actions to recalibrate global and local food systems. Such recalibration may ideally change the food systems so that they better align with climate resilience, soil health and biodiversity while safeguarding agricultural objectives such as food security and productivity. In developed nations, including Europe, agriculture is already permeated by the policy that enables farmers to receive large amounts of public funding. Since Mac Sharry's reform in 1990, the policy



has been constantly shifting away from direct payments toward Agri-environmental supports that compensate income forgone and additional costs accrued for sustainable practices. However, there are numerous barriers and an apparent disconnect between the available or required agri-environmental supports and the actual funds invested in sustainable food systems. One of the major barriers is bureaucracy, which farmers themselves need to face. Consequentially, it is very challenging to apply for support, and farmers fear sanctions in case they make a mistake. Also, there is a time delay before the adapted practice produces the desired outcome. For example, the slow and gradual process that would lead to enhanced soil health and reversal in biodiversity decline, may only become evident in several years. Therefore, policies that take care of transitional funding with regard to climate resilience may be required. It is likely that this would need to be a hybrid policy involving public and private funds (habitat banking or other banking with payments for ecosystems services, conditional leases, guarantees, insurance). Furthermore, policies on educational programmes and training for farmers on the pathway to resilient food systems would be most helpful. Multiple options such as agronomic advice, business advice, mentoring and coaching, peer-to-peer advice would be considered. See any of the ten living labs scenarios highlighted within this document for examples to which policy changes are relevant.

Inter/trans-disciplinarity

While tackling the climate-food-biodiversity nexus can lead to significant synergies, cross-fertilisation and wins for each of the three elements (climate, food and biodiversity), it is important to understand the potential trade-offs that exist when using one of the three elements as a starting point. For example, food production exacerbates climate change through emissions of greenhouse gases and biodiversity loss through habitat conversion from natural environments to farmlands. In a world with multiple challenges, many different actors focus on single elements of the climate-food-biodiversity nexus leading to conflicts in views and actions between actors which are costly to society and detrimental for biodiversity. Interdisciplinary research and engagement are needed to tackle and overcome these trade-offs and conflicts by integrating natural sciences, social science and the humanities. Especially the social



sciences and humanities have the expertise and experience to include a wide range of stakeholders. Key elements of a transformational process towards sustainability in the food-climate-biodiversity nexus are the redistribution of power and social learning, leading to improved awareness, sustainable actions and behaviours among actors. This transformation is needed for removing conflicting interventions and policies as recommended in 2023 by the European Commission's Scientific Advice Mechanism (SAM). Moreover, going beyond the design of interdisciplinary solutions will be their testing and implementation in relevant situations, with further iterative learning that comes for applied such concept into transdisciplinary actions.

Systemic change in the food production system

When taking into consideration the current challenges facing food security, it has become evident that across all living labs examined in this project that change in practice is not easy. Some of the root causes to an inability to change, stems from either the lack of exploration of alternatives, the perception that there is an inevitability to future shocks and not much can be done, or that the farming system presents with too many „lock-in“ processes and policies, such that not much can be changed.

One of the lessons coming from these scenario design tasks is the presentation of an interdisciplinary approach to considering futures. Here, the potential shocks are prioritized through an analysis of drivers for each product, based on probability and severity of the shocks. By anticipating these shocks, farmers and their living labs can plan mitigation strategies to off-set the broader impacts of, for example, extreme weather events, soil erosion, or drought.

It must be taken into consideration that the living labs within Eco-Ready are a select group, in that they were chosen, in part, for their willingness to be experimental. Thus, they will be, in many cases, front-runners in testing new solutions within their regions. Nevertheless, it is of note that all living labs found current policies, subsidy schemes, and over-reliance on industrial actors, and of course economic constraints, to be major obstacles to the implementation to changing food production practices.



5 Conclusion

This Eco-Ready deliverable presents a comprehensive set of storylines resulting from the collaborative efforts of ten living labs across Europe and a scenario development team of experts. The team leveraged the key drivers of the products in the domains of climate change, biodiversity and food security projections for 2030 and 2050, to create detailed scenarios. By analysing key drivers such as drought, heat, biodiversity loss, pest invasion and others, the experts have developed a range of plausible scenarios. These scenarios (five per living lab) encompass the *status quo* (*one per living lab*), potential shocks (two per living lab) and strategic interventions (two per living lab) designed to mitigate the adverse effects of these shocks. These scenarios offer potential activities for the respective living labs to experiment with the suggested adaptation and mitigation strategies aimed at creating a more resilient food system.

Further, the scenarios have been crafted to address the complexity of interconnected externalities that influence sustainability in food systems. Given that each of the living labs have customized scenarios relevant to their region, there are commonalities among the living labs, either through shared drivers, products, or interventions. Here is an opportunity for cross-country, as well as cross-regional learning through the exchange of experiences.

This deliverable will serve as a foundation for Task 1.4 which is the modelling of future scenarios using the MAGNET model, as well as for Life Cycle Assessment modelling in Task 5.2.



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