



UNISECO

UNDERSTANDING & IMPROVING THE SUSTAINABILITY OF AGRO-ECOLOGICAL FARMING SYSTEMS IN THE EU

Deliverable Report D4.2 Report on Participatory Scenario Development of Agro-ecological Farming Systems

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EXECUTIVE SUMMARY

The UNISECO project aims to provide recommendations on how the sustainability of agro-ecological farming systems (AEFS) in Europe can be promoted. These recommendations build also upon scenario development and assessment of territorial effects of a large-scale implementation of agro-ecological farming innovations in the EU. This Deliverable describes in detail the scenarios and related storylines developed with stakeholders and first results from the biophysical modelling of the five scenarios using the BioBaM model.

Five storylines were developed in a participatory process involving all project partners and project stakeholders. The main determinants of the storylines are their level of implementation of agro-ecological farming practises and the localisation of food system (i.e. level of trade within the EU and globally). The first storyline **Business-as-usual**, extends the dynamics and critical aspects of current agri-food systems into the future and highlights current policy barriers to the expansion of agro-ecology. The second storyline, **Agro-ecology-for-export**, depicts a future in which medium-large agricultural farms and large companies in the food processing and distribution sectors promote a weak agro-ecological approach as a marketing strategy. The third and fourth storylines describe a future in which food systems are localised but for different reasons. In both these storylines, local foods, regardless of production methods, are given priority over agro-ecological farming practises. In consequence, production practises remain similar to current ones or further intensify. **Localisation-for-protectionism** do this for reasons of rising nationalism and protectionism, and calls the centrality of the EU into question and promotes further re-nationalization of agricultural policies. The **Localisation-for-sustainability** on the other hand promotes local food system not for protectionist reasons, but in an ambition to increase food system sustainability and resilience by cutting food miles and diversifying local production systems. The fourth storyline, **Local-agro-ecological-food-systems**, reflects the implementation of more advanced stages of agro-ecological transition – redesign.

The qualitative descriptions of the storylines are translated into quantitative inputs to be used in the biophysical modelling, including quantifications of diets (determining total demand), waste, production levels, livestock diets etc. Storylines are modelled at the NUT2 level and results are presented for land use, biomass production and consumption, rates of self-sufficiency and greenhouse gas emissions. Results show that a decrease in land use, land use intensity and greenhouse gas emissions can be achieved without compromising food security and regional food self-sufficiencies. Drivers behind sustainability improvements are an overall reduction of the size of the food system measured in total land use and in particular in total biomass production and in particular biomass production. This is achieved by combining consumption-side measures that mainly aim at realising less animal source food in diets, and production side measures, that aim at shifting from crop-based to roughage-based animal production on the one hand (an agro-ecological systems redesign), and at distributing the different production activities to the regions where they can be done most efficiently, as well as efficiency increases in general (expected yield increases, etc.). The choice of the production systems itself – agro-ecological, organic, or conventional in this case – is less relevant for greenhouse gas improvements than the reduction of the quantities produced. If demand and supply side measures are applied together and in close coordination, trade-offs between less intensive agricultural production and putting land aside for nature-based climate solutions are possible. Thus, a more sustainable and less intensive form of agricultural production that implements agro-ecological practices does not necessarily come at a high price for climate-change mitigation if the size of the total food system is reduced.

The results will be analysed further and more results will be added and analysed in the following months and reported in Deliverable D4.3. This will also include the assessments of the second biophysical mass-flow model SOLm, an intermediate assessment in 2030 and including an analysis of further indicators for environmental and social aspects, as well as certain economic assessments.

1. INTRODUCTION

This document describes the scenario development process that has been carried out to date within Task 4.3 in the UNISECO project. The overarching confronting question in UNISECO scenario development corresponds to one of the objectives of WP4 - what are the territorial effects of a large-scale implementation of agro-ecological farming innovations in the EU? Since the scenario development process is iterative (see section 3) descriptions of storylines and case study integration is subject to change as knowledge about the system under study increases as results from the modelling are gained.

The report is structured as follows: First, a short description of the use of scenarios and scenario development is given (section 2.1). A few existing studies based on the type of biophysical models that will be used in UNISECO are described shortly to give an understanding of the type of modelling that will be performed and outcomes of other previous modelling studies are briefly summarised (section 2.2). In section 3, the methodology and models used in UNISECO are described, including an overview of the stakeholder interactions to date and the main outcomes of these. Section 4 contains the results to date, including the five storylines in section 4.1 and the results from the biophysical modelling using one of the biophysical models, BioBaM in section 4.2. Section 6 presents the overall conclusions so far from the EU level modelling in the UNISECO project. Results from the other biophysical model, SOLm, including results when agroecological innovations are implemented, the results from the economic modelling as well as a more extensive discussion of the policy implications from the territorial modelling will be included in Deliverable 4.3.

2. BACKGROUND

2.1. The use of scenarios

Scenario development and other foresight activities have the common goal of enabling a structured way of thinking about the future and enable effective decision making (Wiebe et al., 2018). Scenarios are descriptions of plausible and possible futures that help investigate outcomes of different actions implemented today or in the future. A scenario has been defined as “*plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about driving forces and key relationships*” (MEA, 2005). Scenarios are also useful for engaging with stakeholders to increase knowledge and awareness of a certain issue and of outcomes of certain actions. They are also used for highlighting and discussing trade-offs and synergies, and handle conflicts of interest.

There are many different types of scenarios. A useful typology is that presented by Börjeson et al. (2006) which divides the scenario types into *predictive*, *exploratory* and *normative* corresponding to the following questions “What will happen?”, “What can happen?” and “How can a specific target be reached?” respectively. Predictive scenarios try to predict what a likely future will look like, using for example historic data, and are most useful for short-term planning purposes. A common assumption for predictive scenarios is that the existing governing systems stay constant within the period studied. When it comes to the agricultural sector, this could for example be agricultural policies and prices. A risk with predictive scenarios is that they can contribute to preserving past trends which might hinder desired goals. For example, predictive scenarios are often used for infrastructure planning based on historic data which might lead to increased investment in road

infrastructure which often increase traffic and associated negative impacts instead of paving the way for alternative mobility systems.

In order to study how the future could develop, one can use exploratory or normative scenarios instead of predictive scenarios. Explorative scenarios are similar to predictive scenarios, but are to a lesser extent based on how the situation is today and instead provide alternative situations where major changes are possible. Normative scenarios are based on reaching a specific target (e.g. GHG reduction targets) in one or more areas. In order to realise exploratory or normative scenarios, larger trend breaks are often needed.

Scenarios can be developed in a multitude of ways. However, all scenario development processes follow the approach illustrated in Figure 1. The Confronting questions, i.e. questions about the future, provide the entry point. An example of such a question investigated by Bock et al. (2002) was “How can genetically modified, conventional and organic crops coexist in European agriculture?”. In the “Structuring dialog” step, stakeholders are engaged in order to create a sense of ownership of the scenario in order to maximise the impact of the scenario development process. Scenarios are then designed jointly by stakeholders and experts in the “Designing scenarios” phase. The degree to which stakeholders are involved varies depending on the purpose of the exercise. Stakeholders may give input to expert-created scenarios, experts and stakeholders may co-design scenarios or stakeholders may lead the full process. Different approaches for the “Analysing impacts” phase are available, including qualitative and quantitative approaches. The latter involve modelling the outcomes of key variables. One of the most well-known scenario processes which is used extensively as a basis for quantitative modelling is the development of the Shared Socioeconomic Pathways (the SSPs) which are established by the climate change research community in order to study future climate impacts, mitigation and adaptation strategies (Riahi et al., 2017).

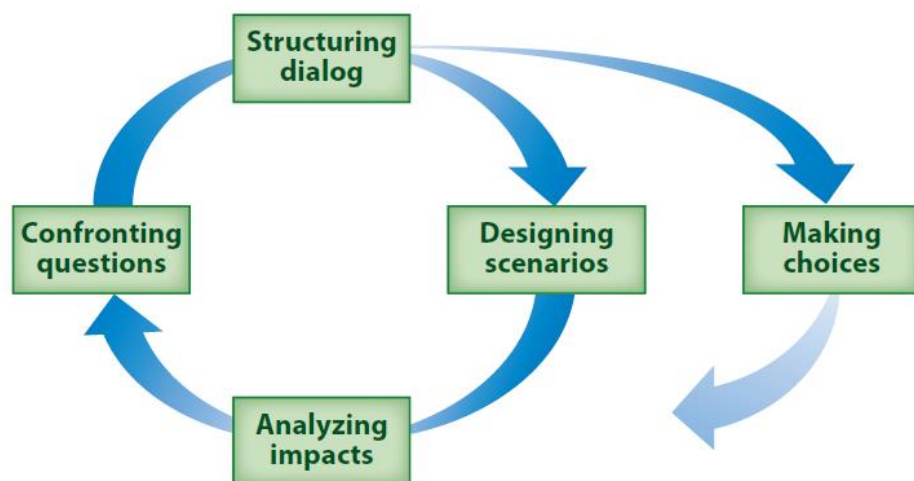


Figure 1: Key steps in scenario development and evaluation. From Wiebe et al. (2018).

Scenarios can be either purely qualitative or quantitative or include both qualitative and quantitative elements. A qualitative scenario is often called a scenario storyline or narrative and aims at creating an image of the future hence providing a broader perspective than quantitative modelling alone can do. Storylines describe the drivers of change, especially those for which the causal relationships within a system are not fully understood which prevents quantification of these in models. Storylines are especially useful for scenario

studies covering longer timeframes as uncertainties are larger (Rounsevell et al., 2010). Using quantitative models to calculate the consequences of alternative futures provides a way to artificially perform experiments about behaviour of the system.

Wiebe et al. (2018) summarise some key learnings from years of scenario development and especially highlight the need for *“clearly formulated questions, structured dialog, carefully-designed scenarios, sophisticated biophysical and socioeconomic analysis, and iteration”* for more effective decision making for a highly complex and uncertain future. It is important to note that scenarios are not always predictions nor always desired or realistic futures, but functions to provoke our perception and thinking of the world. That said to be useful scenarios need to be internally coherent, and interesting and relevant to the target audience.

2.2. Recent scenario work related to food and agriculture

Several scenarios have been developed that focus on the agricultural and land use (see e.g. Audsley et al. (2006), Stürck et al. (2018) and Wolf et al. (2015)). Recently, scenario development has also expanded beyond agriculture to take a food systems approach i.e. including both production and consumption in order to be able to determine how different aspects ‘add up’ on the regional scale, e.g. the whole of the EU. The importance of including the consumption level has become increasingly clear during the latest years in which several such studies using this approach have been published. For example, as organic production requires more land than conventional production, the impression could be that it would not be possible to feed the world on the existing cropland using organic production. However, this conclusion rests on the assumption that food consumption patterns stay constant, i.e. the same amount of food will still be needed (Smith et al., 2019). If consumption changes (which is the case when prices or preferences change), a number of options for high shares of organic production emerge, also without increasing land use or encroaching into forests (Erb et al., 2016; Muller et al., 2017). Conversely, if European organic agriculture expands and consumption does not change that would mean that agricultural production would be pushed into other regions, possibly creating negative effects there. Therefore, in UNISECO we aim at taking a broad food system approach. Below, three recent studies taking a food systems approach, i.e. including both production and consumption, performed by UNISECO team members are shortly described.

A recent study from the Nordic countries used an extensive stakeholder process to develop scenarios of a future food system, including both production and consumption (Johan O Karlsson et al., 2018; Johan O. Karlsson et al., 2019). Researchers worked together with five NGOs over a period of a year to iteratively develop a vision for the future of food production in the Nordic countries (Sweden, Norway, Finland and Denmark). The final vision was based on organic farming and lower meat consumption with livestock fed on pasture and by-products from food production. Stakeholders designed the future food vision by pinning down for them important principles which were translated into consequences for the food system and hence the assumptions relevant for subsequent modelling. The researchers modelled the outcomes of such a scenario for the Nordic food system (in terms of land and energy use, greenhouse gas emissions, foods produced, N and P flows). The results were then shown to and discussed with stakeholders in several workshops and the scenarios were refined based on these discussions. Results were then disseminated mainly by stakeholders and used for communication and advocacy purposes e.g. at two COP-meetings and at several national seminars.

Muller et al. (2017) investigated how high shares of organic production perform regarding a number of environmental indicators covering land use, deforestation, GHG emissions, N and P surplus, soil erosion,

pesticide use, cumulative energy demand and water use. They found that a switch to 100% organic production would result in large land use increases, by 30% in comparison to a business-as-usual scenario from FAO for 2050 (while not increasing GHG emissions). If combined with additional strategies, such as a reduction in food-competing feed (i.e. feed from arable land: cereals, forage maize, etc. that could be consumed directly) with correspondingly reduced shares of animal products in diets, and with reduced waste levels, food systems with 100% organic production are possible, and feasible across all the indicators investigated. A particular challenge for high shares of organic production is nutrient supply, as mineral nitrogen fertilizers cannot be used anymore.

Erb et al. (2016) developed a diagnostic model to assess the biophysical feasibility of 500 different scenario combinations of the global food system in 2050 without encroaching forests. Thus, they systematically combined realistic assumptions on future yields, agricultural areas, livestock feed and human diets. For each scenario, they determined whether the supply of crop products meets the demand and whether the grazing intensity stays within plausible limits, which they indicated as a feasible scenario. They found that many options exist to meet the global food supply in 2050 without deforestation, even at low crop-yield levels. Results showed, that within the option space, individual scenarios differ greatly in terms of biomass harvest, cropland demand and grazing intensity, depending primarily on the quantitative and qualitative aspects of human diets, and that grazing constraints strongly limit the option space. A recent study based on the same model (BioBaM) expanded the scope to also account for AFOLU emissions (Theurl et al., 2020). However, these studies only consider biophysical factors, economic costs and social desirability were beyond the scope of these study.

Apart from the above-mentioned studies there has been an increasing number of similar scenario development studies which all explore and attempt to predict what future developments could look like. One of the most comprehensive reports on the topic is the FAO's *The future of food and agriculture. Alternative pathways to 2050* (2019) which has served as the overall reference point in the scenario development in the UNISECO project (see section 3). Previous relevant scenario studies were reviewed in the UNISECO project in order to ensure uniqueness and relevance of the UNISECO scenario work.

It becomes apparent from previous work that drastic measures are needed to reach different sustainability targets. A good example of this is the Income & Environment-scenario in the Scenar 2030-report (M'barek et al., 2017) which shows that despite a restrictive compliance with agri-environmental objectives in the CAP and support levels being kept at current levels, key challenges in terms of environment and farmer incomes remain. It is also clear that for the environmental impact to be reduced in EU agriculture, production of especially animal products has to decrease which might negatively affect rural jobs. One way of achieving this is through further trade liberalisation and reduction in CAP support (the other scenarios in the Scenar 2030-report) – however such a strategy would not lead to overall decreases in greenhouse gas emissions (and other environmental impacts) as these would leak to other countries if consumption is not in some way moderated. This shows the need to handle both the consumption and production jointly, which is highlighted by several initiatives calling for an integrated EU food policy (e.g. iPES (2015)) or to accept trade-offs, as expressed in the Scenar-2030-report: “*As designing an agricultural policy that meets multiple goals is highly challenging, the policy might need to focus on some key objectives and accept the trade-offs.*”

There is a clear line of division between scenarios aimed at minimizing the climate impact, like the NetZero-scenarios (Lóránt et al., 2019) and A Clean Planet for all-scenarios (EC, 2018), and scenarios that take as their starting point in an agro-ecological future, like the IDDRI-scenario (IDDRI, 2019), the FAO TSS scenario (FAO,

2018b) and also Johan O Karlsson et al. (2018), with the later approach aiming at taking into account aspects like conservation of natural resources and biodiversity, and adaptation to climate change (IDDRI, 2019). The main differences are summarised in Table 1. Note however that even strategies aiming to reach climate neutrality in agriculture fail to do so. From the NetZero-report: *“Yet, even with such extreme changes, emission reductions do not reach net-zero and therefore reaching a climate-neutral agriculture may require the sector to compensate some unavoidable emissions through existing carbon sinks in other land using sectors such as forestry.”*

Table 1. Differences between scenarios aimed at reduced climate impact and with agroecology as their starting point

Climate focus	Agroecology focus
Large reduction of ruminant meat production and consumption	Large reduction in monogastric animals (as minimized feed-food competition is aimed for)
Intensive land use (increased yields and intensification of pastures) and animal production systems (breeding etc.) to spare land for carbon sequestration	More extensive land use (yields decrease in LIC)– a land-sharing approach or spared land is used for nature conservation
Both food and energy production from agricultural land is considered	Bioenergy production largely phased out and limited to e.g. biogas production on some biomass waste streams
Technology oriented	Nature based solutions prioritised

Some general conclusions from the existing scenario work are the following:

- The need to manage demand of animal products is highlighted in all reports but to a varying degree, if less emphasis is put on dietary change, the need for higher production levels increases
- How trade is managed is an important determinant for how food systems are organised
- There is different views on the need to produce non-foods on agricultural land, ranging from “managing the bioeconomy” to a total phase out of biofuel production
- If food is to be produced more sustainability, food prices will go up (especially if externalities are to be included in food prices), highlighting the need for a more equitable food system and society at large
- Significant investment and regulation (of e.g. trade) is needed to reduce negative impacts from agriculture

3. METHODS

3.1. Overview of methodology and models

In UNISECO, explorative scenarios for EU food systems with a focus on the incorporation of agroecological practices will be developed. Outcomes will be compared to 1) a baseline of a business-as-usual future based on the current situation, and 2) existing EU or global targets (e.g. EU greenhouse gas reduction targets and available agricultural land in the EU). A set of different assumption in terms of food waste reductions (e.g. assuming current levels or waste reductions of 50%) and dietary patterns (e.g. current, projected, healthy diet) will be included to illustrate how such changes affect outcomes in combinations with implementation of case study innovations.

The overarching confronting question in UNISECO scenario development corresponds to one of the objectives of WP4 i.e. **what are the territorial effects of a large-scale implementation of agro-ecological farming innovations in the EU?**

Scenario development in UNISECO follow a ‘story and simulation’ approach (Figure 2). This means that stories (here after called storylines) that qualitatively describe possible future developments (Rounsevell et al., 2010) are first articulated. To have more information regarding a range of quantitative parameters, for example greenhouse gas emissions, land, water and energy use etc. these storylines are then translated into numerical input and modelled in order to describe these futures in numbers. Results are then again presented to stakeholders and their input is used to refine the scenarios.

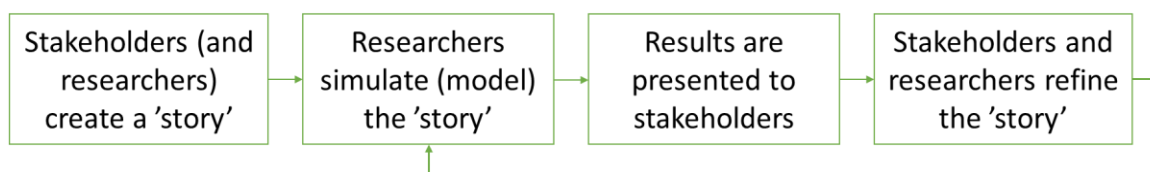


Figure 2: Scenario development approach in UNISECO.

The UNISECO scenario work builds on three main parts:

- The development of qualitative storylines providing a description of possible future developments
- Biophysical modelling providing information of consequences of biophysical outcomes from a combination of drivers (the option space) and outcomes from the specific storylines
- Macroeconomic modelling providing information on food prices, farmer income and policy options to reach the futures described in the storylines

Outcomes of these three parts form the UNISECO scenarios. Data and other input from a range of sources including the FAO scenarios (FAO, 2018b), the Decision Support Tools (DST) from WP3 and Eurostat, FAOSTAT etc. (see section 3.4, 3.5. and Deliverable D4.1). The modelling framework is depicted in Figure 3. This report presents the storylines and a subset of results from one of the biophysical models (BioBaM) while the rest of the results, including more environmental, social and economic indicators from the other biophysical model, and the results from the economic modelling will be presented in Deliverable D4.3.

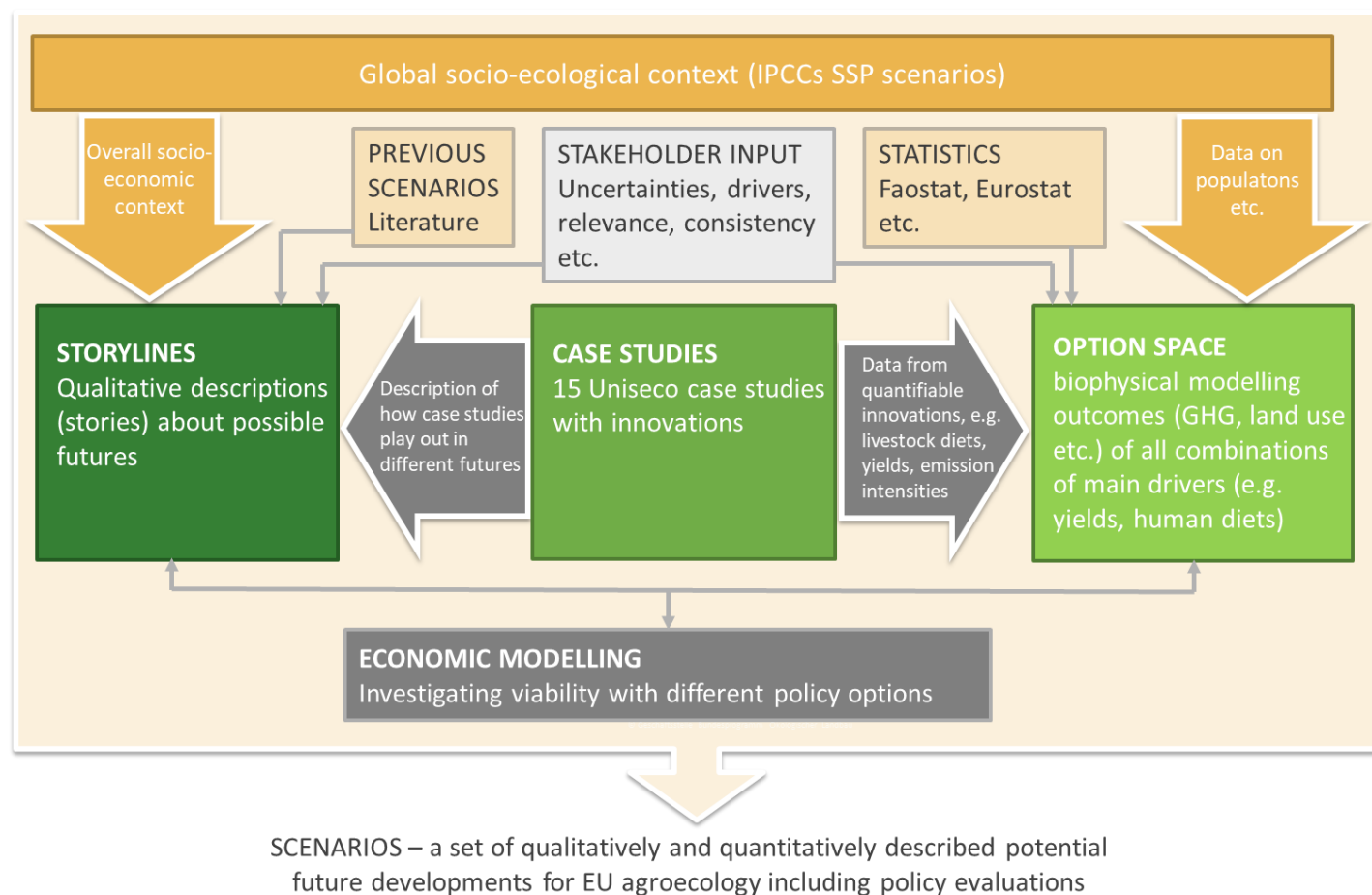


Figure 3: Scenario development framework in UNISECO.

3.2. Development of storylines

The commonly used and well-established matrix approach was used to create the storylines (Rounsevell et al., 2010). In this approach two important drivers or major uncertainties concerning the system under study are chosen and drawn out along two axis, forming a scenario cross. The axes create four quadrants, in which storylines consistent with the characteristics of the axes can be developed.

There are many challenges in successful storyline development. Storylines need to be salient (i.e. relevant to the policy question and stakeholders, explore a range of plausible futures including what could be considered surprises), credible (i.e. scientifically sound and consistent, revealing developers and stakeholder biases and expectations) and legitimate (i.e. societally accepted and transparent) (Pérez-Soba et al., 2015; Rounsevell et al., 2010). To ensure that storylines in the UNISECO project were salient, they were developed in an iterative manner involving EU level and local stakeholders. Stakeholder input was used to first identify the uncertainties on the two axes and then to iteratively refine the storylines. All project partners, hence representing knowledge and views from 13 EU member states and Switzerland and the UK, were also involved in the storyline development. Stakeholder interactions and their output is described in section 3.3. Stakeholder engagement was also used to ensure credibility and legitimacy of the storylines, and credibility is also given through (planned) publication of the scenario work in peer-reviewed journals.

3.3. Stakeholder interactions and storyline refinement

Table 2 summarises the stakeholder interactions that have been taking place so far in the scenario development process in UNISECO. Under the table the main outcomes of the stakeholder interactions are summarised.

Table 2. Overview of the stakeholder interactions in the scenario development process in WP4.

Time	Activity	Participants
1st of March 2019	First stakeholder workshop in Brussels with the following objectives: - Develop a shared understanding of the scenario development purpose and process - Create an understanding of which analyses are possible with the models that will be used in UNISECO and their relevance for EU policy assessment and development - Collect input from stakeholders on what should be explored in the scenarios	13 stakeholders representing the European Commission, farmer organisations and environmental NGOs, and 5 UNISECO researchers
9th of May 2019	Second follow –up workshop with stakeholders in Helsinki with the objective to further discuss the identified critical uncertainties; the level and type of implementation of agro-ecology and the level of trade.	14 stakeholders (PAG members and EU level MAPs), and UNISECO project members
July-Aug 2019	Written feedback from all project partners on the storylines, answering the following questions: - In what way (if any) do you find this scenario interesting and relevant? - Do you find this scenario plausible i.e. could the future develop in this direction? Are there current evidence of developments in this direction in your country? - As the scenario is described now do you see any major inconsistencies? - What kind of policy developments would be likely in this scenario? - How would your case study play out in this scenario?	All UNISECO project partners
14th of Nov 2019	Third workshop with stakeholders in Basel to gather feedback on the drafted storylines and further discuss issues of trade, case study innovations and policy.	19 stakeholders (PAG members, EU level MAPs and local MAP members), and UNISECO project members
14 th of May 2020	Fourth workshop with stakeholders – online to discuss updated storylines. Participants focussed on one storyline each and guiding questions for the group discussions were the following: - What would agro-ecological farming practices look like in this future in your country/context in this future? Area-wise, product-wise, production system-wise. - How would conventional agricultural practices have changed in your country/context in this future? - How would human diets look like? What foods would be traded and where to/from? - What policies or other developments could lead to this future? Are there signs today in your country of developments in this direction?	25 stakeholders (PAG members, EU level MAPs and local MAP members), and UNISECO project members

	If you find the scenario assigned to you not interesting / not plausible / not desirable – why is this?	
July-Aug 2020	Written feedback from all project partners on the refined storylines, answering the same questions as in the previous consultation.	All UNISECO project partners

At the first workshop in March 2019, the first discussion centred on the usefulness of the scenario approach in general, its pros and cons, and potential limitations to overcome. The purpose of this discussion was to gain insights that would make the scenario development in UNISECO relevant to stakeholders. Issues raised here included the necessity to include many environmental aspects, not just greenhouse gas emissions as has many previous studies, but aspects such as eutrophication and pollution of oceans, impact on biodiversity, as well as social and economic aspects. One limitation to date in modelling that was highlighted was the lack of spatial resolution. Another challenge to overcome is to include also social and economic sustainability aspects, most current food systems studies focus on environmental sustainability. However, stakeholders acknowledge the difficulty in modelling outcomes of policy implementation over long time periods. Stakeholders brought up the difficulty in building realistic and interesting dietary scenarios and the need for dietary scenarios to be country specific. Next, time horizons were discussed and there was quite strong consensus among stakeholders that a time horizon of 2030 would be the most relevant although 2050 was also deemed interesting in order to cover more long term developments. However, stakeholders justified using 2030 by alignment with the Sustainable Development Goals and the 2030 Agenda. There were quite strong opinions that 2030 is much more relevant and that UNISECO should definitely include 2030, at least as a linear development until 2050 and including 2030 as a mid-point.

In order to find the critical uncertainties on which to base the scenario development, stakeholders were further asked to give their view on the most important uncertainties related to the future supply and food in the context of the UNISECO project. Food security/food sovereignty in relation to open-trade was a key issue raised by several stakeholders. There were differing views on what is preferable here and to what degree food should be traded internationally. This is relevant on an EU scale i.e. self-sufficiency of the EU versus global trade, but also within the EU. For example, investigating the benefits of keeping supply chains short. However, stakeholders highlighted that scenarios have to be plausible to be relevant (for example, closed border scenarios are not relevant), while they can show a range of trade options. In addition, as agro-ecology supports food sovereignty and EU is for open borders, there are concerns with agro-ecology for that reason. Other uncertainties that were mentioned included climate change and loss of biodiversity (e.g. pollinator) impacts on yields, the level of bioenergy production, biotechnology, the level of segmentation of markets (local foods, expensive luxury foods etc.) and implementation of precision farming.

Based on the discussions at the first stakeholder workshop it was decided by the WP4 team to continue with the following two critical uncertainties as the main focal issues in the scenario development; 1) the level of implementation of agro-ecological farming practises, and 2) the localisation of food system (i.e. level of trade within the EU and globally). Therefore, in Helsinki a short follow-up workshop was held in which stakeholders were asked to give their view on these issues. Based on these discussions the WP4 team drafted four initial storylines (qualitative descriptions), see section 4.1 for an overview. These storylines were sent out to all project partners which were asked to reflect upon the relevance, plausibility and consistency of the storylines, and to consider how their case study would play out in the different scenarios. Based on this feedback, the storylines were refined and thereafter sent out to stakeholders participating in the Basel project meeting in November 2019. Here the storylines were discussed in a large group among participants. The major critique raised by several stakeholders and also some project members was the nationalistic framing of the future in

which local food systems developed in combination with a low level of implementation of agro-ecology. However, other stakeholders and project members found that future highly relevant and interesting. To cater for this, a fifth storyline was added (see section 4.1 and 4.5). Based on these discussions, the WP4 team also further refined storylines and also aligned them more with the SSP scenarios. On an online workshop (due to the COVID-19 situation) the updated storylines were discussed with stakeholders and project members in four breakout groups. Each group discussed one of the storylines each (except the Business-as-usual storyline) focussing on finding inconsistencies in scenarios and anchoring them more in local contexts. The storylines were slightly updated based on discussions in the groups and sent out again to all project partners to gather further input. However, no major revisions were made at this stage as feedback as no major inconsistencies were pointed out at this point. Outcomes from the online workshop were also used to refine modelling input, i.e. the translation from storylines to quantitative model input.

3.4. Biophysical modelling

3.4.1. Overview of the BioBaM model

In UNISECO, two biophysical mass- and nutrient-flow models – BioBaM and SOLm – are used to model the outcomes of the storylines. In these models, the EU is divided into 227 regions (NUTS2-level, for more details see Uniseco Deliverable 4.1). The aim of applying BioBaM and SOLm is to understand the wider scale implications and feasibility of the diffusion of agro-ecological farming systems at different spatial scales and across a range of consumption levels. BioBaM is spatially explicit and thus provides the basis for detailed spatial assessment and allows for integration of the impacts of land use change induced by the diffusion of agroecological farming systems. It covers (1) changes in the flows of biomass from cropland and grasslands and induced land use changes, (2) GHG emissions from agricultural production including upstream flows and land use change, and (3) biodiversity pressures as indicated by the HANPP (human appropriation of net primary production) framework. SOLm in turn follows a similar approach, it is however not spatially explicit, but relies on more detailed modelling of agronomic aspects of the production systems (e.g. for animal production systems with herd structures and correspondingly differentiated feed supply, nutrient excretion and emissions), thus providing the basis for detailed assessment of various production systems.

As mass- and nutrient-flow models, BioBaM and SOLm do not include an endogenous decision structure, such as an assumption of profit-maximizing farmers. They serve to line out the biophysical option space of potential agro-ecological futures with a focus on potential synergies and trade-offs between different aspects. This allows for assessment of the biophysical viability of various storylines developed in participatory workshops without any restriction on how farmers may make their decisions on farming operations, on how these production changes may affect prices and on how consumers and trade may react to price changes. Evaluation of the consequences of these scenarios in a political and economic context is thus not part of these two models but is assessed separately by complementary macroeconomic modelling. This then indicates how compatible certain scenarios in the option space are with common economic incentive and decision structures, how much these scenarios may deviate from the current or business as usual future situation, and how strong potential economic instruments or assumptions on changed consumer preferences thus may need to be to achieve those scenarios. This approach facilitates transparent analysis of the system-specific trade-offs and synergies and helps to identify the option space within which societally acceptable solutions then have to be found. This report is limited to the results obtained with the BioBaM model. Results from SOLm and the economic modelling will be presented in Deliverable 4.3.

3.4.2. Indicators used

Key indicators to capture and communicate the results from models cover the central aspects of the sustainability of agro-ecological farming on EU-level. The core results will be presented on aggregate EU level with due regionalisation (down to NUTS 2), based on the results from the two models BioBam and SOLm.

The main strength of BioBaM and SOLm is the combination of a broad variety of different parameters supply and demand food system parameters such as cropland and grassland yields, area expansion, livestock systems, and human and livestock diets. The models assess the biophysical feasibility of these combinations, which are considered as different options in the option space, and are able to show systemic interlinkages between the individual parameters, e.g. synergies and trade-offs at higher spatial and thematic levels. These parameters are currently: Human diets, livestock diets, wastes and losses (demand side), and cropland yields, grasslands yields, maximum cropland allowances. Baseline data is taken from the CAPRI model (Britz et al., 2015) and complemented with additional data where necessary (Herrero et al., 2013; Plutzar et al., 2016). Currently, the ranges of these parameters for the scenarios in 2050 are derived from well-established and published agricultural outlooks such as the Food and Agriculture Organization (FAO or the EAT-Lancet commission). In BioBaM, a series of indicators and environmental effects are calculated for each storyline (see Table 3). For more details on indicators see Deliverable D4.1.

Table 3. Overview of the indicators used in BioBaM.

Indicator	Items
Land use (Mha)	Cultivated cropland
	Grazing land
	Fallow cropland
	Cropland converted to grazing land
	Cropland left to natural succession
	Grazing land converted to cropland
	Grazing land left to natural succession
Cropland area by cropgroups (Mha)	14 crop groups
Grazing land by classes (Mha)	All grazing class names and 'original cropland'
Net imports by cropgroups (Mt)	All cropgroup names
Crop production (Mt)	All cropgroup names
Crop consumption for food (Mt)	All cropgroup names
Crop consumption for feed (Mt)	All cropgroup names
Crop residues used as feed (Mt)	Crop residues
Crop consumption for feed by agriproduct (Mt)	All agricultural product names , followed by ' - ' and all cropgroup names
Crop residues used as feed by agriproduct (Mt)	All agricultural product names , followed by ' - crop residues'
Crop consumption for other uses (Mt)	All cropgroup names
Agri.products production (Mt)	All agricultural product names
Agri.products consumption for food (Mt)	All agricultural product names
Agri.products consumption for other uses (Mt)	All agricultural product names

Grass supply (Mt)	All classes
Grass demand (Mt)	Total grazed biomass
Grazing intensities (1)	All grazing class names and 'original cropland'
Potential self-sufficiency (1)	Land-based self-sufficiency on region level
	Land-based self-sufficiency for regional aggregates level 1
	Land-based self-sufficiency for regional aggregates level 2
Self-sufficiency (all crops) (1)	all crops
Self-sufficiency by crops (1)	All cropgroup names
	All cropgroup names
	All cropgroup names
Self-sufficiency by agri.products (1)	All agricultural product names
	All agricultural product names
	All agricultural product names
GHG emissions from land use change (annual) (Mt CO ₂ e)	Total annual LUC emissions
GHG emissions from land use change (cumulative) (Mt CO ₂ e)	Total cumulative LUC emissions
GHG emissions from manure management (Mt CO ₂ e)	All agricultural product names
GHG emissions from enteric fermentation (Mt CO ₂ e)	All agricultural product names
GHG emissions: upstream emissions by cropgroup (Mt CO ₂ e)	All cropgroup names
TBA: Harvested biomass as share of total NPP _{pot} (1)	A proxy indicator for HANPP, the human appropriation of net primary production
Regional grazing feasibility (1)	Regional grazing feasibility

In this deliverable, the following headline indicators are calculated:

1. Total GHG fluxes resulting from a) the emissions from soil management through the application of fertilizers, manure application and amounts of crop residues that are left on fields, b) emission from manure management, c) the upstream emissions for the external inputs, i.e. mineral fertilizers, fossil fuels required for land management (see below), d) emissions from enteric fermentation as well as e) carbon sinks created due to land abandonment (see above). This assessment follows IPCC best practice guidelines (Dong et al., 2019). Additionally, we draw a distinction between GHG emissions including or excluding carbon emissions from land use change.
2. A surrogate indicator for the “Human Appropriation of Net Primary Production”, an index for land-use pressures on biodiversity, was constructed by calculating the total amount of agricultural appropriation (TBA) per prevailing potential NPP on each NUTS2’s utilized agricultural area (see, e.g. Erb et al. (2016); Pelletier et al. (2010)).
3. For all NUTS2 regions the self-sufficiency ratio (domestic production per domestic consumption) for crop products and monogastric and ruminant livestock products is assessed (Mayer et al., 2020).

3.4.3. Modelling input

In order to model the outcomes of the qualitative storylines, these had to be translated into quantitative input for the biophysical models. The model input for the different storylines are summarised in Table 4.

Table 4. Model input for the different storylines. RUMI = ruminant livestock, MONO = monogastric livestock. EFF = efficiency, CL = Cropland, GL = Grassland, EU = European Union, Row = rest of world, NUTS = Nomenclature des unités territoriales statistiques, BAU = business as usual, LS = livestock, AE = agro-ecology.

	BAU	Agro-ecology-for-exports	Localization-for-protectionism	Localization-for-Sustainability	Local-agro-ecological-food-systems
Population	FAO 2019. Country-wide changes applied to NUTS regions				
Diets	FAU BAU	FAO TSS	FAU BAU	Eat Lancet (Willett et al. 2019)	Eat Lancet with higher shares of beef/dairy instead of pig/poultry (Willett et al. 2019)
Waste levels	Current levels	Current levels	Current levels	-50%	-50%
Livestock diets	CAPRI (EU), Herrero et al. (2014) for RoW	Grass-based RUMI, -10% EFF MONO	CAPRI (EU), Herrero et al. (2014) for RoW	CAPRI (EU), Herrero et al. (2014) for RoW	Grass-based RUMI, -10% EFF MONO
Animal products distribution	Current patterns	AE re-distribution to CL/GL potentials within EU	AE re-distribution to CL/GL potentials within country	AE re-distribution to CL/GL potentials within country	AE re-distribution to CL/GL potentials within country
Cropland expansion (allowance)	+20%	+70%	+70%	none	none
Usage of free areas if CL 2050 < CL 2012	Vegetation regrowth				
Maximum Grazing intensity (Harvest/NPPact)	Standard	Standard	Intensification	Extensification	Strong extensification
Conventional yields	BAU	BAU	BAU	BAU	BAU
Share of land under AE practices	Same as in 2012	Specific for crop groups and LS products (high share under AE practices)	Same as in 2012	Specific for crop groups and LS products (medium share under AE practices)	Specific for crop groups and LS products (high share under AE practices)
Share Conventional	100	All other	75	75	50

Share Organic / AE	0	Fruits, Vegetables, Nuts (100% Organic)	25	25	50
Cropland yields: organic systems	Lower yields for all crops (based on Ponisio et al., from Seufert et al. 2018), reflecting also areas needed for legumes, no fossil-based N fertilizer				
Trade clusters	Global trade, no restrictions	EU-wide trade first, then to RoW	Country-wide trade first, global trade only if deficits Surplus production in Europe for exports.	Country-wide trade first, global trade only if deficits	Country-wide trade first, global trade only if deficits

Implementation of baseline practices

The baseline consists of the current mixture of conventional and organic systems, i.e. the cereal yields per NUTS2 region are the result of organic and conventional systems in BioBaM. We define the baseline as the 2012 mix.

Baseline practices are the same across scenarios. Cropland yields, livestock feeding efficiencies, nitrogen use and energy efficiencies in the agricultural sector develop according to projections in the FAO Business-as-usual scenario. As for other land uses, e.g. fibers and biofuels, these were accounted for according to the FAO commodity balances as in 2012 (FAO, 2018a) and held constant across all scenarios.

Diffusion rate of agro-ecological practices

For the scenarios with a low level of implementation of agro-ecological practises (Business-as-usual, Local-for-protectionism and Local-for-sustainability) we model these as if the implementation rate does not change, i.e. it corresponds to the current situation (data from 2012). This baseline situation includes a combination of organic and conventional production reflecting the situation in 2012. The land under organic practices in 2012 was 5.7% in the EU, ranging from 0.3% on Malta to 19% in Austria (Eurostat, 2020).

In the scenarios with high implementation of agroecological practices (AE-for-exports and Local-AE-food-systems), we model this as a 50% diffusion rate in terms of land use under agroecological practises in 2050. (The EU Farm-to-Fork strategy has a goal of 25% of organic farming in 2030). In the AE-for-exports, AE practices will only expand for certain export-oriented products. These are fruits, vegetables, wine, oil and nuts and milk (in the form of milk powder). In the Local-AE-food-system we assume the same diffusion rate for all crops and livestock production systems i.e. 50% of all wheat, 50% of all pork (however total absolute numbers of these will change following dietary changes i.e. food demand).

Implementation of agro-ecological practices in models

The implementation of agroecological practices in cropping are modelled as yield reductions based on Ponisio et al. (2015) which in turn determines the needed nitrogen input (according to crop needs). If land use is under organic practices, an area of legumes is added in order to supply nitrogen.

As for livestock diets, the starting point in BioBaM are the livestock diets from CAPRI for the EU, while for the rest of the world livestock feeding ratios from Herrero et al. (2013) were taken. CAPRI livestock diets were converted to feed conversion ratios, i.e. feed input (DM) / animal product (DM). The differences between organic and conventional monogastric production, was implemented as a yield gap of 10%. For eggs, the yield

gap refers to output per animal per year; for pork, the yield gap refers to slaughter weight. In organic systems, often the same slaughter weight as in conventional systems is reached, but after a longer time (and higher feed use) than in conventional systems. The model is set up in such a way that this can be captured equivalently by using a lower slaughter weight. In the agro-ecology for exports and the local AE-systems scenarios, ruminant livestock production is based on grass and by-products from sugar and oil crops (amounts depending on local availability) only.

Livestock production in all scenarios except Business-as-usual is re-linked to domestic production potentials. This means that in the Localization-for-protectionism, Localization-for-Sustainability, and Local-AE-food-systems ruminant and monogastric livestock production in the year 2050 follows grassland (ruminant livestock) and cropland (monogastric livestock) production.

Diets and waste

In the Business-as-usual, and the Local-for-protectionism scenarios, the diets follow FAO Business-as-usual projections, in the Agro-ecology-for-exports scenario follows FAO TSS projections (i.e. a sustainability oriented scenario), while in scenarios Local-for-sustainability and Local-AE-food-systems, diets change to reach the EAT-Lancet diet (Willett et al., 2019) in 2050. In Local-for-sustainability, amounts of foods follows the EAT-Lancet strictly while in the Local-AE-food systems, ruminants are linked back to land, i.e. increasing ruminant production in Europe to a maximum extent of domestic grassland biomass and by-product biomass availability per NUTS region. By-products will be complemented with cereals to accomplish suitable pig/chicken diets. If the red meat limit is reached, only chicken will be produced instead if there are remaining by-products (on by-products and some cereals).

Trade

The self-sufficiency rates of regions and countries in cropland products depend on the area availability and diets. Thus, if domestic cropland from the year 2012 is not enough to cover local demand, cropland expansion into suitable grasslands is allowed. For example, in the Localization-for-protectionism scenario, a 70% expansion of cropland into suitable grassland in relation to the land use in year 2012 is allowed. If this is not sufficient, regions are allowed to import. In the Agro-ecology-for-exports scenario, net-deficits in EU regions are firstly covered from surplus within the EU. If regions have spare cropland and global demand exists, regions utilize cropland for the production of export goods, high value products (fruits, vegetables, nuts) are produced in an agro-ecological system. We distinguish three trading cluster. Firstly, within one country, secondly within the European Union, thirdly global trade. We further prioritize imports from specific trade clusters in each scenario, and only if these are not sufficient to close net-trade deficits, trade from beyond the prioritized cluster is allowed.

4. RESULTS AND DISCUSSION

4.1. The storylines

The storylines form the qualitative context (i.e. narratives) in which the quantitative outcomes from the modelling should be interpreted. The development of the storylines builds on the input gathered through the stakeholder participation process (see section 3.2), and literature data (review of recent scenario studies). The storylines were developed in an iterative manner with several points of stakeholder interactions (see section 3.3).



The storylines are formed out of the following two dimensions, which were identified by stakeholders as some of the key dimensions that determine the future food systems:

- Level of implementation of agro-ecological farming practises
- Localisation of food system (i.e. level of trade within the EU and globally)

Out of these uncertainties, five storylines are drawn up as illustrated in Figure 4. The first one, 1) **Business-as-usual**, extends the dynamics and critical aspects of current agri-food systems into the future and highlights current policy barriers to the expansion of agro-ecology. The second storyline, 2) **Agro-ecology-for-export**, depicts a future in which medium-large agricultural farms and large companies in the food processing and distribution sectors promote the agro-ecological approach as a marketing strategy. This brings out the duality between the production of added-value goods for the global markets and that of low-cost food commodities. Hence, this storyline is a case of industrial ecology, in which a weak level of agro-ecology is widely implemented, justified primarily for reasons of market demand from consumers. In the third quadrant of the scenario cross, two storylines arise, Localisation-for-protectionism and Localisation-for-sustainability. Both are based on more localised food systems and with a low level of implementation of agro-ecological practices, but for different reasons. In both these storylines, local foods, regardless of production methods, are given priority over agro-ecological farming practises. In consequence, production practises remain similar to current ones or further intensify. 3a) **Localisation-for-protectionism** do this for reasons of rising nationalism and protectionism, and calls the centrality of the EU into question and promotes further re-nationalization of agricultural policies. The 3b) **Localisation-for-sustainability** on the other hand promotes local food system not for protectionist reasons, but in an ambition to increase food system sustainability and resilience by cutting food miles and diversifying local production systems. The fourth storyline, 4) **Local-agro-ecological-food-systems**, reflects the implementation of more advanced stages of agro-ecological transition – redesign. This future might be difficult to implement given the forces that today block changes in production systems including large agri-food companies and stakeholder interests for the current structure of the CAP. A radical change would be needed to reach the future described in storyline four. The Local-agro-ecological-food-systems storyline differs from the Localisation-for-sustainability in the that the later relies more on the route of ‘sustainable intensification’ and technology for reaching sustainability, while the Local-agro-ecological-food-systems embraces the agro-ecological approach to food system sustainability¹¹. The storylines are further described in section 4.1.1 to 4.1.5.

¹¹ For an explanation on the ‘sustainable intensification’ concept versus agro-ecology see e.g. Bernard et al. (2017); Godfray (2015) and Garnett et al. (2013).

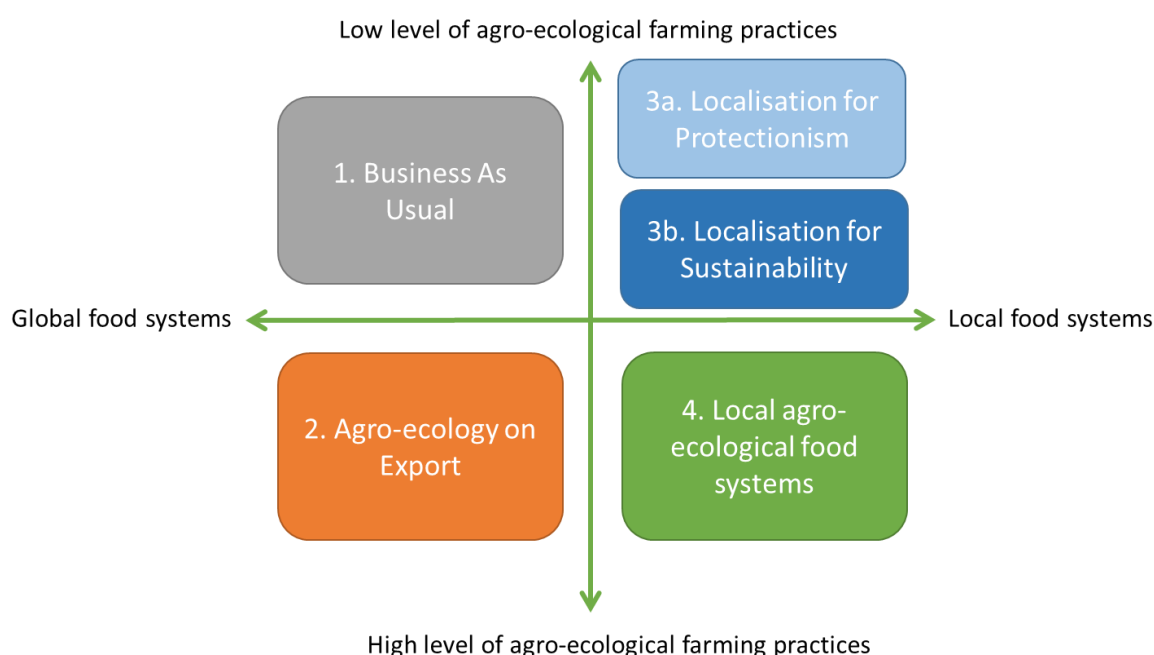


Figure 4: The UNISECO storylines.

The UNISECO narratives build on the Shared Socioeconomic Pathways (SPP) developed by the climate change community and commonly used as a basis in recent scenario development, e.g. in the latest FAO scenarios (FAO, 2019). The SSP narratives are described in O'Neill et al. (2017). The SSPs are qualitative descriptions of socio-economic future developments that can be combined with greenhouse gas concentration trajectories known as the Representative Concentration Pathways (RCPs) to be run in Integrated Assessment Models (IAMs). SSP deliberately do not give all numerical information, which gives modellers freedom of interpretation (Riahi et al., 2017). SSPs do not directly include any effect of climate change or any climate change policies, but are consistent with various RCPs.

An overview of the main characteristics of the storylines are given in Table 5.

Table 5. Storyline overview

	1 Business-as-usual	2 Agro-ecology for exports	3a Localisation for protectionism	3b Localisation for sustainability	4 Local agro-ecological food system
Global socio-economic context	SSP2 – Middle of the road	SSP5 - Fossil-fuelled Development – Taking the Highway	SSP3 - Regional Rivalry – A Rocky Road	SSP1 – Sustainability – Taking the Green Road	SSP1 - Sustainability – Taking the Green Road
Corresponding FAO scenario	BAU (builds on SSP2 with elements of SSP3)	BAU (builds on SSP2 with elements of SSP3)	BAU (builds on SSP2 with elements of SSP3)	TSS (builds on SSP1)	TSS (builds on SSP1)
Trade	Increased trade between member states and with non-EU countries	Even higher level of trade compared to the BAU-scenario	Decreased trade between members states and with non- EU countries, protective trade policies	Decreased trade between members states and with non- EU countries due to deliberate support for local food systems	Decreased trade between members states and with non- EU countries, protective trade policies
EU agricultural policy developments	A continuation of current policies	Continuation of current policies, but heavy focus on investments to expand exports.	A continuation of current policies, but a less centralised CAP	A continuation of current policies, but a less centralised CAP	Integrated food policy, heavy focus on local agro-ecological food systems
Type of agro-ecological practises in the EU	Mainly weak	Mainly weak	Mainly weak	Mainly weak	Mainly strong
Technological developments	SSP2: Moderate developments, tech developed in high-income countries only slowly shared	SSP5: Widespread technology optimism	SSP3: Very slow tech developments, including agricultural tech with limited tech transfer to developing countries	SSP1: Rapid tech development focussed on energy efficiency, clean energy and yield-enhancing tech for land, including in agriculture	SSP1: Rapid tech development focussed on energy efficiency, clean energy, with more nature based solutions in agriculture
Energy system developments	SSP2: Slow decrease in fossil fuel dependency, growing energy demand	SSP5: Low investments into renewable energy, major investments in fossil	SSP3: Maintaining domestic energy supplies, unconventional fossil fuel resources	SSP1: Increase in energy efficiencies, phase out of fossil fuel subsidies	SSP1: Increase in energy efficiencies, phase out of fossil fuel subsidies

Food consumption patterns (EU)	As now, develop according to current trends	As now, develop according to current trends	As now, develop according to trends, but with more local foods	Less impacting and more local, more high-tech and more local	Less impacting (reduced animal consumption), more local foods
Food waste in the EU	As now, or slightly decreased	As now, or slightly decreased	Slightly decreased	Decreased by 25-50%	Decreased by 25-50%

*The rates will be different between different member states, scaled up for different products based on current shares, environmental awareness or similar. TBD.

4.1.1. Storyline 1: Business-as-usual

Globalised food systems - current level of implementation of agro-ecological farming practises

Global context

The SSP2 scenario, Middle of the Road, provides the overall context for this storyline. In the SSP2 scenario, it is assumed that the historical social, economic and technological trends are sustained, income growth develops unevenly and there is slow progress towards reaching sustainability goals (O'Neill et al., 2017). Technological developments are moreover modest and only slowly shared with developing countries. Low-income countries continue to experience food and water insecurity. There is a slow decrease in fossil fuel dependency and a growing energy demand (SSP2).

Food system orientation and policy landscape

Based on this, the Business-as-usual storyline describes a future in which globalisation of the EU food system continues². In this system, farmers are incentivised to produce low value commodities leading to further specialisation of farming systems and regions. Trade increases both between EU member states and between the EU and global markets - specialisation in production in different regions continues (SSP2). A few multinational food industries and retailers dominate the global food market. Diets and the range of products on offer become increasingly homogeneous both within the EU and globally. Obesity levels continue to rise as does its associated health problems.

On a global level there is weak cooperation between international and national institutions, the private sector and civil society (SSP2). Access to global markets are slowly opening up for developing countries. The structure of the EU agricultural policy remains similar to the current CAP and continues to drive agriculture production towards specialised, large-scale and export-oriented agricultural production. The EU budget is somewhat decreased due to Brexit; however, most member states push for keeping the EU agricultural budget constant and rather decrease expenses in other areas. The CAP structure is similar to today; Pillar 1 has low requirements for greening. Although Pillar 2 includes support for e.g. organic production and other agro-ecological practises, variation in the implementation rate of such agro-environmental policies is large between countries and efforts uncoordinated, due to further increasing freedom for member states to allocate CAP money. Although there is an ambition at the EU-level for more agro-ecological practices (cf. The Farm to Fork Strategy) these are only half-heartedly supported by most national governments. There is a constant discussion on the ability of agro-ecology to “feed the world” and a push from large multinational agro-chemical and seed companies to implement more industrialised types of agriculture. There is only weak or no policy targeting demand in EU member states, such as taxes on unhealthy or high-impacting foods, restriction on advertisements and similar – these have been effectively counteracted by powerful lobbying groups.

² The organisation of the EU food system is in this scenario well described by Therond et al. (2017) socio-economic context for farming called “Globalised commodity-based food systems” in which increasingly efficient industrial processes are used to “produce large amounts of food that are inexpensive, convenient, safe and attractive”.

Agricultural production and practises

As for production trends, these are assumed to continue similar to the trends described by the EU Agricultural Outlook³ which assumes:

- “• a continuation of current agricultural and trade policies;
- normal agronomic and climatic conditions;
- no market disruption”.

In summary, the outlook is as follows: The utilised EU agricultural area will continue to decrease by 0.2% per year reaching 172 million ha by 2030. Although total sugar consumption decreases by 5% by 2030 because of increased health concerns, total sugar production increases by 12% by 2030, making the EU a net sugar exporter. Cereal production also increases to 341 million tons by 2030 while oilseed production will decrease due to decreased demand for biofuels. The production of feed is expected to rise due to increases in poultry, dairy and intensive beef production. Dairy exports to China are expected to increase considerably with the EU supplying 30% of the increase in dairy products mainly as cheese and skimmed milk powder. Dairy consumption increases also within the EU up to close to 900,000 tons of milk per year, mostly consumed as cheese, other processed dairy products and included in convenience foods. Milk drinking meanwhile decreases. Meat consumption per capita first slightly increases but then decreases to current levels in 2030. Beef production decreases slightly while pigmeat will increase marginally (consumption in the EU stabilises and exports increase somewhat). Poultry meat production increase by 5% until 2030.

It is assumed in this storyline that the same trends continue beyond 2030 until 2050.

Consumer interest in healthier and more sustainably produced foods including organic foods and locally produced foods increases somewhat in the EU in this storyline. However, due to lack of major public investments in, or support for the implementation of agro-ecological farming methods, these remain close to current levels on average (the share of organic farming area was 7.5% in 2018⁴) or increase slowly (reaching an average of somewhere between 10-15% of agricultural land in 2050) although with large regional variation. Certified organic products, produced using mainly weak agro-ecological practises, dominate the output from the agro-ecological farming systems in the EU; these come in the form of high-value products like wine and other alcoholic beverages, fruits and vegetables, cheese and charcuteries, jams and juice etc. sold in niche markets to high-income urban citizens, as well as cheaper bulk commodities sold in ordinary supermarkets. Diversity in crops produced in the EU are constant from current levels or somewhat further decreased (following trends in Kummu et al. (2020)).

Diets and waste

Food waste levels remain similar to current levels or decrease somewhat in countries in which waste reduction policies are implemented. Diets are not substantially changed but follow current trends.

³https://ec.europa.eu/agriculture/sites/agriculture/files/markets-and-prices/medium-term-outlook/2017/2017-fullrep_en.pdf

⁴ https://ec.europa.eu/eurostat/statistics-explained/index.php/Organic_farming_statistics

4.1.2. Storyline 2: Agro-ecology for exports

Globalised food systems - high level of implementation of agro-ecological farming practises in the EU

Global context

The SSP 5 scenario, Fossil-fuelled Development – Taking the Highway, forms the basis for this storyline. In this future, focus is on competitive markets, innovation and participatory societies with the goal of reaching sustainable development through rapid technological progress and diffusion, including geo-engineering if needed (O'Neill et al., 2017). Integration of global markets continues with further removal of trade barriers, including giving access to disadvantaged actors, leading to high levels of international trade. The increased global wealth leads to the adoption of resource and energy demanding lifestyles by the growing global middle-class as developing countries follow the resource and fossil energy demanding developments of industrialised countries. Faith lies in solving the environmental consequences of this with different types of engineered technical solutions (SSP5). There is low investments into renewable energy while major investments in fossil energy continues (SSP5).

Food system orientation and policy landscape

In this storyline, food systems, as other sectors, have become increasingly globalised with high trade both within the EU and across the globe. In the EU specifically, strong support for and investment in organic farming following the goals set up in the Farm-to-Fork Strategy launched in 2020 (EC, 2020) has led to a large increase in land managed with (weak) agro-ecological practises and the total area reach somewhere between 20-50% in 2050⁵. Although the initial ambition in the Farm-to-Fork Strategy was to promote organic production to reduce environmental pressures, the main driver has gradually changed to using agro-ecological approaches (in this future interpreted as organic farming) as a means to produce high-value foods for trade between EU member states but also for exports to the newly affluent economies where a rapidly growing upper and middle class (SSP5) is demanding “clean and healthy” foods, especially foods low in pesticide residues, but there is also an increasing awareness among consumers on the risks with industrial livestock production after a series food related crisis such as zoonosis outbreaks and problems with antibiotic resistance, making them demanding organic foods.

Since most commodities are traded on the EU or global markets which require large-scale production able to deliver stable volumes to large food industries, large-scale farms dominate both the conventional and agro-ecological (here organic) farming in Europe. Infrastructure and other support for local markets are not prioritised, which further drives small-scale farmers out of business. Imports into the EU of cheap, bulk commodities like soy for feed and palm oil increase to supply low-price food to large low-income population groups in the EU. Several export-oriented policies and initiatives have been put in place in EU member states in order to meet the consumer demand for “clean and healthy” foods⁶.

⁵ An example of this being a plausible future development of EU agriculture is the Swedish food strategy launched in 2017 which suggests increased organic production (goal for 2030 is 30% of agricultural land), including exports, to increase rural employment and economic growth. There are also examples from Lithuania of tendencies of “industrialisation” of the organic farming sector as new very large players emerge aimed at exports to e.g. China and Australia.

⁶ See for example Danish governments investments in export activities related to organic foods.
https://www.foedevarestyrelsen.dk/english/SiteCollectionDocuments/Kemi%20og%20foedevarekvalitet/Oekologiplan%20Danmark_English_Print.pdf

Products are sold on global and EU markets under third-party verified certification schemes – digital technologies (SSP5) has enabled the efficient control and management of such certification systems. Increased cooperation on global level to facilitate trade (SSP5) has led to the development of a global standard for organic production based on mainly weak agro-ecological principles (input substitution). Focus is on the ban of pesticides in organic production to prevent potential negative effects on human health. EU Quality Schemes like the PDO (Protected Designation of Origin) and PGI (Protected Geographical Indication)⁷ also gain in importance and are increasingly marketed and recognised abroad. Apart from increased investments in export-oriented strategies to market organic products and other ‘greener’ products, the agricultural policy in the EU is similar to that of today with the majority of the money going to un-coupled area based payments with weak greening requirements. In this future, small-scale agro-ecological producers have a hard time competing with large companies that have a much greater capacity to invest heavily in promotion of ‘greener’ products on global markets.

According to several definitions of agro-ecology, this storyline includes an inherent inconsistency as the concept of agro-ecology includes consumption of foods produced locally i.e. large scale global trade is not part of an agro-ecological food system. However, as this is a likely development in a case in which investments in weak agro-ecological practices to produce added-value products for a global market are prioritised in combination with free trade policies, this storyline was deemed interesting and valuable.

Agricultural production and practices

Most agro-ecological farming systems resemble current mainstream organic practices and are more of the ‘substitution’ rather than the ‘redesign’ variant and policy focus mainly on the substitution of problematic inputs. It is mostly high-value crops and livestock products that are grown and marketed in agro-ecological systems. For example, the recent strong trends of Spanish exports of organic products such as fruits, vegetables, wine, oil and nuts, continue due to the strong boom in demand by consumers from the central-northern countries of Europe. In addition, livestock products including milk powder, cheese and processed meat are organic products that are traded to a large extent.

Globally, EU agriculture’s large share of land under agro-ecological practices is an exception, supplying a global niche market. In general, global agriculture, including the remaining EU agriculture, is dominated by input and technology intense high yielding conventional production practices (SSP5). A growing share of food is also produced in entirely industrialised systems that require little or no agricultural land for its feedstock⁸.

Diets and waste

Eating patterns develop according to current projections, staying rich in meat and other resource intense food products and unhealthy foods in developed countries, with increasing meat and dairy consumption in developing countries, but with variations between income groups. Policy targeting demand to support healthy or sustainable diets is non-existent. Current developments with low-income populations struggling with diet-related diseases continue while the eating patterns of high-income populations improve somewhat partly due to technological solutions that facilitate for individuals to maintaining a healthy diet⁹. That is, a highly

⁷ https://ec.europa.eu/info/food-farming-fisheries/food-safety-and-quality/certification/quality-labels/quality-schemes-explained_en

⁸ See for example <https://solarfoods.fi/#vision>

⁹ <https://academic.oup.com/ajcn/article/87/5/1107/4650128>

segmented food market is evident in this storyline in which anonymous agro-ecological products are consumed by the informed well-educated populations and exported outside the EU, while the majority consumes conventional low-quality food. Food waste levels remain similar to current levels or decrease somewhat in countries where waste reduction policies are implemented.

4.1.3. Storyline 3a: Localisation for protectionism

Local food systems - low level of implementation of agro-ecological practises in the EU

Global context

This scenario plays out in the future described in the SSP 3, Regional Rivalry – A Rocky Road, scenario. The world experiences a rise in nationalism and regional conflicts which pushes countries to focus on national security issues which includes trade barriers particularly in energy and agricultural markets (O'Neill et al., 2017). Countries aim to reach energy and food security goals within their own nation or region - global cooperation and trade is low (SSP3). The world is separated into several regional blocks of countries that have little exchange between them, which prevents efficient action to reach sustainability goals (SSP3). Reaching environmental sustainability goals have very low priority in this future (SSP3).

Food system orientation and policy landscape

In this storyline, we see a development in which nationally or locally produced foods, regardless of production methods, are prioritised in the EU. Investment in agro-ecological farming systems is low. To what extent localisation of food systems is achieved varies across EU member states based on the suitability of soils and climate to produce different foods, and the role of the agricultural sector in different countries, e.g. the extent of exports. In some member states, this development is a direct consequence of a continued rise in nationalism and protectionism. Some countries are experiencing discontent with EU membership and aim for greater independence (cf. Brexit). Global trade wars, reoccurring pandemics starting with the COVID-19 situation in 2020 and global political tendencies for less international cooperation and increased competition between regions (SSP3) add to the sensation of the importance of self-sufficiency in food supply. In the wake of this, some EU member states are putting policies in place to promote more national food production based on arguments like supporting local farmers and/or reducing the dependency on imported foods e.g. to be prepared for cut-off situations due to conflicts or interruptions due to trade wars.¹⁰ In other member states, nationalism is not as pronounced and support for continued EU-cooperation (including a large CAP budget) is maintained. However, these countries are also affected by the global political situation and strategies for food production emphasize the need for high level of self-sufficiency and independency from large food imports. Many countries look to Finland for inspiration. Finland has managed to maintain high market shares for Finnish products due to explicit goals, strategies and policy investments into strengthening the competitiveness of Finnish farming and the promotion of Finnish foods¹¹.

<https://www.cambridge.org/core/journals/british-journal-of-nutrition/article/prospective-associations-between-socioeconomic-status-and-dietary-patterns-in-european-children-the-identification-and-prevention-of-dietary-and-lifestyle-induced-health-effects-in-children-and-infants-idefics-study/CAD97E2AC8B25B513F5D8C9797D2BCD1>

¹⁰ Example from Sweden of a municipality which might abandon their policy to purchase organic food in favour for locally produced and seasonal foods. https://www.sydsvenskan.se/2019-10-28/lunds-kommun-kan-helt-stryka-krav-pa-ekologisk-mat?redirected=1&fbclid=IwAR0KxVmGLKlvIn53HCMX8wqMVNFWO_KPpMBjWZ51mVYlv3c_v5qMmDdfV1o

¹¹ <https://mmm.fi/en/food-and-agriculture/policy/food-policy>

Due to the conflicting views on the role of EU institution between EU member states, the centrality of the EU CAP and the contrasting re-nationalization of agricultural policies is heavily debated. The EU has continuously been losing centralised power. However, there is still a common agricultural policy in 2050 but with a smaller budget and member states are left to make most decisions on how it is to be implemented, i.e. EU-level policies are weak. Member states keep agriculture strongly protected and financially supported. Member states manage to keep up with the international competition due to mainly protective trade policy but also by consumer demand for domestic products. On the demand side, most countries implement policies to promote consumption of local foods, e.g. requiring that public meals are “based on local traditions” and made out of domestically produced commodities and information campaigns to promote local food. Member states find creative ways to put up inter-EU trade barriers, e.g. referring to health effects etc. There is an increasing amount of publicly funded projects and initiatives to support local production, including labelling schemes¹² and policies to support short supply chains.

Agricultural production and practises

In terms of agricultural production in the EU, focus is on increased output of bulk commodities and continued growth of the agricultural sector to supply primarily the national populations, but also to achieve gains on a growing EU market through exports of surplus to other member states. An indirect effect of more local food systems is a higher diversification of food production in most countries, although within countries and at farm level production is still specialised. Although national/local food is commonly marketed as healthier and more sustainable (and perceived as such by consumers) concern for negative health or environmental outcomes is in general secondary. Local production is prioritised over implementing agro-ecological practices or other more sustainable ways of farming, which are often seen as in-efficient use of land. The influence of multinational agro-input and food companies has remained strong, but their influence has gradually decreased somewhat for a number of reasons. In countries with nationalist influences for example, people are increasingly suspicious and negative towards anything that relies on cooperation across countries and tend to prefer buying from national companies. New national food companies therefore arise, and existing ones are strengthened. Major investments into local food processing facilities, locally adopted machinery and production of agricultural inputs such as fertilisers, pesticides and machinery have been needed in many countries to enable local food systems. Still, power in the food chain continues to be concentrated to a few large food industries and retailers in each country. However, there is also an increased interest in local farmer markets although the volumes sold via these channels remain small. Due to the focus on national food production and nationalistic trends, local food cultures thrive in many countries.

The implementation of agro-ecological practises hence remains low or increase only slightly (maximum 15% of total agricultural area [croplands and grasslands] in 2050) to support mainly three niches of citizens; 1) those who oppose current nationalist trends and relentlessly, but not very successfully, continue to fight against environmental pollution, 2) those that use nationalist arguments for “saving our national environment” and therefore see an interest in agro-ecology¹³, and 3) rich consumers in and outside the EU. Agro-ecology is limited to weak agro-ecological practises as the focus on high-yield is prevailing in the agricultural discourse. In the EU, there is a strong push to intensify national agricultural production (both in fertile and marginal areas including grasslands) with the demand for increased food output overruling

¹² E.g. <http://euskolabel.hazi.eus/es/>

¹³ Potentially this organisation is such an example <http://www.ecopop.ch/de/>

objectives to reduce environmental pressures. Globally, investments in and development of agriculture is slow (SSP3).

Diets and waste

Still, most citizens continue to eat a highly environmentally impacting diet with high levels of animal products, as there are few consumer side policies put in place to steer consumption in a different direction and additionally continued investments and support for intensive livestock production. Food waste decreases slightly due to somewhat higher food prices.

4.1.4. Storyline 3b: Localisation for sustainability

Local food systems - low level of implementation of agro-ecological practises in the EU

Global context

This is an alternative storyline which emerges in the same scenario quadrant (Figure 4) as Localisation-for-protectionism, i.e. out of a combination of a high localisation of food systems and with a low level of implementation of agro-ecological practises. Compared to the previous scenario which played out in SSP3 scenario; Regional Rivalry – A Rocky Road scenario, **Localisation-for-sustainability** plays out the SSP 1 scenario: Sustainability – Taking the Green Road.¹⁴ In the SSP 1 sustainability scenario, the growing evidence of the multi-faceted cost of inequity and environmental breakdown is pushing for the prioritisation of reaching sustainability goals, with a shift in focus from economic growth towards improvements in well-being, especially in developing countries (O'Neill et al., 2017).

Food system orientation and policy landscape

Therefore, in this storyline, local food systems do not arise for reasons of nationalism and protectionism, but rather as an outcome of a deliberate policy goal of creating sustainable and resilient food systems. Support of local food production to sustain and develop rural communities is one important socio-economic sustainability goal that is given high priority in this narrative, but other advantages with local food production also acts as important drivers. These include cutting food miles¹⁵, closing nutrient cycling and avoiding further regional specialisation and concentration of food production which leads to water stress, loss of soil carbon, the spread of pests and negative outcomes for biodiversity. Thus, within the framework of the CAP (which design stays close to the post 2020 one), member states prioritise policies that steer towards local production systems (cf. Finland which has achieved that to a certain degree within the current CAP system).

At the same time as local food systems are promoted by global, European and national institutions, global agricultural markets are opened to developing countries (SSP1) to promote greater equity. However, due to the promotion of local and regional food systems for reaching sustainability goals, trade volumes are not substantially increased. It is mostly high value specialised cash crops that are imported into the EU, e.g. coffee, tea, cocoa, nuts, tropical fruits etc., while the EU is a net exporter of some surplus, mainly bulk commodities (cereals, legumes, milk powder) but also some limited amounts of high value foods (wine, spirits) to regions which do not have enough agricultural land to sustain their populations (e.g. the Middle East), and to regions and consumer groups (e.g. urban middle-class) that can afford and demand these high value foods. International, as well as EU internal trade exchanges, are important for increased resilience as different regions are affected by climate change aggravated extreme events.

Agricultural practices

The main difference between this storyline and the Local-agro-ecological-food-systems-storyline (see next section), which both include a transition to local food systems, is that the Local-agro-ecological-food-systems-storyline has a strong focus on agro-ecological food systems, including more 'nature' based practises and redesign of agricultural systems, while this scenario focuses on the localisation aspects and relies more on

¹⁴ This scenario was added after the third workshop as several stakeholders had strong opinions on the negative framing of Localisation for protection. They argued that local food systems could be established without the negative connotations of nationalism.

¹⁵ <https://www.euractiv.com/section/agriculture-food/news/sr-agri-local-zero-kilometre-products-start-to-take-spain-by-storm/>

technical solutions to reach sustainability i.e. it is more aligned with the 'sustainable intensification' perspective of agriculture (Godfray, 2015). For example, in this scenario, using mineral nitrogen fertilisers produced using renewable energy¹⁶ would be seen as a sustainable practise, while in the Local-agro-ecological-food-systems-storyline nitrogen fixation using legumes would be the preferred option. In line with the sustainable intensification perspective, further deforestation or cultivation of grassland is heavily regulated in this storyline. Agro-ecological practises are not increased from current levels and dominated by weak practises.

Diets and waste

A prerequisite to 'the pursuit of a sustainable and resilient localised food systems' is a shift in diets to increased seasonality, determined by local availability of foods. Depending on location, eating patterns in the EU hence stratify. In the southern parts of Europe, climate change induced droughts drive up prices of crops and the economic viability of feeding cereals to livestock diminishes and diets hence become mainly plant-based – vegan and vegetarian diets become the norm. In the northern parts of Europe, variation in climatic conditions increase markedly, making the availability of fruits, vegetables and cereals volatile. Increased use (and dependence) on low-cost grazing on marginal lands however makes milk and ruminant meat more abundantly available. Rapid technological advancement additionally introduces an array of novel food products stemming from sources with low environmental impact, e.g. synthetic extration of protein from inedible biomass, insects and lab-cultivated foods, as well as the processing of legumes, cereals and agro-byproducts (e.g. rapeseed cake) into very meat like steaks, burgers and sausages, often indistinguishable from real meat.

High investments in health and education and an accelerated demographic transition (SSP1) result in larger shares of the global population demanding fresh and seasonal foods, which acts as a positive feedback loop on health. Supply is however continuously dominated by a narrow range of foods such as wheat, maize, rice, tomatoes, apples etc. and few local and/or traditional crop types are cultivated. That is, current trends of reduced nutrient content in globally widespread crops continue which hamper some of the positive outcomes for health.

¹⁶ First renewable fertilisers will be on the market in 2022. <https://lantmannen.com/newsroom/press-releases/lantmannen-and-yara-lead-the-way-towards-worlds-first-fossil-free-food-chain/>

4.1.5. Storyline 4: Local agro-ecological food systems

Local food systems - high level of implementation of agro-ecological farming practises in the EU

Global context

This scenario plays out in a global context as laid out in the SSP1 scenario: Sustainability – Taking the Green Road. Here growing evidence of the multi-faceted cost of inequity and environmental breakdown is pushing for the prioritisation of reaching sustainability goals, with a shift in focus from economic growth towards improvements in well-being, especially in developing countries (O'Neill et al., 2017).

Food system orientation and policy landscape

A rapid increase in climate and environmental concerns among large population groups in the EU and fierce campaigning for stricter policies to prevent climate and environmental breakdown drive change in this storyline. The first sign of this development was seen in 2019 with the Friday for Future movements and in the 2019 election to the European parliament when the green parties increased their mandates by 40%, followed by the new Green Deal. The COVID-19 pandemic help raise the recognition of the importance of rapidly transitioning to resilient food systems. The EU level Farm-to-Fork Strategy¹⁷ for a fair, healthy and environmentally friendly food system and the EU Biodiversity Strategy for 2030¹⁸ launched in 2020 are hence given high priority and are successfully implemented at local level in the member states.

Globally, cooperation between national and international institutions are strengthened, and new global institutions arise to reinforce the rule of law and decrease corruption in order to effectively work towards greater sustainability on the global level (SSP1). This integrated approach to EU food security presented in the Farm-to-Fork Strategy, rather than the silo approach of separate agricultural, environmental and health policies, has been largely adopted by most member states in the year of 2028. The strategy's high ambitions for organic farming (goal of 25% of total farmland in 2030) spurs investments and interest in agro-ecological transitions to overcome multiple problems including nutrient and chemical pollution, soil erosion and soil carbon loss, high use of antibiotics and poor animal welfare and to enhance social sustainability by promotion of more small-scale and diverse farming and food production practises. As a consequence of the COVID-19 pandemic public support for factory livestock farming is heavily decreased due to their role in the development of zoonosis. Different types of alternative food systems are rapidly expanding including different types of community supported agriculture and short supply chain/direct sales online systems. To enable more localised food systems, support is also given to the establishment of small-scale processing. International markets are opened up to developing countries, but trade stays limited due to the focus on regional production (SSP1). European farmers are protected from the international competition primarily by industry and retail introducing local produce as a base criteria due to consumer demand, but also by trade agreements that implement sustainability criteria, e.g. for countries lacking tax on CO₂ emissions duties on imported goods are introduced. In combination with, and actually proceeding the changes in policy, many EU member states experience an explosion in bottom-up initiatives fostering agro-ecological farming practises and local food systems. Local town councils and regions play an important role here by prioritising local foods from agro-ecological systems in public procurement, providing space for marketing local food and financial support to

¹⁷ https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/farm-fork_en

¹⁸ https://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm

local initiative – hence showing political leadership towards local and agro-ecological food systems. In developing countries, yield increases are accomplished thanks to rapid introduction of best practises and effective technologies, alleviating food security challenges in these regions (SSP1).

As for the CAP, it is now handled under the umbrella of the integrated food policy and has in 2050 radically changed. Most importantly, support to industrial livestock holdings have been abolished, and major investments have gone in to improving productivity of smaller agro-ecological farms and supporting transitions to agro-ecological farming. Results Based Payment Schemes and such system are largely expanded between 2030 and 2050 in most EU member states. Greater consumer awareness is achieved by coherent marketing campaigns, and with the dissemination of clear, accurate and complete information about the benefits of agro-ecological production systems for society. Programs for knowledge transfer among practitioners and producers in rural areas have also been implemented and are available for most farmers in the EU. The investment in agro-ecology is also used as a strategy to adapt to unavoidable effects of climate change. CAP Pillar 1 support is thus reformed from purely area-based to being based on several sustainability criteria. One important example is the recognition of the inefficiency of feeding human edible crops to livestock that lead to the implementation of incentives to feed ruminants more grass and forage and to the rapid rise in poultry production to level off. Intensive pork production also decreases.

Agricultural production and practices

In 2050, on average across member states, between 20-50% of land is farmed with strong agro-ecological practises serving mostly local markets. Industrial pig and poultry holdings have been drastically decreased as consumers support for such systems are heavily affected by increased awareness of animal welfare, antibiotic resistance and risk of zoonosis. Ruminant populations are not affected to the same extent as these can be incorporated into agro-ecological systems more easily. However, many intensive ruminant production systems are redesigned to be grass-based and animal numbers adjusted to local land availability. The support for local agro-ecological production has been easiest to adopt for small-scale family farms which have thrived in this policy and market environment. Despite the positive development for agro-ecology, specialised, often large scale farms, producing using conventional methods still occupy 50-80% of the land, due to their economy-of-scale advantages and sunk costs that has made it difficult for these farms to transition, and a remaining demand of cheap bulk food from large parts of the population.

An important success factor of the rapid transition to strong agro-ecology at a large scale has been food retailers' and industries' commitment and involvement in the new food strategy. Driven initially by consumer demand¹⁹ and as a result of the societal discourse, food industries have started to work actively with farmers to enable the implementation of agro-ecological schemes and then bit by bit incorporated this into their company strategies²⁰.

¹⁹ Example of recent developments of consumers driving change: <https://www.politico.com/news/2019/10/10/food-industry-consumer-brands-association-043892>

²⁰ Dairy company Danone is an example of a large multinational company already promoting agro-ecology, in their case under the concept of “regenerative agriculture” <https://www.danone.com/impact/planet/regenerative-agriculture.html>

Diets and waste

The concept of locally adapted agro-ecological food systems in this storyline also includes striving for more healthy and sustainable consumption patterns. This includes a view that excess intake of “unnecessary” unhealthy foods (sugar-sweetened foods and beverages), excess consumption of livestock products, especially from animal species consuming human edible feed (i.e. pigs and poultry), and excess intake of food in general is a waste and should be prevented by powerful policy measures²¹. As should of course ordinary food waste which is reduced between 25-50% mainly as a result increased public awareness but also through a range of different policies. The Farm-to-Fork Strategy includes an initiative to make policy targeting demand and production coherently, directing the CAP support towards the production of foods desired in a healthy and sustainable diet. In order to receive CAP funding, EU member states have to develop and implement certain health promoting policy such as fiscal and social policies to promote healthy eating. As a result of the action put in place in many areas, production, consumption and waste reduction, diets are drastically changed to more sustainable, mainly plant-based, diets (see Willett et al., 2019, EAT-*Lancet* diet), although in some regions substantial amounts of beef and dairy from grass-based systems will be included in diets.

²¹ For example, taxes on unhealthy foods and policies that steer away from using grains for animal feed.

4.2. Biophysical modelling

4.2.1. Land use and biomass use of storylines and trade

Land use

The five scenarios described above harvest distinct biophysical patterns in the year 2050. Based on the assumed narratives, we modelled specific variants of dimensions in the EU food system, while we assume that non-EU regions develop according the FAO business as usual business from FAO (2018b). We thus are able to compare the specific changes in biophysical indicators from changes in the European food system from the sub-national to the global scale.

Figure 5 presents an overview for the development of croplands and grasslands in the EU between 2012 and 2050 for Northern, Eastern, Southern and Western Europe. In 2012, 122 million hectares cropland (including fallows) and 97 million hectares of grasslands was used for agriculture in the EU. Eastern, Southern and Western Europe have a similar extent of croplands (32-35 Mha), and Northern Europe approximately half with 18 Mha. The latter region has, conversely, larger grassland areas (22 Mha), while the other three regions have similar (Southern Europe) or considerably smaller grassland areas.

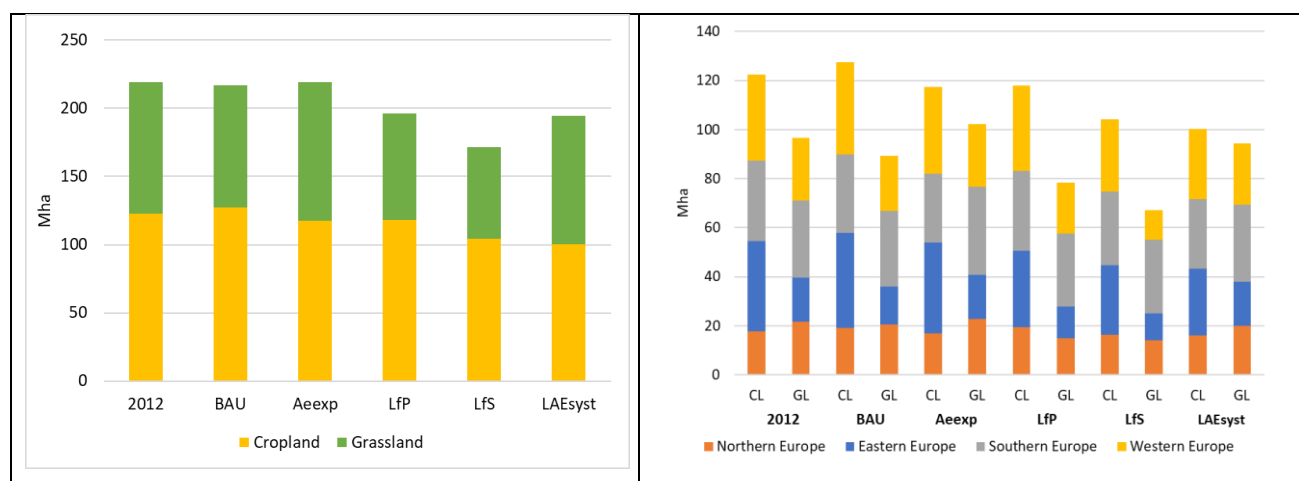


Figure 5a and 5b. Land use in million hectares (Mha) in 2012 and 2050. Figure 5a shows total land use for cropland and grassland for the EU. Figure 5b shows cropland (CL) and grassland (GL) for Northern, Eastern, Southern, and Western Europe for 2012 and for 5 scenarios for the year 2050. Eastern Europe (Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Poland, Romania, Slovakia, Slovenia), Northern Europe (Denmark, Finland, Ireland, Latvia, Lithuania, Sweden), Southern Europe (Greece, Italy, Portugal, Spain, United Kingdom), Western Europe (Austria, Belgium, France, Germany, Luxembourg, Netherlands, Switzerland). Sum of all regions together is Europe. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

Agricultural land use in the EU is decreased in all scenarios in the year 2050 compared to the Business-as-usual 2012 scenario. In Business-as-usual 2050, slightly less agricultural land will be needed than in 2012, but the use of cropland increases marginally. This pattern is at the one hand driven by slight population increase and dietary patterns, which is however counterbalanced by higher yields and better efficiencies in the conversion of primary biomass into animal-based foods. The use of grasslands is decreased due to increasing livestock efficiencies, as well as a continuation in the slightly decreasing shares of ruminant based meat and dairy

products in Western diets. No shifts in the shares of organic or agro-ecological practices or trade patterns are implemented in the Business-as-usual scenario, thus the shares stay at 2012 levels.

In the Agro-ecology-for-exports scenario, cropland production is slightly reduced due to dietary changes including fewer animal products, but the EU is remaining a strong exporter for animal products, especially ruminant products. Additionally, cropland and grassland that will not be used in 2050 due to reduced domestic demand, will be used to produce agro-ecological export goods. These are high-value products such as vegetables, fruits and nuts, and their production increases domestic cropland use by 16 Mha. Additionally, since ruminant livestock production is adopting agro-ecological practices, i.e. a higher share of grass in ruminant diets, grassland use increases in the Agro-ecology-for-exports scenario. The Localization-for-protectionism scenario shows the second highest land use for croplands in 2050, which is nearly as high as in the baseline year. Increasing self-sufficiencies are the main drivers of agricultural production in this scenario, thus agricultural production is primarily targeted towards covering domestic demand and export production in regions which were net-exporters in 2012. Thus, cropland use within the EU declines slightly compared to the baseline year, while the reduction in grassland use is larger, with a reduction of 24%. The larger reduction in grassland use reflects an expansion of cropland onto grassland in order to secure the provision of domestic demand for cropland products. Additionally, the reduction of grassland use is also a result of fewer ruminant products in the projected diets, as well as higher feed conversion efficiencies of ruminant livestock systems in 2050. In total, 196 Mha of agricultural land will be used in 2050 in the Localization-for-protectionism scenario.

The impact of the two sustainability-driven localization scenarios shows a slightly smaller extent of future agricultural land use of 194 Mha in the Local-agro-ecological-food-systems scenario, while in the Localization-for-Sustainability scenario, land use will decrease considerably to 171 Mha in 2050. Here, different extents and levels of the implementation of agro-ecological practices strongly shape future land use (see section 3.4.3), resulting in trade-offs between demand for cropland and more extensive management.

Despite and overall declining production, Western and Southern Europe will also host the largest agricultural areas in 2050 for most scenarios, with a slight tendency of production shifts from Western towards Southern Europe. Northern Europe shows only small changes, while the land use shares of Eastern Europe increase in the Business-as-usual and Agro-ecology-for-exports scenarios. Population growth is bound to be small or even negative across the EU due to lower birth rates and emigration in the FAO population outlook (FAO, 2017). For most Eastern European countries the population growth is assumed to be negative, which leads to patterns of future cropland use in Eastern Europe that are different than in the other regions. In the Business-as-usual scenario, cropland use in Eastern Europe is slightly larger than in 2012 and in the Agro-ecology-for-exports and Localization-for-protectionism scenarios cropland use decreases only slightly compared to 2012. Here, more of the large and underutilized cropland potentials will be exploited to a higher extent as in the other EU regions, where underutilized agricultural lands are smaller.

Biomass production and consumption

Crop consumption for food, feed and other uses such as fibres or biofuel production are closely driven by population growth (Krausmann et al., 2013; Krausmann et al., 2008; Krausmann et al., 2012) and changing dietary patterns (i.e. levels of animal products in human diets and livestock feeding ratios). For all non-European countries, crop consumption will increase by more than 2 Gt, from 3 Gt to around 5 Gt in 2050, following the Business-as-usual projections of the FAO (FAO, 2018). In these non-European regions, dietary shifts, but more importantly, population growth will drive the total growth in agricultural biomass demand. As population growth is rather modest in Europe until 2050, shifts in dietary patterns and livestock feeding ratios

is the main driver of agricultural biomass demand in the five scenarios. In the Business-as-usual scenario, crop consumption will increase strongly in Europe.

Under a Business-as-usual scenario, crop consumption in Europe will increase considerably from 386 Mt DM to 544 Mt DM. Here, increasing demand from nearly 75% of all sub-national regions in Europe is leading to the overall increase. In the Agro-ecology-for-exports and Localization-for-protectionism scenarios, crop consumption remains fairly constant in comparison to 2012, while only in the Agro-ecology-for-exports scenario, Southern Europe is considerably increasing its biomass demand, mostly driven by an increasing livestock population. Due to dietary shifts towards less animal-based food, total crop consumption from domestic livestock systems in the Localization-for-Sustainability and Local-agro-ecological-food-systems scenarios is much lower, with only half and one third in comparison to 2012, respectively. In the Local-agro-ecological-food-systems scenario, reduced cropland demand is due to more Agro-ecological practices in ruminant livestock production systems (i.e. more grassland based instead of cropland feed). Overall, crop consumption in Europe in 2050 may range from 544 Mt to only 148 Mt across all five scenarios (From 464 Mt in 2012).

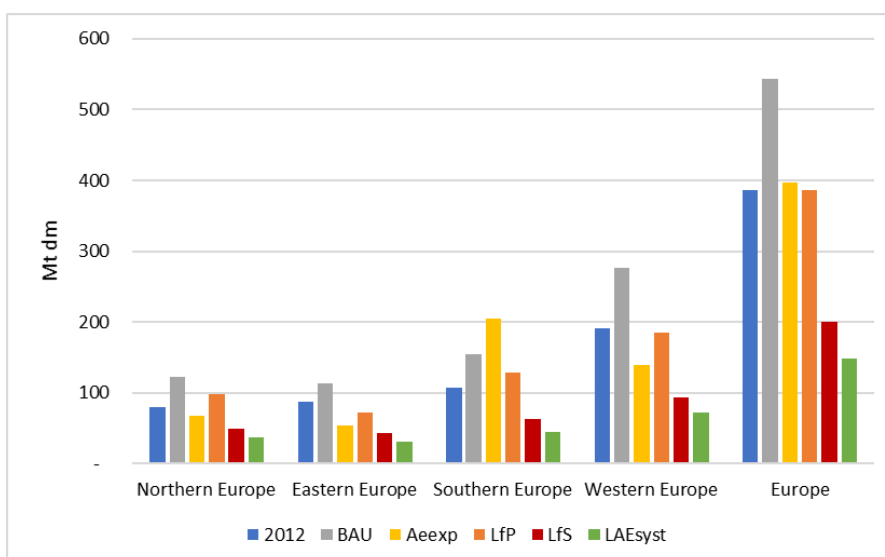


Figure 6: Total crop consumption (food, feed, other uses) in Million tonnes (Mt) dry matter for Northern, Eastern, Southern, and Western Europe for 2012 and for five scenarios for the year 2050. Please note that this figure does not show biomass consumption from grasslands. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

This strong decline in the consumption of cropland products in the EU is not only linked to human dietary shifts, but also to changes in animal production systems in the EU. While in the Business-as-usual, Localization-for-Sustainability and Localization-for-protectionism scenarios livestock systems remain unchanged in their structure and gain only efficiency through improved feed conversion ratios, in the Agro-ecology-for-exports and Local-agro-ecological-food-systems scenarios two important shifts are implemented. Firstly, an increasing shift towards more organic pig and poultry production systems, resulting in a lower feed conversion ratio, and secondly a massive reduction of cropland-sourced feedstuffs in ruminant systems. The latter restructuring also means strengthening the link between domestic resource endowment and livestock production as ruminant

livestock is increasingly fed from grasslands. However, shifting livestock feed demand from croplands to grasslands reduces food-feed competition on croplands, but comes at the cost of grassland intensification, i.e. more biomass removal from grasslands.

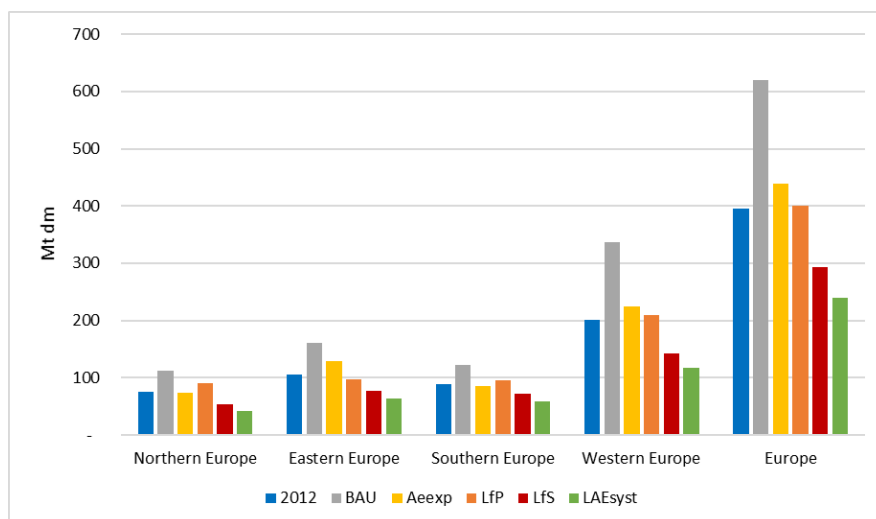


Figure 7: Total crop production (food, feed, other uses) in Million tonnes (Mt) dry matter for Northern, Eastern, Southern, and Western Europe for 2012 and for five scenarios for the year 2050. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

Across the five scenarios, different driving forces steer crop production patterns, with e.g. the aim to reach full autarky in the Localization-for-protectionism and Localization-for-Sustainability scenarios or high levels of food self-sufficiency combined with high levels of agro-ecological food production in the Agro-ecology-for-exports and Local-agro-ecological-food-systems scenarios. 396 Mt dry matter (DM) of cropland production in 2012 will increase considerably in the Business-as-usual scenario until 2050, with 620 Mt DM primary biomass production from cropland (Figure 7). In the Agro-ecology-for-exports and Localization-for-protectionism scenarios, cropland production slightly increases, due to massive cropland expansion for domestic food production in the Localization-for-protectionism, and the utilization of surplus agro-ecological production of free cropland in the Agro-ecology-for-exports scenario increases cropland production in the EU. There, 25.3 Mt of additional high-value products for exports outside the EU will can produced.

In all other scenarios, cropland production in the EU will decrease and fall below 300 Mt DM in the Localization-for-Sustainability and Local-agro-ecological-food-systems scenarios. This is a result of changes in diets, and in the Local-agro-ecological-food-systems scenario also due to more agro-ecological practices (i.e. lower yields). Prioritizing local self-sufficiency in the Localization-for-protectionism scenario this leads to reduced production for exports in regions with cropland larger than they need to cover domestic food and feed demand, and in the Agro-ecology-for-exports scenario it is a result of more agro-ecological practices in high-value export-oriented products such as fruits, vegetables and nuts.

Production of animal-based products

Under the Business-as-usual assumption, the global demand and production of animal-based feed items increase from 250 Mt DM to 381 Mt DM. In all the scenarios, the development in the EU takes a different

pattern (Figure 8). In Business-as-usual and Agro-ecology-for-exports scenarios, the EU is likely to produce more animal products than in the year 2012. Especially in Western Europe, by far the largest producer of beef and milk, pork, poultry and eggs, a slight increase from 27 Mt DM to 32 Mt DM is expected, similar to the developments in all other regions. In the Localization-for-Sustainability and Local-agro-ecological-food-systems scenarios, livestock production in the EU will decline even stronger, to less than one third of the production in 2012. These – in part – drastic reductions in livestock production are caused by re-linking livestock production systems with domestic land resources. Monogastric livestock production is shifted towards subnational regions with high cropland production potentials, which is an important measure towards closing nutrient cycles. Ruminant livestock is shifted towards regions with more grasslands, also meaning a better closure of nutrient flows.

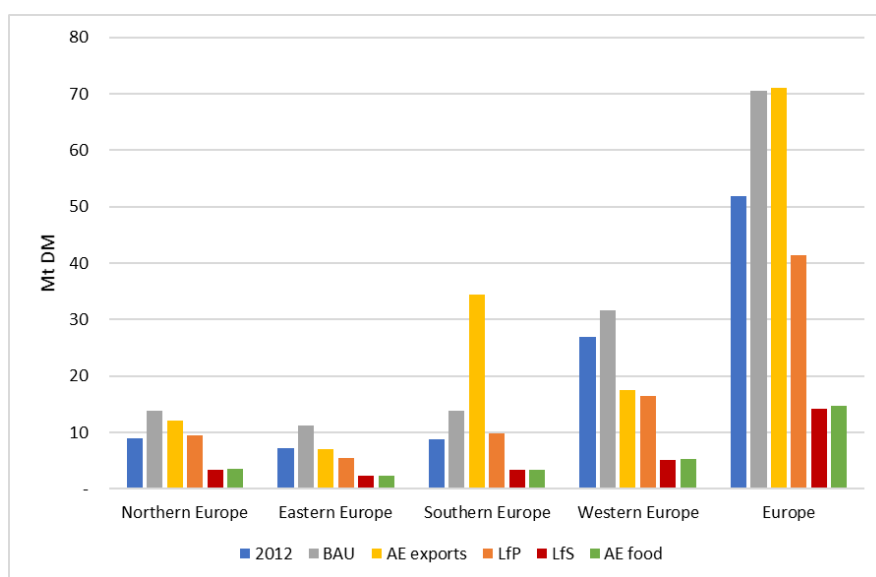


Figure 8: Production of animal-based food items in Million tonnes (Mt) dry matter (DM) for Northern, Eastern, Southern, and Western Europe for 2012 and for five scenarios for the year 2050. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

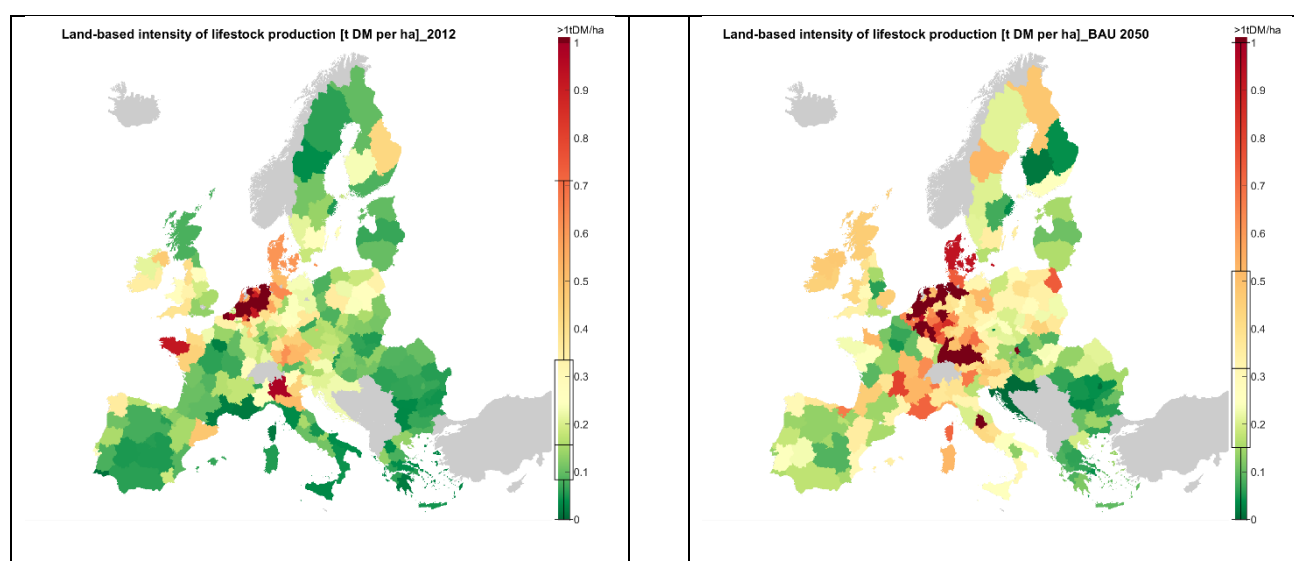
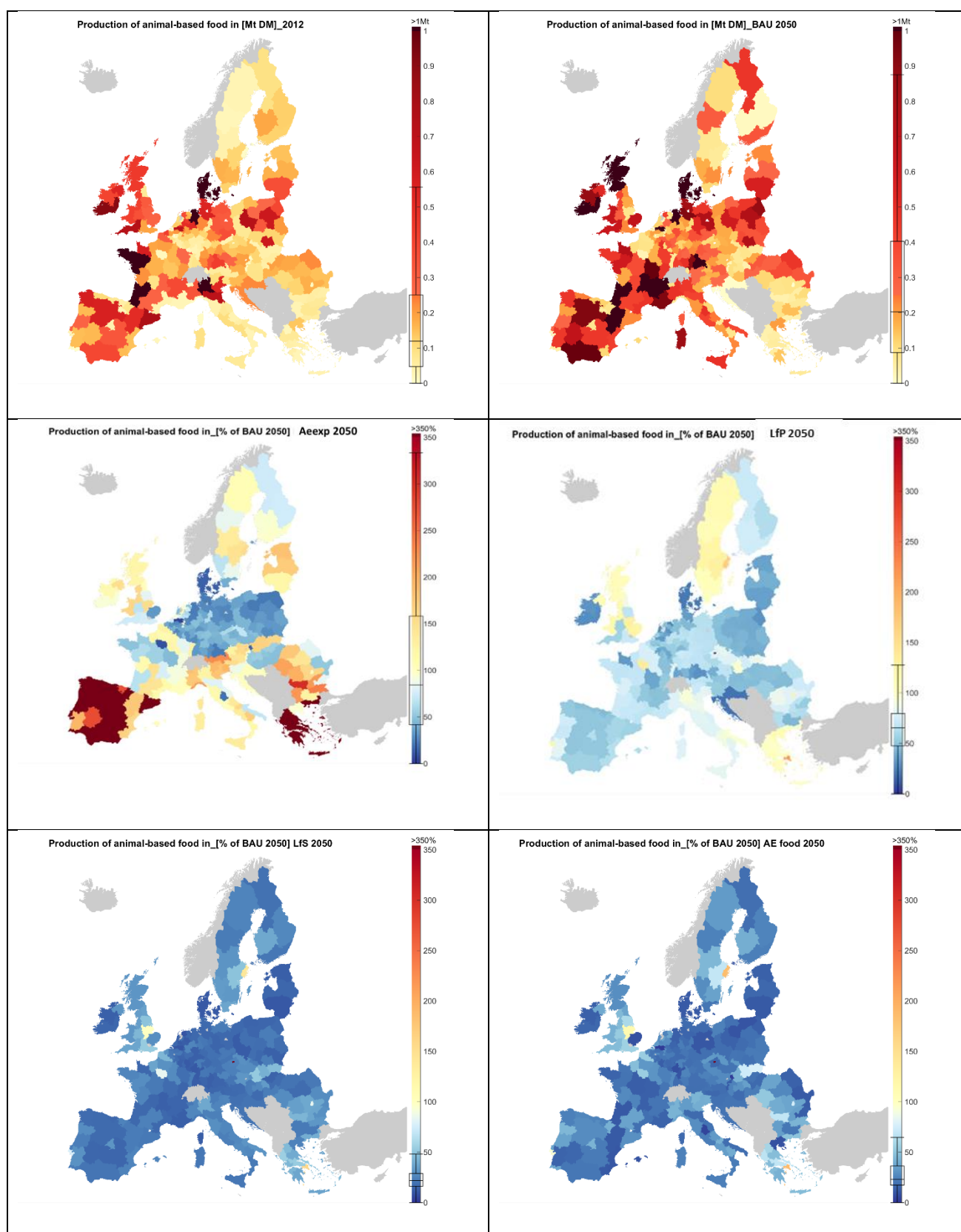


Figure 9a and 9b: Land-based intensity of livestock production in t DM per ha.

Livestock production is an important economic sector in European agriculture, but also responsible for a range of environmental impacts, such as greenhouse emissions from manure management and enteric fermentation. Figures 9a and 9b show the land-based intensity of livestock production in the EU for the baseline year and for the Business-as-usual scenario in 2050. In 2012, the Benelux countries and Western France, as well as Northern Italy show the highest intensities, and in 2050, a slight redistribution can be observed. There, regions with the highest intensities reduce their livestock production, while other regions increase their production and consequently land-based intensity. Regions in Southern Europe, for example, show a slight increase, while they still show lower values than the regions where the livestock to land ratio is still highest across the European Union.



Figures 10a-10f: Production and change in the production of animal-based food in 2012 and 2050. Figure 10a shows production in the year 2012 in Mt DM, Figure 10b shows production under a Business-as-usual scenario assumption in the year 2050 in Mt DM, Figures 10c-10f changes in production in comparison to Business-as-usual 2050 in % for the Aeexp, LfP, LfS, and LAEsyst scenario. Less animal-based food production is shown in

blue, similar rates in yellow, and increasing rates in red. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

The production of animal-based food is an important part of the European agricultural sector, both in terms of value added, but also in terms of primary biomass requirements to feed the livestock. Figures 10a – 10f show the production of animal-based food in the base year (2012) and in the 5 scenarios for 2050. Figures 10c-10f compare the production rates for each respective scenario to the baseline scenario in the year 2050, i.e. Business-as-usual 2050. Results show that in Business-as-usual 2050, animal-based food production is in general projected to increase across the EU, with notable increases in parts of Southern and Western Europe, but also on the British Islands. In comparison, all alternative scenarios for 2050 mostly show decreasing animal-based food production, except for the Agro-ecology-for-exports scenario, where regions in Spain and Greece increase their animal-based production. In these regions, livestock production per agricultural land unit was low in the baseline year if compared to regions where the ratio of livestock production to domestic agricultural land was considerably higher, i.e. in Belgium, the Netherlands, Denmark or in Northern France. Thus, in the export-oriented scenario in 2050, the relatively large cropland areas and especially grassland potentials allow to considerably increase domestic livestock production (see Figure 10c).

Potential self-sufficiency rates and regional food systems autarky

Strengthening local food autarky is the primary goal for agricultural policies in the Localization-for-protectionism and Localization-for-Sustainability scenario, albeit this is also an important aim of agricultural policies in the Local-agro-ecological-food-systems scenario. We here assess changes in potential self-sufficiency rates for all European regions between 2012 and the respective scenarios in the year 2050. Potential self-sufficiencies show how much of the domestic food demand can be produced on current agricultural lands, and not only included biomass from cropland for direct human consumption, but also includes the feed that is required to produce the animal-based foodstuffs included in human diets. Thus, self-sufficiency rates measure the domestic demand for primary agricultural biomass to feed the human population and the domestic livestock, as well as to cover non-food demand (seed, fibers, biofuels) against the domestic agricultural land production potential, i.e. biomass production from domestic croplands and grasslands.

Potential self-sufficiency rates are calculated as the ratio of agricultural land actually available and the agricultural land required to supply the total demand for crops and agricultural products in the respective region. Self-sufficiencies are higher in regions with large shares of agricultural land and low population, and lower in urban regions with only little agricultural land. Combined cropland and grassland self-sufficiencies (i.e. potential self-sufficiencies) on the sub-national scale are developing differently in the five scenarios (Figure 11).

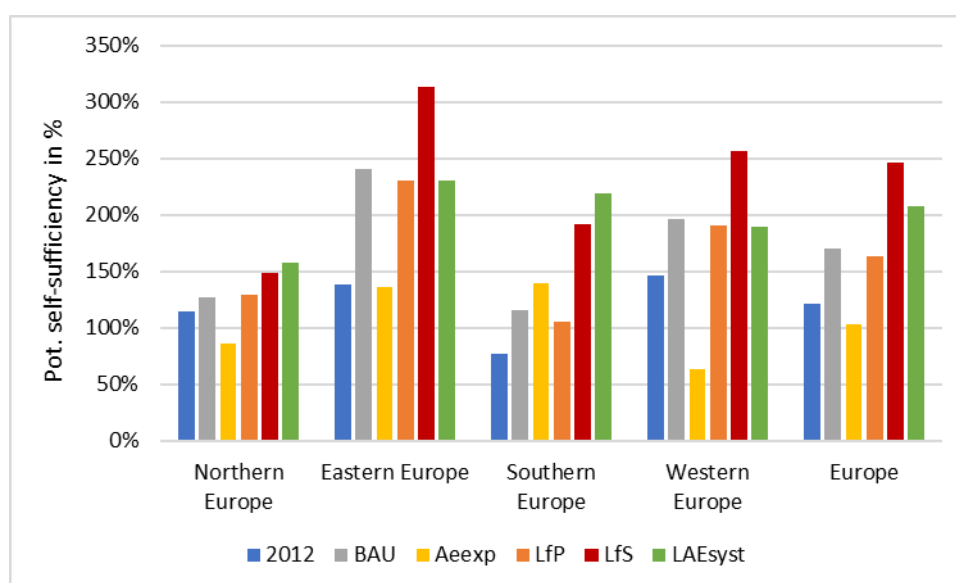
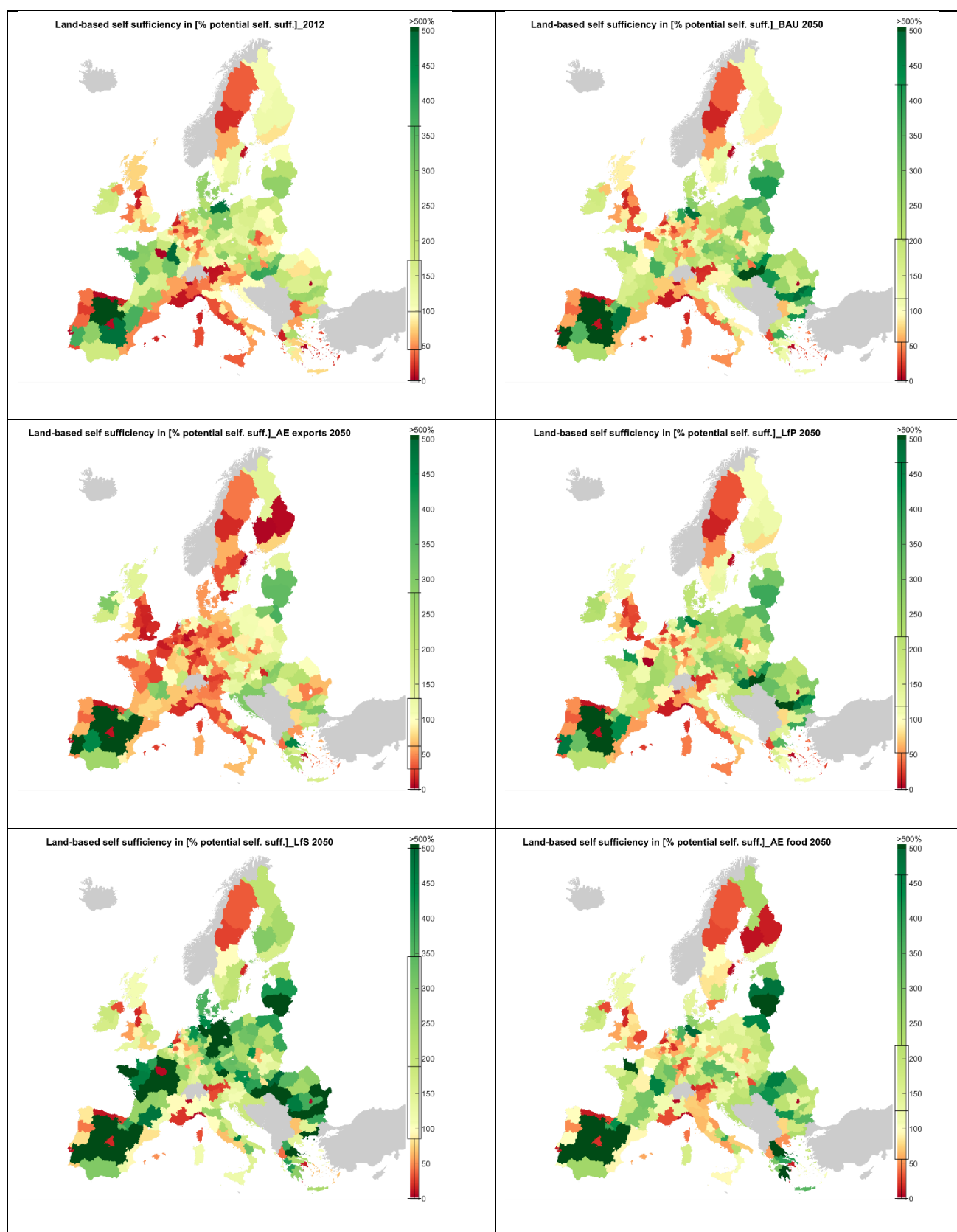


Figure 11: Potential self sufficiencies in %, calculated as total demand/total supply for Northern, Eastern, Southern, Western Europe and for the whole European Union (including the UK) for 2012 and for five scenarios for the year 2050. Ratios above 100% mean that a region produces more than the inhabitants in this region consume. Please note that surplus production for exports outside the EU in the Agro-ecology-for-exports scenario is not included here. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

The potential self-sufficiency in the EU in 2012 was 120%, i.e. the EU had 20% more agricultural land than it needed to cover the primary biomass demand for the domestic final demand for agricultural products. Additionally, all regions except Southern Europe were potentially self-sufficient in 2012. Note again that potential self-sufficiencies not only comprise croplands but also grasslands. In 2050, potential self-sufficiencies will considerably increase in the Business-as-usual scenario, to nearly 170%, meaning that the EU is assumed to produce 70% more agricultural products than its population is assumed to consume in 2050. Increasing yields and better livestock efficiencies, combined with a population that is not growing in the 38 years following the base year, results in this increasing self-sufficiency. In the Agro-ecology-for-exports scenario, potential self-sufficiency is decreasing, as livestock production under agroecological practices requires more grasslands, which also does not allow to expand croplands if needed. The two localisation scenarios, Localization-for-protectionism and Localization-for-Sustainability, yield increases potential self-sufficiencies, albeit often at the cost of cropland expansion into grasslands in the Localization-for-protectionism scenario, leading to carbon emissions from land use change. In the Local-agro-ecological-food-systems scenario, self-sufficiencies increase, albeit to a lower extent than in the Localization-for-Sustainability scenario due to larger land use required for a higher share of agroecological practices in total agricultural production.

On the member state level, each member state only produce what the domestic population requires, except in the Agro-ecology-for-exports scenario, where production is more oriented on global demand. This leads to considerably changes in production patterns and maximum production in several regions. However, self-sufficiencies remain > 1 on a country scale, meaning that this capping of domestic production potentials are enough to cover domestic demand for agricultural biomass in across these countries in 2050. Overall, the highest self-sufficiency rates are found in the Localization-for-Sustainability and Local-agro-ecological-food-systems scenarios. Here, less animal-based products in human diets allow for higher potential self-sufficiency rates and consequently to spare domestic production potentials or to produce additional goods for exports, as envisioned in the Agro-ecology-for-exports scenario.



Figures 12a-12f: Land-based self-sufficiencies in 2012 and 2050. Values are shown as percentage of domestic production / consumption (in primary equivalents, i.e. animal-products measured as feed demand). Shares >100% show that a region produces more than it consumes (in primary equivalents, i.e. animal-products are

shown as livestock feed demand equivalents). BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

The spatial patterns for land-based self-sufficiency show very distinct levels at the sub-national scale. In 2012, the majority of regions in the EU show positive rates, i.e. ratios above 100%. Only in Southern Europe, mostly Italy and regions along the Mediterranean coast, and some regions in Portugal and Northern Europe could not cover their domestic demand. Notably, also most regions in Belgium and individual regions in the Netherlands could not cover their demand, the latter driven by high population densities and less caused by low yields. In 2050, self-sufficiencies will mostly increase across all regions and scenarios, with the exception of the Localization-for-protectionism scenario. There, often grasslands pose a strong constraint to domestic self-sufficiency, as the primary goal of expanding croplands to meet food demand reduces grassland extents (i.e. avoiding deforestation only allows cropland expansion into grasslands). Thus, increasing self-sufficiency while maintaining current dietary patterns will lead to strong trade-offs with available grasslands to feed ruminant livestock. Adopting less meat based diets in the Localization-for-Sustainability and Local-agro-ecological-food-systems scenarios (12e and 12f) allow for higher self-sufficiencies, and thus also for additional scope to decrease overall land-use intensity or set-aside land for conservation purposes.

4.2.2. Environmental impacts

GHG emissions

While agro-ecological farming promises a number of positive effects on ecosystems, it is not yet clear whether there are also synergies between agro-ecology and climate-smart farming practices (see Table 1). We here assess total GHG emissions for all scenarios, while explicitly showing the effect of carbon uptake from vegetation regrowth on unused farmland if less cropland is needed in the future (see Figure 5) due to e.g. dietary shifts, less cropland feed for livestock or higher cropland yields.

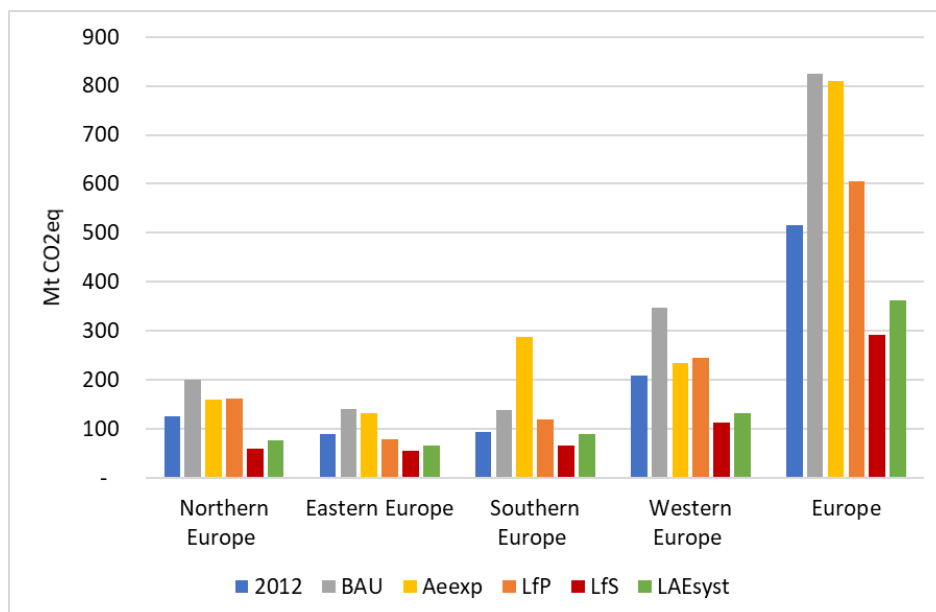


Figure 13: Total GHG emissions in million tonnes CO₂ equivalents (Mt CO₂eq) excluding the effect of additional carbon uptake through vegetation regrowth on unused cropland in 2050. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

Figure 13 displays total agricultural emissions which include emissions from agricultural management incl. upstream emissions, livestock systems and land conversion of grasslands into croplands (and vice versa). Total agricultural emissions are measured in million tonnes of CO₂-equivalents and are developing differently across the five scenarios for 2050. The highest emissions of around 824 and 811 Mt CO₂eq were found in the Business-as-usual and Agro-ecology-for-exports scenarios, the lowest emissions of 292 and 363 Mt CO₂eq in the Localization-for-Sustainability and Local-agro-ecological-food-systems scenarios, respectively. Thus, the scenarios with a medium share of the implementation of organic (25% organic production in the Localization-for-Sustainability) and agro-ecological (50% agro-ecological production in the Local-agro-ecological-food-systems) production systems have the lowest emissions, due to lower production volumes caused by reduced domestic demand, especially of livestock products. Interestingly, both agro-ecological scenarios range close to the highest and the lowest total GHG emissions in 2050, underlining the necessity of considering total production volumes and not only production technology. Additionally, the importance of the reduction of the domestic demand for livestock products is the main leverage point that allows to reach synergies between agro-ecology and less climate impact in these scenarios.

Figure 14 shows the total GHG emissions under the assumption of vegetation regrowth on abandoned croplands. In the Agro-ecology-for-exports scenario, no additional carbon sinks are created since freed up cropland is used to produce export-goods. If all cropland that is not needed to fulfill the domestic demand in Europe is used to allow for vegetation regrowth, the Localization-for-Sustainability scenario would even result in a significant net carbon sink of 123 MtCO₂eq in 2050. The specific combination of a human diet with less meat, efficient livestock systems and a medium share of organic production systems form a climate-friendly scenario, while livestock systems are mostly kept conventional and large afforestation or vegetation regrowth needs to be implemented, with possibly negative effects of other ecosystem services.

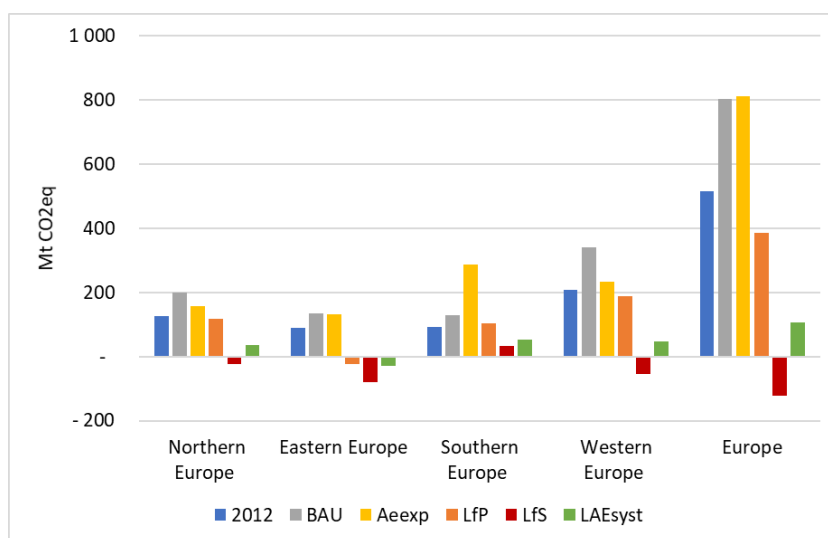


Figure 14: Total GHG emissions in million tonnes CO₂ equivalents (Mt CO₂eq) including the effect of additional carbon uptake through vegetation regrowth on unused cropland in 2050. BAU=Business-as-usual, Aeexp=Agro-ecology-for-export, LfP=Localisation-for-protectionism, LfS=Localisation-for-Sustainability, LAEsyst=Local-agro-ecological-food systems

In general, Eastern Europe would contribute the largest share of carbon emission reductions in the Localization-for-Sustainability scenario, but would also provide a net-carbon sink in the Localization-for-protectionism and Local-agro-ecological-food-systems scenarios. Large areas of underutilized agricultural land

are assumed to be abandoned and put aside as carbon sinks, probably having adverse effects on rural employment possibilities if no dedicated policy measures are undertaken, e.g. payment schemes for the provision of carbon sinks. But also in the other EU regions, the four alternative storylines (apart from the Business-as-usual 2050 scenario) provide a range of sustainability-driven and agro-ecological scenarios which are also beneficial for climate policies.

5. CONCLUSIONS

From this first assessment of five different scenarios for the EU, we derive several preliminary conclusions. The results will be analysed further and more results will be added and analysed in the following months, also including the assessments of the second biophysical mass-flow model SOLm, an intermediate assessment in 2030 and including an analysis of further indicators for environmental and social aspects, as well as certain economic assessments.

First, the various scenarios show that a decrease in land use, land use intensity and GHG emissions can be achieved without compromising food security and regional food self-sufficiencies. Regional differentiation is however important to identify hotspot regions where specific actions within such broad strategies as described in the scenarios may be needed to curb local stronger adverse effects.

Second, the drivers behind sustainability improvements are an overall reduction of the size of the food system measured in total land use and in particular in total biomass production and biomass production from animals in particular. This is achieved by combining consumption-side measures that mainly aim at realising less animal source food in diets, and production side measures, that aim at shifting from crop-based to roughage-based animal production on the one hand (an agro-ecological systems re-design), and at distributing the different production activities to the regions where they can be done most efficiently, as well as efficiency increases in general (expected yield increases, etc.). Re-balancing agricultural land potential and livestock production, an important measure of agro-ecological transitions brought up during stakeholder-meetings within UNISECO, is possible within scenarios that reach less environmental impacts than if the structure of the current production patterns remain in 2050.

Third, the choice of the production systems itself – agro-ecological, organic, or conventional in this case – is less relevant for GHG improvements than the reduction of the quantities produced. This is for example illustrated with the Agro-ecology-for-export scenario contrasted with the Local-agro-ecological-systems scenario, where the former has considerable emissions and volumes, albeit being an agro-ecological scenario, while the latter performs well regarding emissions – and also being an agro-ecological scenario.

Fourth, if demand and supply side measures are applied together and in close coordination, trade-offs between less intensive agricultural production and putting land aside for nature-based climate solutions are possible. Thus, a more sustainable and less intensive form of agricultural production that implements agro-ecological practices does not necessarily come at a high price for climate-change mitigation if the size of the total food system is reduced.

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