Project acronym: SURE-Farm
Project no.: 727520

Start date of project: June 2017
Duration: 4 years

D1.2 Scenarios for EU farming

Erik Mathijs, Jo Deckers, Birgit Kopainsky, Sina Nitzko, Achim Spiller

(Contact: Erik Mathijs)

Due date	31 January 2018
Version/Date	31 January 2018
Work Package	WP 1
Task	T. 1.2
Task lead	KU Leuven
Dissemination level	Public

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

INDEX

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

1 INTRODUCTION

When developing strategies or policies to increase resilience, private and public decision makers need to anticipate to future shocks and stresses affecting the systems they manage (Boyd et al., 2015). However, they face the difficulty that the future is not fully known. Uncertainty exists with respect to key factors affecting the actions of interest. Scenarios are a useful tool to cope with such future uncertainties and can be used both as a way to explore—not predict—the future through the identification of potential opportunities and threats and as a way to make action more future-proof (Schoemaker, 1995; Fink et al., 2004).

As the SURE-Farm conceptual framework distinguishes between different types of resilience—i.e., robustness, adaptability and transformability (Meeuwissen et al., 2018), the question arises as to what kind of resilience is fostered most by the use of future scenarios. The answer to this question depends on the time scale that relate to these different types of resilience. One may assume that given the accumulated pressure of shocks and stresses over time, systems that do not adapt or transform will collapse in the long run. Hence, actors striving for robustness are more likely to focus on the short run, using forecasting tools rather than foresight methods, such as scenarios. This makes long-term future scenarios more suitable for strategies that foster adaptability and transformability.

The objective of this deliverable is to develop medium- to long-term explorative scenarios describing possible futures for the external environment that EU farming systems face. The external environment will include environmental issues, economic issues and social issues. Consumer trends are typically not or insufficiently included in farming systems related scenarios and will therefore get particular attention. The purpose is to produce scenarios that encompass a wide range of issues characterised in both a quantitative and a qualitative way that can be used to guide further work in SURE-FARM.

This deliverable is organised as follows. Section 2 describes the methodology that is used to construct contextual scenarios for EU farming systems. Section 3 discusses consumer trends and how they may affect farming systems. Section 4 provides the narratives of the scenarios. Section 5 discusses the causal loop diagrammes underpinning our scenario development and section 6 concludes the paper.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

2 METHODOLOGY

2.1 Introduction

Generally, exploratory, contextual scenarios are built for a specific purpose, such as the analysis of future policy challenges related to food safety and nutrition challenges (JRC, 2016) or the analysis of the vulnerability and resilience of the EU food system (Vervoort et al., 2016). The main advantage of building purpose-specific scenarios is that they are optimally targeted at the purpose of the project in which they are developed, but this approach also comes with some major disadvantages. First, it is costly in terms of financial resources and time—particularly stakeholder time—to develop scenarios de novo. Second, usually scenarios remain rather qualitatitve, as developing quantitative scenarios requires specific models and skills. Third, scenarios are often not comparable across projects. Hence, it was decided to develop scenarios that are in line with the scenarios used in the framework of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5), called Shared Socioeconomic Pathways (SSP) (O'Neill et al., 2014), as these scenarios have been used and quantified in several projects (Bauer et al., 2017; Popp et al., 2017; Riahi et al., 2017). We thus need to expand the available SSP narratives developed at global level for the economy as a whole into narratives that matter for EU farming systems. SSPs are defined based on two critical uncertainties, i.e., adaptation and mitigation challenges (figure 1).

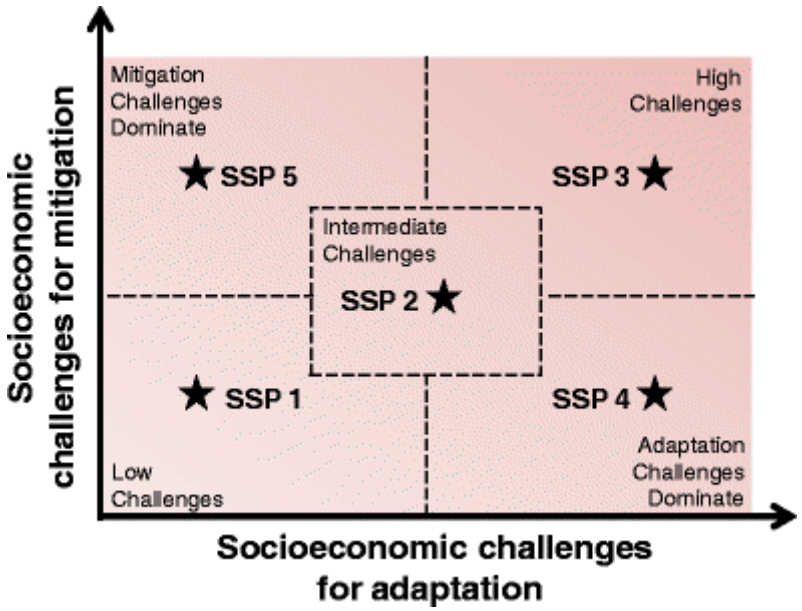


Figure 1: Shared Socioeconomic Pathways (O'Neill et al., 2014)

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

However, we need to address three drawbacks of the SSPs. First, the SSPs take climate change as point of departure, such that other drivers influencing the food system may not receive enough attention. Second, although they contain both qualitative and quantitative information, the SSPs are primarily used in modeling exercises that quantitatively assess for instance food security. Hence, developments that cannot be captured by such models also risk of not receiving enough attention. Third, the SSP narrative content was developed based on expert judgment (Ebi et al., 2014). We tackle these drawbacks by enriching the narratives using an extensive literature review on food consumer trends, by complementing the narravtives with information from other EU scenario exercises and by using systems thinking to help making our scenarios more coherent.

The coherence of scenarios developed for the SURE-Farm project is ensured by mapping the underlying dynamics in Causal Loop Diagrams (CLDs). Scenario narratives are often structured using a framework in which a maximum diversity of factors and factor states is sought (e.g., Vervoort et al., 2016; Kok and Pedde, 2016; Mora, 2016). This framework is the output of a process of identifying the most important and most uncertain factors and their possible states, followed by an analysis of the most optimal factor diversity. The resulting subsets are reviewed for consistency, plausibility and diversity informally by the experts and stakeholder or formally by designing a compatibility matrix.

However, this procedure has resulted in scenarios that partially lack coherence, for example because of biophysical infeasibility. An example of incoherence is found in one of the global shared socioeconomic pathways (O'Neill et al., 2017) in which improved health is assumed because of high investments in health and public access to health facilities, water and sanitation, even though people's lifestyles are characterised by high levels of consumption and meat-rich diets and there is increasing environmental degradation. Such incoherencies arise when a framework that lacks insight into the interrelationships between factors is the foundation of the scenario narrative.

Some researchers (e.g., Stave and Kopainsky, 2015; Schmitt Olabisi et al., 2010) argue that the coherence of scenarios can be ensured by mapping the underlying dynamics as a chain of causal relationships in a CLD. Such a diagram consists of structural thinking tools – stocks, flows, feedback loops, system boundary – that communicate the existence of causally closed feedback processes, an endogenous perspective towards patterns of behaviour and the boundaries of a system (Sterman, 2000). Feedback loops indicate reinforcing or counteracting patterns of behaviour in the system that may be subject to delays of various durations. Causal relationships between a wide variety of indicators are the backbone of the scenario narratives. Altogether, these relationships indicate the pace at which interactions across sub-systems take place.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

2.2 Development of scenario logics and narratives

The development of scenario logics and narratives proceeds in three steps: (1) identification of key assumptions in the SSPs that relate to farming systems; (2) analysis of how these assumptions influence variables affecting farming systems, and (3) development of additional narratives from the consumer literature review and other scenario exercises.

With regards to changing consumer preferences, an extended literature review will be carried out on consumer trends in the food sector as well as their impact on various EU farming systems. As a first step megatrends (duration of at least 20 years) will be identified based on the analysis of appropriate trend studies. By analyzing the scientific research regarding central drivers of consumption in the food sector, relevant megatrends will be chosen for the study. For the subsequent identification of specific food-trends, a two-stage procedure is planned (Lester & Waters, 1989). In the first stage („scanning“) specific consumer trends in the food sector will be compiled based on a comprehensive literature research (scientific literature, study results of market research agencies) and different media (blogs, forums, relevant websites). In the second stage (“monitoring”) all identified food trends will be checked for their relevance by means of an internet-based google trend search analysis. Via the google trend search analysis the development of the trends will be comprehended retrospectively over the period from 2004 until today (November 2017). In the following analysis all those trends that show an increasing trend curve in the google trend search analysis (minimum period of 3 years) will be considered. These identified food-trends will be assigned to the previously selected megatrends and will be evaluated regarding their impact on EU farming systems.

Finally, to make SSP scenarios more relevant for a broader set of research questions, we enrich our EU-Agri-SSP narratives with insights from three EU scenario exercises: (1) the Agrimonde-Terra foresight (Mora, 2016), (2) the JRC/DG SANTE foresight (Mylona et al., 2016) and (3) the TRANSMANGO scenarios (Vervoort et al., 2016.).

2.3 Systems mapping

The scenario narratives offer statements about how the identified uncertain factors (i.e., the facts) develop over time in a particular context (i.e., the case). Systems mapping uses inductive reasoning to derive information about the causal relationship between indicators, their polarity and delaying effects (i.e., the rule) underlying obersved or expected development over time. Inductive reasoning for the construction of systems maps or causal loop diagrams (CLDs) in SURE-Farm follows a three-step coding process adapted from Andersen et al. (2012). The process starts with open coding by formulating concise descriptions about the time and context of statements in the narrative, and is followed by axial coding that links uncertain factors to the descriptions,

This Project has received funds from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No. 727520

and eventually by selective coding that identifies relationships between the indicators underlying the uncertain factors.

The output of the final step in the coding process, selective coding, is a list of causal relationships between indicators, their polarity and their delaying effect. Annex 1 provides insight into how the original scenario narrative is represented as a dynamic chain of causal relationships (for explanation, see: Results) when following the three-step coding process. In addition, Annex 2 provides a complete list of selective codes derived from the scenario narratives described in the Eur-SSPs.

The scenario narratives developed for the SURE-Farm project are tailored to agriculture and EU farming systems and thus go beyond socioeconomic developments as described in the SSPs. For this reason, also academic literature that contains conceptual information about agriculture and EU farming systems is accessed. This is performed in the form of a narrative literature review, which is summarised and connected in the results section of this report.

In existing academic literature, the concept of causal feedback is rarely considered. Instead, direct, mediating and moderating relationships are the basis of most existing research. Although it is possible to represent these relationships as causal relationships as well, existing academic literature often lacks a comprehensive picture of the system under research. Good reasons may exist for not considering such a closed chain of causal relationships. For example, the relationship is not assumed to be relevant for the specific purpose of the research, the relationship is assumed to be common sense or the relationship is simply not yet subjected to investigation. Given the endogenous feedback perspective being rooted in this scenario-exercise, expert knowledge from consortium members working on this task is accessed for the identification of causal relationships that are not explicitly provided in existing academic research.

The output from coding scenario narratives and literature and converting the codes into causal relationships is established in two Causal Loop Diagrams (CLDs) of respectively the SSPs and the farming system. This paragraph provides a generic description of dominant and dormant system behaviour represented in simplified versions of the CLDs. The comprehensive CLDs that are used for developing the scenario narratives are given in Annex 3. The causal logic between two indicators is represented with a one-way arrow, indicating that the indicator from which the arrow originates is the cause of change in the indicator at which the arrow is pointed (see figure 2). A positive link (+) indicates that an increase in the cause results in an increase in the effect as well (i.e., moving in the same direction), whereas a negative link (-) indicates that an increase in the cause results in a decrease in the effect (i.e., moving in the opposite direction). Relationships with

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

a significant delay, for example between bank deposit and next year's interest rate, are indicated with a double stripe crossing an arrow (||).

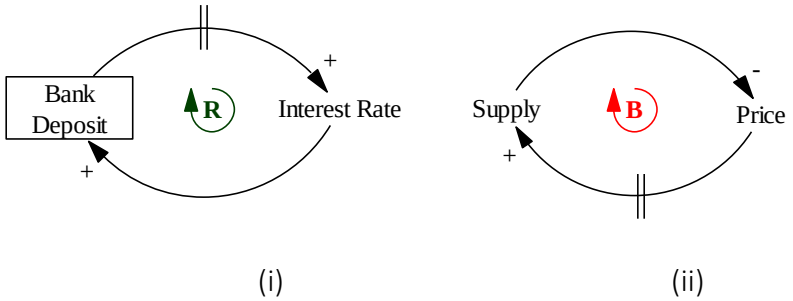


Figure 2: Causal relationships between indicators with polarity, delay and feedback loop: (i) reinforcing loop; (ii) balancing loop

Following Sterman's (2000) and Ford's (2009) instructions, a closed loop of positive links between indicators (note: two negative links make a positive link) indicates that the behaviour in the feedback loop is reinforcing (R). For example, the interest received over one's bank deposit is indicated with a positive link from interest to bank deposit and vice versa because an increased bank deposit results in higher interest in the next period of time. In this limited system (Figure 2(i)), the bank deposit increases exponentially. A closed loop of equally as many positive as negative links between indicators indicates that the behaviour in the feedback loop is balancing (B). For example, the price of a good is indicated with a positive link from price to supply, but with a negative link from supply to price because an increased supply of a good results in a decreasing price when assuming that demand remains equal. In this limited system (Figure 2(ii)), the price reaches an equilibrium value.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

3 FOOD CONSUMER TRENDS

Due to the knowledge that changing consumer preferences can have an impact on agricultural production, the present study aims to identify food-specific trends and highlights their possible impacts on EU farming systems. Until now, these aspects have only been barely considered in agro-economic research.

"Trend" means a change movement or a process of change (Horx et al., 2007; Pillkahn, 2007). A trend can be described as an already observable, statically detectable development or tendency of development (Duden, 2017). Trend research is located between market research and futurology (Pfadenhauer, 2004). It tries to understand changes and the dynamics behind them (Otto, 1993). Trends can be further differentiated into megatrends, trends and fashions. Megatrends have a decade-long effective force (at least 20 years) and impinge on different sectors of society. Trends are medium-term change processes (duration of 10—20 years) and often draw on megatrends. Fashions (duration of 3—9 years) appear as short-term trends with a fleeting character (Horx, 2010).

Based on an analysis of the scientific research on central drivers of food consumption (e.g. Kearney, 2010; Gracia-Arnaiz, 2010; Brunner et al., 2010; Alba & Williams, 2013), the following eight megatrends were selected with relevance for the present study: health and well-being, slimness and body shape, diversity, sustainability, origin, convenience, pleasure, and naturalness. These eight megatrends as well as their central drivers and resulting environmental changes are illustrated in Figure 3.

A two-stage procedure was undertaken for the subsequent identification of specific food trends (Lester & Waters, 1989). Within the initial "scanning" phase, a comprehensive literature research (scientific literature and study results from market research agencies) was carried out and different media (blogs, forums and relevant websites) were analysed. In the "monitoring" phase, all the identified trends were checked for their relevance by means of an internet-based google trend search analysis (adjustments: countries: worldwide; time period: 2004-today [November 2017]; categories: all categories).

Food trends with an increasing trend curve (minimum duration of 3 years) in the google trend search analysis were chosen for further scrutiny. The so-identified specific food trends were assigned to the predefined eight megatrends. Food trends that could not be clearly assigned to one megatrend, were assigned to more than one megatrend (see Table 1).

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

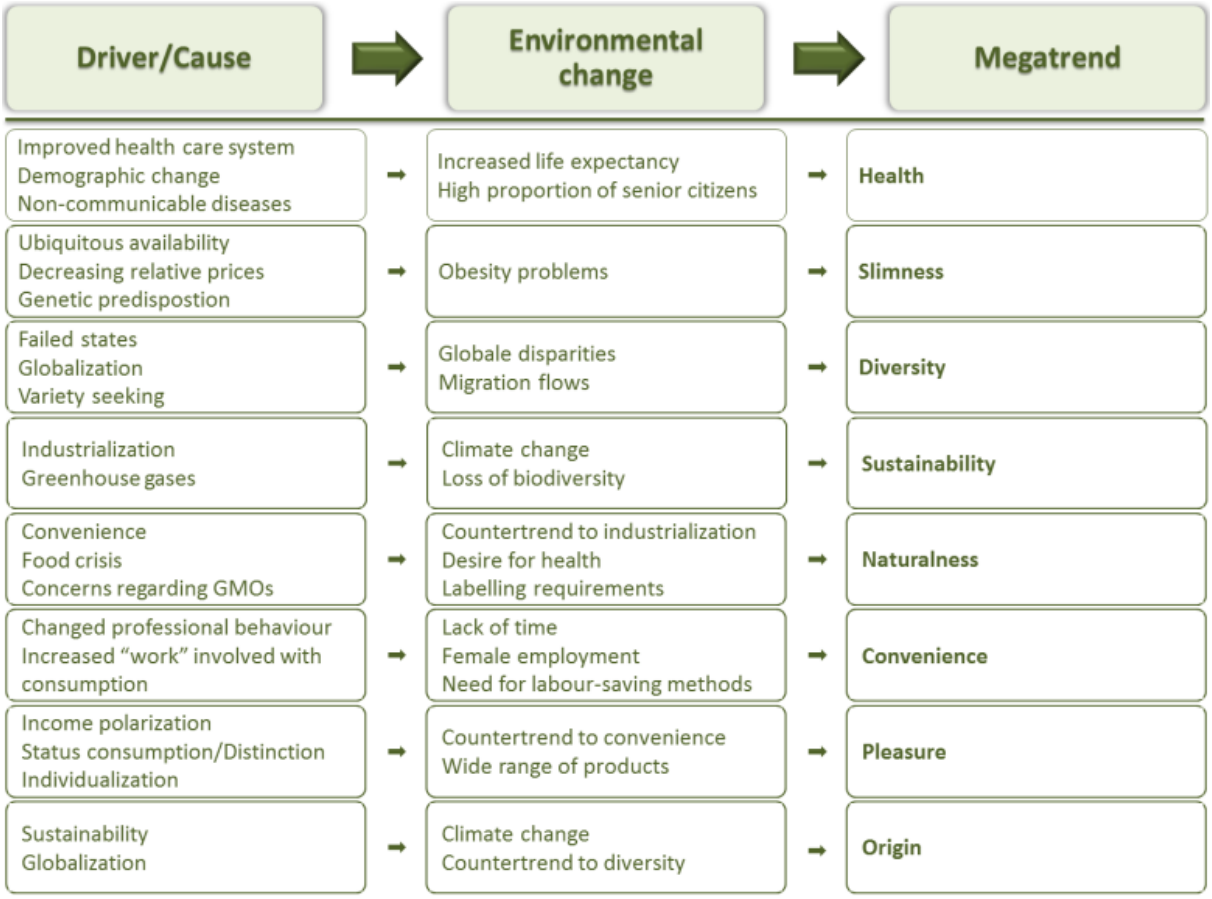


Figure 3: Identified megatrends with their associated central drivers and environmental changes

In the next step, the impact of each of the eight megatrends on EU farming systems was estimated as well as the degree of certainty of the estimations (see Figure 3). Furthermore, for every specific food trend, it was estimated whether and to what extend the trend is a risk and/or chance for EU farming systems.

Four different dimensions could be identified regarding the impact of the food trends on European agriculture: (1) impact on the production range (elimination/reduction of raw material production or production of new raw materials/products), (2) impact on distribution/distribution channels, (3) impact on production methods, and (4) impact on communication. The food trends with an influence on EU farming systems as well as the type of their impact are illustrated in Figure 4.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Table 1: Megatrends and their associated superordinate trend dimensions (with examples)

Health and well-being	Pleasure
▪ vegetarianism (e.g. vegetables) ▪ veganism (e.g. aquafaba) ▪ flexitarianism ▪ free from … (e.g. lactose free) ▪ attitude to life/ life philosophy (e.g. mindful eating) ▪ preparation (e.g. slow cooking) ▪ herbs/spices (e.g. cumin) ▪ algae (e.g. spirulina) ▪ fermented food (e.g. kimchi) ▪ fruit (e.g. smoothie) ▪ nuts/seeds/cereals (e.g. walnuts) ▪ legumes (e.g. chickpeas) ▪ fish/seafood (e.g. salmon) ▪ meals (e.g. bowl meal) ▪ food supplement (e.g. probiotics) ▪ beverages (e.g. wellness drink) ▪ other (honey)	▪ meat (e.g. pulled pork) ▪ dairy products (e.g. goat milk) ▪ egg products (e.g. egg yolks) ▪ vegetarian products (e.g. dragon fruit) ▪ specific products (e.g. freak shake) ▪ forms of preparation (e.g. grilled) ▪ attitude to life/ life philosophy (e.g. foodie) ▪ meals (e.g. social dining) ▪ flavour (umami-like)
Diversity	**Sustainability**
▪ attitude to life/ life philosophy (e.g. halal) ▪ flavour (e.g. galangal) ▪ national cuisines (e.g. Asian food) ▪ mixed national cuisines (e.g. fusion food) ▪ products (e.g. Naan Pizza) ▪ other (hybrid food)	▪ attitude to life/ life philosophy (e.g. food waste reduction) ▪ plant products (e.g. ugly fruit) ▪ animal products (e.g. low meat) ▪ production (e.g. aquaponic fish) ▪ other (e.g. food taxes)
Naturalness	**Origin**
▪ attitude to life/ life philosophy (e.g. root to leaf) ▪ specific products (e.g. ancient grains)	▪ traditional food production (e.g. handmade) ▪ primary production (e.g. urban farming) ▪ values (e.g. authenticity) ▪ attitude to life/ life philosophy (e.g. butcher-to-table)
Slimness and body shape	**Convenience**
▪ trends (e.g. slim food) ▪ sacrifice (e.g. low carb) ▪ fruits (e.g. fruit to go) ▪ other (detox)	▪ “to go” (e.g. street food) ▪ takeaway deliveries ▪ simplification (e.g. frozen food) ▪ other (fresh casual)

The megatrend “health and well-being” can be described as having a relatively high influence on agriculture. The predicted impact can be classified as very certain. The megatrend is connected to developments like the demographic change, which is associated with an increase in health problems and a resulting higher health consciousness (Jurack et al., 2012). An increase in lifestyle-related diseases (with nutrition playing a central role) is also of relevance (WHO, 2000). The high impact of this megatrend results from the relatively large number of assigned food trends and from some drivers with an influence on important agricultural sectors. The flexitarianism food trend is associated with an increased demand for high-quality meat, meaning that there are

This Project has received funds from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No. 727520

potentials for EU agriculture regarding organic or certified meat. In contrast, an expansion of the vegetarianism trend and the associated decrease in the demand for meat is a high risk for the livestock sector and therefore a threat to half of the value-added agricultural sector. Meat substitutes and especially in-vitro meat production shift the added value from agriculture to the food industry. These risks will not be able to be offset by some of the possible positive options open to EU agriculture. For example, the demand for plant-based proteins (legumes) has increased during the course of the vegetarianism and flexitarianism food trends. In addition, the consumption of egg yolks as another trend offers potentials for poultry farming in the EU. The trend potential of health claims also provides other opportunities for EU agriculture (e.g. the verified health-promoting effect of roughage).

Fruit and vegetables are further food trends. The increased cultivation, the breeding/cultivation of new species or new crosses as well as the cultivation of old varieties offer opportunities for agriculture. In addition, nuts (especially almonds and walnuts) as a food trend are also characterised by an increased demand. In addition to these changes in eating habits, consumers have an increasing desire for local products. As at present, the EU relies on imports, this locavore trend means there are potentials for European agriculture to expand its cultivation of various foodstuffs.

Superfoods is another food trend with an impact on agriculture. The cultivation of these mostly exotic raw materials in the EU offers potentials. Chia (Amato et al., 2015), quinoa (Lavini et al., 2014), matcha (a special form of cultivation and preparation of Camellia sinensis) (Sharangi, 2009) and moringa (Moringa oleifera) can all be cultivated in Europe.

The attributed impact of the megatrend “sustainability” on agriculture is high; the certainty of the attribution is in the medium range. The efforts to reduce greenhouse gases (GHG) will probably increase, but significant changes without important policy interventions are improbable. In connection with the reduction of GHG, the reduction of meat consumption, food-related air transport as well as cultivation in heated greenhouses are of relevance (Scientific Advisory Board, 2016; McMichael et al., 2007; Garnett, 2011). The trend towards a reduction of food waste is a potential risk for agriculture because less food waste would entail a reduction of food demand. The increased acceptance of ugly (imperfect) products (fruit and vegetables that do not meet the present-day trading standards) by consumers provides potentials for agriculture. These products could then be marketed at suitable prices rather than being thrown away.

This Project has received funds from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No. 727520

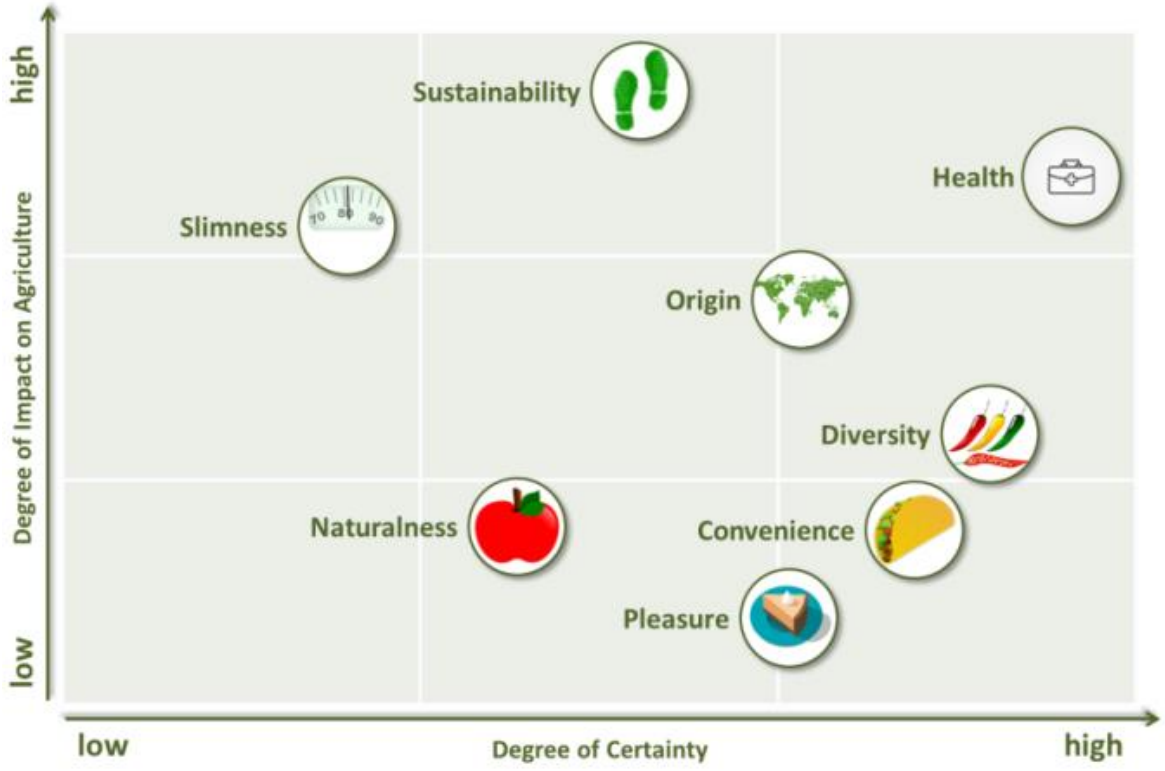


Figure 4: Degree of impact of the megatrends on agriculture and degree of certainty

The impact of the megatrend "convenience" on agriculture could be assessed as being rather small, though the degree of certainty of this attribution is very high. This small impact is a result of the low number of assigned food trends. The background for the convenience trend is the lack of time (inter alia caused by high media consumption). The developments regarding this lack of time are relatively stable. Certainly, convenience offers a suitable alternative if consumers only want to spend a small proportion of time on their nutrition. The "meal kit" food trend (consumers get a recipe and the ingredients for the preparation of a meal in a so-called menu box) is usable by farmers. Menu boxes with self-produced ingredients can be sold by direct farmer-to-consumer marketing. Furthermore, the production of single components for menu boxes is possible.

A small to medium impact on agriculture is attributed to the megatrend "naturalness". The need for naturalness has mainly resulted from diverse food crises, an increased health consciousness and the fear of chemical additives in food. The certainty of the attribution is in the medium range because different developments have had a variable influence on the relevance of naturalness for consumers (e.g. additional labelling requirements would contribute to an increased uncertainty and desire for naturalness). The food trend clean eating/clean food offers potentials for European

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

agriculture because fruit and vegetables as fresh and unprocessed foods are particularly in the foreground of this development. The clean-supreme trend is associated with the clean-food trend and means a maximum of naturalness and environmental friendliness (Williams, 2017). Naturalness thus promotes unprocessed food but endangers some common production methods (e.g. the use of glyphosate). On the other hand, trends like the preference for ancient grains offer a chance for European agriculture as sorghum, einkorn wheat, emmer and spelt can be cultivated in Europe (Schütt, 1972).

The attributed impact of the megatrend "origin" on agriculture is in the medium range; the certainty of this attribution is in the medium to higher spectrum. Due to the ongoing climate change and environmental concerns, local production is gaining in importance. It is very likely that the origin trend, which is determined by a sense of loss through globalisation and political developments, will continue. Home- and handmade specialties offer potentials for farmers, especially for the direct marketing of artisan products or products registered under one of the schemes in the EU regulation on the protection of geographical indications and traditional specialties. Urban farming/urban gardening as a trend is a potential risk for agriculture. Loss of sales are possible, especially if there is a progression of this type of food production on a large scale. The trends towards local meat and local seafood offer possibilities for farmer-to-consumer direct marketing. The need for more transparency can be addressed directly by agriculture. Farmers can inform the consumers about their production methods and products via traditional and new social media. Another chance for agriculture is the trend "meet food". Agriculture can thereby fulfil the consumers' need for closeness to food products and production by personally meeting the producer and watching the production (Rützler, 2017).

The megatrend "pleasure" can be attributed as having a small impact on agriculture; the degree of certainty of this attribution is in the medium range. Status consumption as well as individualisation in combination with a manifold range of food products are the background for this megatrend. The search for pleasure implies new forms of conspicuous consumption such as sophisticated consumption and variety-seeking behaviour. For example, goat milk as an associated food trend offers potentials for an increase in goat milk production in Europe. Another chance for agriculture are colourful food varieties (i.e. the breeding and cultivation of fruit and vegetables in special colours). The trend towards the consumption of special cuts of meat (e.g. tenderloin steak) is also a chance for agriculture, especially regarding the production of quality meat.

An impact of medium range on agriculture can be attributed to the megatrend "slimness and body shape". The degree of certainty of the attribution can be rated as small when it means that people actually achieve a greater degree of weight reduction. Behind this megatrend lies the obesity

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

problem, which is determined by the "obesity environment" and a genetic predisposition. This megatrend would be of high importance for agriculture if the quantity of food consumed would be reduced as a whole. However, this development is improbable. An increased consumption of fruit and vegetables, which is often associated with the striving for slimness, would have a positive effect on agriculture, especially with respect to the consumption of locally grown products. The "sugar-free" food trend is a potential risk for agriculture because of a reduced demand for sugar. Another potential risk for agriculture is the trend "low carb", i.e. a reduction of the proportion of carbohydrates in the diet.

The attributed influence of the megatrend "diversity" on agriculture is small. The degree of certainty of the attribution is high, because the diversity is caused by migration which will continue to spread with a high degree of certainty. Another important driver for this megatrend is the variety-seeking behaviour of consumers. Trend segments like Asian cuisine can boost new ingredients, some of which cannot be grown in Europe. However, none of the food trends which are associated with the megatrend "diversity" has had a major impact on EU agriculture.

Conclusions: In general, human food consumption does not change either very quickly nor very fundamentally due to the high degree of habitualisation. Structural breaks, as in the case of beef consumption after the BSE crisis, are rare. A massive decline in demand, as in the consumption of nicotine (a comparable habituated behaviour), only takes place after strong interventions in the consumption behaviour by means of a massive use of policy instruments. Therefore, without interventions or a massive crisis, consumer behaviour changes very slowly – this speaks for limited consumption-induced risks for agriculture.

However, the dynamics of food consumption has increased during the last years. In many developed countries, the importance of nutrition has increased for various reasons as well as the preference for variety (variety seeking). The viral distribution of food-related trends via social media has also enhanced an increasing spread of innovation. Additionally, new instruments of nutrition or sustainability policy (e.g., sin taxes or meat taxes, respectively) could boost some inherent trends.

The identification of food trends is complex. The research field is confusing and the forecasts of trend agencies are not very transparent. However, an early identification of niche trends will open up opportunities for European farmers to get innovation-based profits in special market segments. A stronger analysis of consumer trends by agricultural organisations could be the basis for a stronger market orientation of the farming sector and a focus on consumer needs.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

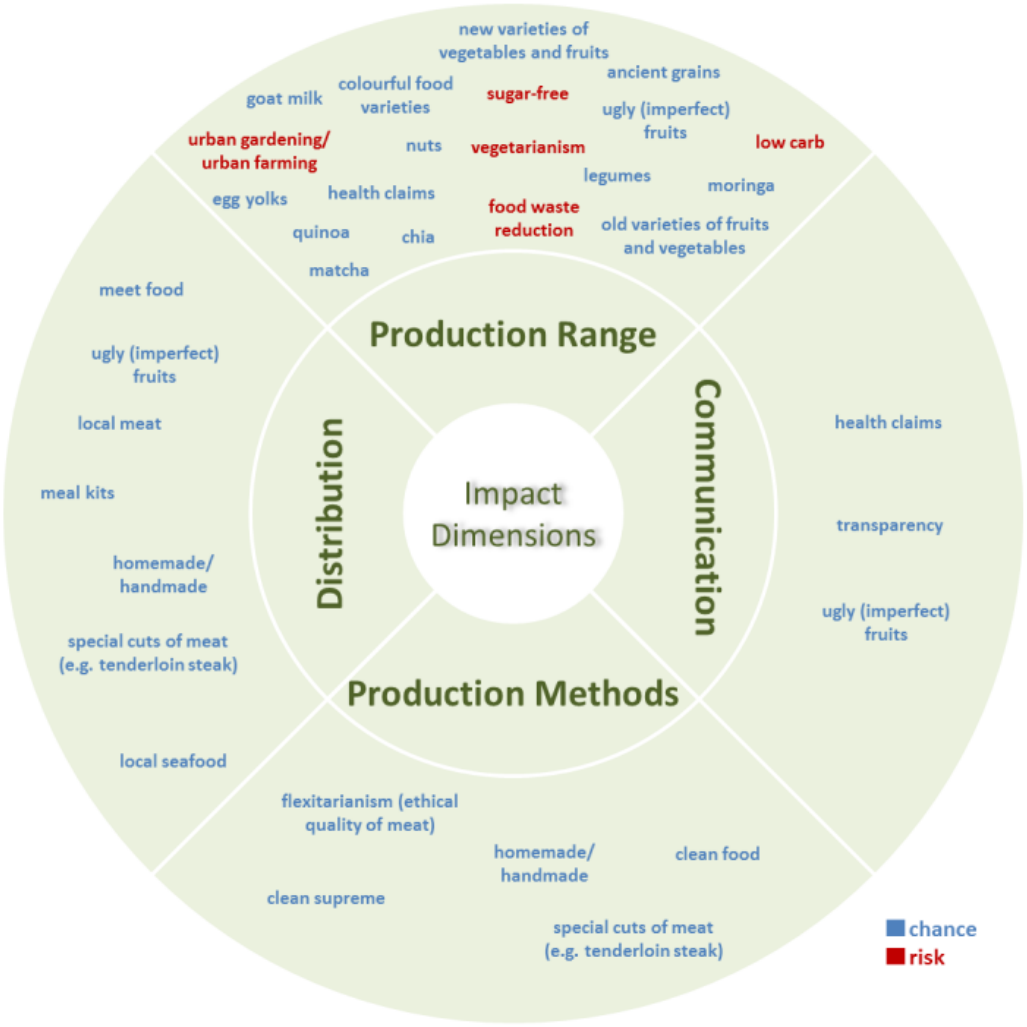


Figure 5: Food trends with an influence on EU farming systems and the type of their impact

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

4 SCENARIO NARRATIVES

4.1 Scenario logics

O'Neill et al. (2014) distinguish between five SSPs based on the level of adaptation and mitigation challenges (figure 1). Annex 5 summarizes the assumptions for the main variables determining these SSPs, as decribed by O'Neill et al. (2017), including per capita growth, inequality, international trade, globalization, consumption & diet, international cooperation, environmental policy, policy orientation and institutions. On the one extreme, SSP1 (Sustainability) is a pathway in which society has taken sufficient measures to result in low adaptation and mitigation challenges. It is a pathway characterized by high environmental awareness and effective international cooperation. On the other extreme, SSP3 (Regional rivalry) is a pathway in which insufficient measures have been taken, such that both adaptation and mitigation challenges remain. Environmental awareness is low, while international collaboration and trade are limited. In SSP4 (Inequality), mitigation is realized, but at the expense of the poor resulting in high inequality and insufficient adaptation. SSP5 (Fossil-fueled development) is a pathway in which the continued use of fossil fuels leads to a range of adaptive measures, but with mitigation lagging behind. SSP2 (Middle of the road) is an intermediary pathway that may capture business-as-usual dynamics.

Popp et al. (2017) have developed land use scenarios based on the five SSPs. Annex 6 summarizes the assumptions for the main variables, including land-use change regulation, land productivity growth, environmental impact of food consumption, international trade, globalization and land-based mitigation policies. These variables bridge the global SSPs to our EU-Agri-SSPs. Narratives are enriched by information on consumer trends from chapter 4 and other EU scenario exercises (TRANSMANGO, annex 7; DG SANTE, annex 8; Agrimonde-TERRA, annex 9). Annex 10 provides the quantitative assumptions used by various models regarding a number of key variables.

In SSP1 (Sustainability), environmental externalities are internalized through effective policy leading to reduced meat conusmption but also reduced trade. In SSP3 (Regional rivalry) and SSP5 (Fossil-fueled development), diets are still high in meat, but while free trade prevails in SSP5, it is severely constrained in SSP3. SSP4 (Inequality) has elites enjoying high resource based consumption at the expense of the poor. The combination of meat demand, environmental policy and trade orientation, leads to EU-Agri-SSPs that in first place can be differentiated in terms of livestock and feed production and imports. In addition to these dynamics, it is assumed that technological developments as assumed in the SSPs will influence price dynamics together with the aforementioned factors. Assumptions on food industry structre, vertical coordination and conumption trends were added. Table 2 summarizes our assumptions.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Table 2: Overview of farming system description for the 5 EU-Agri-SSP scenarios

	SSP 1 Sustainability	SSP 2 Middle of the road	SSP 3 Regional rivalry	SSP 4 Inequality	SSP 5 Fossil-fueled development
Demand for meat in EU	Low	Medium	High	Elites: high; Rest: low	High
International Trade	Moderate	Moderate	Strongly constrained	Moderate	High, with regional specialization in production
Land productivity growth	High improvements in agricultural productivity; rapid diffusion of best practices	Medium pace of technological change	Low technology development	Productivity high for large scale industrial farming, low for small-scale farming	Highly managed, resource-intensive; rapid increase in productivity
Feed import	Low	Moderate	Low	High	Moderate
Meat production	Low	Moderate	High	Moderate	High
Feed production	Moderate	Moderate	High	Moderate	Moderate
Agricultural prices	Relatively high	Moderate	High	Relatively low	Low
Price volatility	Moderate	Moderate	Low in EU	High	High
Land availability	Low	Moderate	Low	High	High
Labour availability	Moderate	Moderate	Low	High	High
Food industry structure	Mixed	Mixed	SMEs	Multinationals	Multinationals
Vertical coordination	High	Moderate	Low	Mixed	Low
Food waste	Low	Moderate	High	High	High
Consumption trends	Healthy, natural and sustainable	Mix	Origin	Slenderness	Diversity

Source : Own elaboration

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

While all relationships were derived from inductive reasonsing, some of the relationships were not so straightforward. For these relationships, we developed a short online questionnaire for validation. 40 stakeholders (most of which academics, n=33) completed the survey. Most respondents were Spanish (8), Belgian (7) or Dutch (7) with representation from the UK (4), Bulgaria (3), France (2), Finland (2), Sweden (2), Austria (1), Germany (1), Greece (1) and Ireland (1). Results are provided in table 3.

Table 3: Online validation results of a subset of relationships (number of respondents indicated)

	1	2	3	4	5	NA
Multinational food companies benefit more from free trade than small and medium size enterprises	1	5	5	14	14	1
The incentive to vertically integrate food supply chains increases with environmental regulation.	0	7	14	16	2	1
The availability of labour for agriculture strongly depends on trade openness.	3	11	14	10	2	0
The European middle and higher classes will not suffer from climate change mitigation.	11	13	2	9	5	0
More food is wasted when prices are low.	1	4	4	20	11	0
More food is wasted when incomes are high.	2	7	4	18	9	0

1 = strongly disagree, 2 = rather disagree, 3 = neither agree, nor disagree, 4 = rather agree, 56 = stronglye agree, NA = no answer

Most respondents agreed with the statement that multinationals benefit more from free trade than small and medium size enterprises. Many respondents were neutral with respect to the statement relating environmental regulation to vertical coordination, with slightly more respondents supporting the statement. The relationship between food waste on the one hand and income and prices on the other were largely validated.

This was not the case for the statement related to labour and to inequality. The statement related to labour assumed that labour availability in agriculture strongly depends on migration and thus on trade openness. However, there was no agreement among respondents, as results followed a rather normal distrubution. The statement related to different impacts of climate change mitigation on different income classes is also undecided, with a slight dominance of rejection. Further developments and translations of the scenario narratives will have to unravel these relationships in more detail, as they seem to be more context-specific than other relationships.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

4.2 Scenario narratives

For the sake of brevity, we will not describe EU-Agri-SSP2 Middle of the road, as the narrative for this pathway is a mixture of all other narratives.

4.2.1 EU-Agri-SSP1 Sustainability

Environmental awareness has led to environmental action in the form of strict environmental legislation, pro-environmental corporate strategies and sustainable food consumption. As a result, the cost of trade increased and the price of food includes the external costs of pollution. The consumption of meat has been drastically reduced and substituted for by plant-based alternatives. In addition, fruit and vegetables are sourced locally and consumed in season. Food waste and losses are also drastically reduced. Food prices have increased but further increases are limited due to high improvements in agricultural productivity on the hand and demand shifts due to behaviour change on the other. Price volatility is moderate. High yields are obtained through precision agriculture, genetic improvements and ecological intensification. EU-based meat production has decreased and is primarily based on own feed production, as soy imports have been drastically reduced. As a result, livestock production has become spatially more dispersed across the EU (away from the harbours) and water and air pollution hotspots have disappeared. Land is relatively scarce due to environmental restrictions, leading to high land prices. Labour availability is moderate. Food industry consists of a mix of multinationals and SMEs and collaborates closely with the farming sector due to the stringent environmental requirements. Consumer preferences are strongly infleunced by considerations of health, sustainability and naturalness.

This narrative partially corresponds with TRANSMANGO's Protein Union scenario and AGRIMONDE-TERRA's Healthy scenario, as they are all based on a synergy between human health and the environment through a shift from meat consumption to other protein sources (plant-based, insect-based). In the TRANSMANGO scenario, healthy diets also imply a reduction in sugar consumption. While in the TRANSMANGO scenario farming systems are increasingly industrialised and integrated within supply chains, the AGRIMONDE-TERRA scenario foresees an agro-ecological future for livestock systems. As a result, the European livestock sector is highly contracted, as similar trends have occurred at the global scale.

4.2.2 EU-Agri-SSP3 Regional rivalry

Environmental awareness is low and international trade is strongly constrained by protective border measures. Consumption patterns have not changed a lot in terms of composition, but more attention is given to convenience and locally produced food. As a result of the relatively high meat consumption and the reduced import of soy and other feedstuffs, own feed production as

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

well as the use of by-products and waste streams for animal nutrition has increased. Food prices are high, as productivity growth remains slow due to limited adoption of biotechnology based innovations. Prices are relatively stable due to government intervention. Temporary food surpluses are used for feed and non-food purposes. Due to the reduction of trade, the concentration of livestock production and the accompanying air and water pollution in North Western Europe has decreased, while livestock production in Central and Eastern Europe has increased. Also dairy production has decreased due to export limits. Land is scarce because of the high demand for feed production and the relatively low level of technology development. Labour is also scarce as migration is restricted in line with the protective trade policy. SMEs play a relatively large role in the food industry as many multinationals are non-European. Vertical coordination between food industry and farms is limited due to the heavy market intervention policies.

TRANSMANGO has several regional scenarios, but its scenario *The Gravy Train* matches best with SSP3, as it is the only one assuming high meat consumption. However, most other scenarios, such as TRANSMANGO's *Retrotopia* and DG SANTE's *Regional Food* scenario foresee a reduction in meat consumption. The reason is that *The Gravy Train* and SSP3 assume low environmental awareness, while *Retrotopia* assumes high environmental awareness, leading to lower meat consumption. Most scenarios do agree on the decentralized nature of the food sector based on SMEs, which matches consumer preferences towards locally sourced food.

4.2.3 EU-Agri-SSP4 Inequality

Environmental awareness focuses mainly on local issues while ignoring global issues. International trade primarily serves the globally connected elites. Diets are rich in meat for the elites, while the poor cannot afford high meat consumption. Meat is both imported and produced in the EU using imported feedstuffs. The pressure to reduce food waste and losses is low. Food prices are low, mainly because of high productivity gains, but highly volatile. The concentration of livestock production and the accompanying air and water pollution in North Western Europe remains, while reliance on imported feedstuffs even increases as there is no agreement to fully include land use in international climate change collaboration. As land use is strongly regulated in the EU to improve local environments, manure is increasingly processed and animals are increasingly confined. Land and labour are relatively abundant due to the high levels of productivity and the openness of trade. Technological development is mainly oriented at large-scale farms, accelerating even more the emergence of very large farms. Issues related to monocultures, such zoonoses and biodiversity increase. The concentration in the agri-food industry increases even more, such that food industry is dominated by multinationals. Vertical coordination between farming and food industry remains limited, except for high-value niche markets serving the elites.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Consumers mainly care for the social status food relays, as showcased for instance by the image of slenderness.

SSP4 is about inequality, which is probably the most difficult scenario to match, as it is typically not a feature of EU-based scenario exercises. It seems to match best with TRANSMANGO's Fed Up Europe scenario that is characterized by very strong power and market concentration. There is also some correspondence with the Agrimonde-Terra scenario Metropolization, which suggests that the rising inequality as suggested by the SSPs goes hand in hand with rising inequality between urban elites and rural areas.

4.2.4 EU-Agri-SSP5 Fossil-fuelled development

Environmental awareness focuses mainly on local issues while ignoring global issues. International trade is very open, resulting in regional specialisation in production. Diets are rich in meat which is both imported and produced in the EU using imported feedstuffs. The pressure to reduce food waste and losses is low. Food prices are low, mainly because of high productivity gains, but highly volatile. The concentration of livestock production and the accompanying air and water pollution in North Western Europe remains, although reliance on imported feedstuffs eventually decreases due to the full participation of the land use sector in international climate change agreements. Land and labour are relatively abundant due to the high levels of productivity and the openness of trade. Technological development is still supported by fossil fuels, such that there is a high emphasis on resource efficiency through precision agriculture. Issues related to monocultures, such as zoonoses and biodiversity loss remain prominent problems. The concentration in the agri-food industry increases even more, such that food industry is dominated by multinationals. Vertical coordination between farming and food industry remains limited, as global spot market transactions prevail. Consumer sovereignty rules, as the consumer prefers a wide range of choices from products from all over the world.

This is the most neo-liberal pathway, which corresponds to DG SANTE's Pharma Food, but matching it with TRANSMANGO and Agrimonde-Terra scenario is not so straightforward, as the same scenarios corrspond to SSP5 as to SSP4, that is, Metropolization and Fed Up Europe. It seems that the differences between EU-Agri-SSP4 and EU-Agri-SSP5 are to be found more in nuances in the nature of trade and production, giving rise to a more inequal world in EU-Agri-SSP4 versus EU-Agri-SSP5.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

5 CAUSAL LOOP DIAGRAMMES

The causal loop diagrams in this section describe the generic processes and impact pathways linking the scenario narratives from section 4 and farming systems. These processes are defined by biophysical as well as socioeconomic relationships. How exactly theses relationships play out over time depends on the relative strength of scenario variables and on how actors within food and farming systems make and adjust decisions, that is, on a specific scenario. The CLDs serve several purposes:

- They provide a visual representation of the generic processes underlying the various scenario narratives from section 4.
- They ensure the coherence of a specific scenario narrative.
- They provide an analytical framework for the formulation of additional scenarios and for the adaptation of existing scenarios to specific countries and/or farming systems. They do so by facilitating a guided, step-by-step reflection on what plausible as well as coherent assumptions about scenario variables need to look like.

5.1 Dynamic European scenarios of socioeconomic pathways

The SSPs (and Eur-SSPs) describe assumptions about future's society regarding the categories of human development, demographics, consumer preferences, economic development, technology, governance developments, policy, environmental developments and natural resources (O'Neill et al., 2017 ; Kok and Pedde, 2016). In the dynamic representation of the Eur-SSPs, we boiled these assumptions down to four major categories of developments: human (including demographics and consumer preferences), economic (including technology), governance (including policy) and environmental (including climate) developments. Dynamics primarily take place endogenously within the category of development, but occasionally interact with developments in other categories as well. A simplified CLD of interactions in the European 'macro environment', rooted in the Eur-SSPs, is found in Figure 6 and explained in the remainder of this paragraph.

The money available for human development policy aims at improving education and health. Investments in education directly pay out in improved human development policy as it reinforces societal participation of EU citizens (R1a – Participation in Society). In addition, improved education together with improved health increase society's human capital, which is a major element in the social welfare that citizens in the EU experience. Adequate social welfare reduces the occurrence of social crises (e.g., resistance due to economic inequality). Over time, this results in a reduced awareness about the need to keep investing in human development, causing

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

governments to decrease their priority for human development policy and thus balance investments in education and health (B1a – Social Policy). Human capital, however, is not the only driver of social welfare. Purchasing power and food and nutrition security have a positive impact on social welfare and the impact of environmental crises understandably has a negative impact on social welfare, just to name a few.

Human capital is a driver of the demographic transition as improved health and education both reduce mortality and fertility rates, initially causing an increase in total population size but over time balancing and potentially reducing population size. Furthermore, human capital indirectly causes population growth through refugee migration to the EU when social welfare in the EU is perceived to be better than elsewhere in the world. The positive effect of human capital on total population size resounds in rural population size, provided that the urbanisation rate is low. An increase in rural population size in combination with an increase in job availability causes increased employment in rural areas. The result is a higher per capita income in rural areas, reducing the desire of people to move to urban areas and thus having a positive effect on rural population size (R1b – Ruralisation). In addition, the development of the rural population size is further reinforced when – over time – the increase in average income results in an increase in labour migration (R1c – Labour Migration) and an increase in fertility rates (R1d – Economic Certainty). Both forces have a positive effect on rural population size and consequently increase rural employment and average rural income.

The other side of the coin is that an increase in average rural income results in an increase in purchasing power and thereby job availability. Both directly because higher income causes higher consumption and thus more demand for products and services (R1e – Job Creation) and indirectly because higher income causes higher gross domestic product and thus expansion of product and service markets (R1f – Market Growth). The increase in purchasing power causes higher employment rates and subsequently higher average incomes. Note that an increase in purchasing power also improves social welfare, but at the same time demands higher extraction rates of resources.

Social developments heavily interact with economic developments in a wide variety of aspects and because of that, governments care about economic development. The money available for economic development policy aims at technological development and market competition. Investments in technological development positively influence the technology transfer and thereby reinforce technological development itself (R2a – Technology Catalyst), a process that is even further accelerated by EU-level collaboration that fosters the diffusion of best practices across countries.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

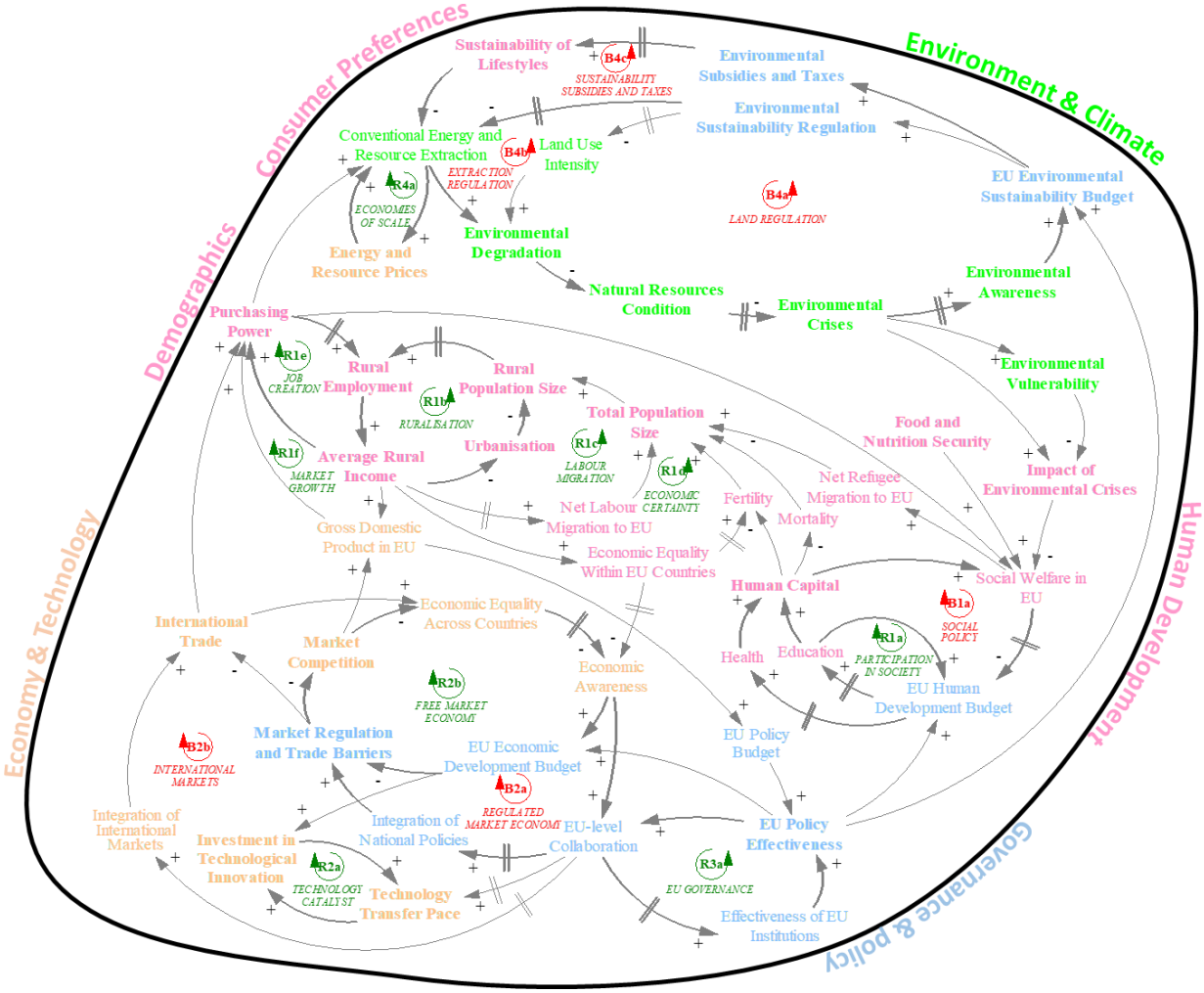


Figure 6: Simplified CLD of the European scenarios of socioeconomic pathways

Notes : Annex 3 provides a comprehensive guide on how to read causal loop diagrams and on the color coding of the variables. The different colors in Figure 6 refer to the different categories of development describd in the SSPs.

Investments in market competition is stimulated by taking away regulations and trade barriers. It increases the gross domestic product, thereby accelerating policy budget and thus reinvestment in economic development (R2b – Free Market Economy). At the same time, however, market competition reduces economic equality across countries so that economic crises (e.g., a bankruptcy wave due to heavy competition) become more frequent and more complex. Over time, this results in an increased awareness about the need invest in economic prosperity. On the

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

one hand, this reinforces further stimulation of market competition (R2b – Free Market Economy), but on the other hand, this stimulates new regulations and trade barriers through integration of national policies (e.g., fiscal policies) by EU-level collaboration (B2a – Regulation Market Economy). Another item on the agenda in EU-level collaboration is the integration of international markets (e.g., public access to labour markets). The integration of international markets stimulates international trade, which has positive effects on both gross domestic product and economic equality across countries (B2b – International Markets). The latter two trends, however, in the end reduce the awareness about the need to keep investing in economic prosperity because it improves economic equality and thus reduces the occurrence of crises – just as with money available for human development policy.

In sum, EU-level collaboration works through different pathways. In itself, EU-level collaboration is a reinforcing process in which is sought to improve the effectiveness of EU institutions and thereby improve the EU policy effectiveness (R3a – EU Governance). Several other factors also improve EU policy effectiveness, amongst which the policy budget (a share of gross domestic product collected through taxes). EU policy effectiveness is a reinforcing factor responsible for the success and governance capacity of development policies when human, economic, governance and environmental developments have been put into motion.

The latter category of developments starts with money invested in environmental sustainability policy. Just as with previously described policy budget dynamics, also the main components of the environmental sustainability policy – regulation, subsidies and taxes – in the end reduce environmental degradation, by which the condition of natural resources improves, environmental crises (e.g., climate change shocks) occur less often and environmental awareness decreases as well. Apart from this general balancing tendency in how governments prioritise certain policies, regulations do make a difference when it comes to land use intensity (B4a – Land Regulation) and conventional energy and resource extraction (B4b – Extraction Regulation) – both responsible for heavy degradation of natural resources. Furthermore, subsidies and taxes do improve the sustainability of people's lifestyles and thereby reduce the demand for conventional energy and resource extraction (B4c – Sustainability Subsidies and Taxes). The development of conventional energy and resource extraction is subject to many other dynamics as well, amongst which reinforcing energy and resource prices (R4a – Economies of Scale) is likely to be one of the dominant interactions that influences the incomes generated at farming systems.

5.2 Farming system dynamics

Meeuwissen et al. (2018) have defined farming systems as the systems that emerge due to the interrelationships between actors (farmers, suppliers, buyers), material elements (biophysical flows, infrastructure) and immaterial elements (knowledge, institutions) at a level higher than the

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

farm. However, due to the complexity of farming systems, we start our CLD development from the farm as central element, subsequently linking farm dynamics to the wider farming system, but a relatively simple conceptualization of the wider farming system.

According to academic literature (e.g., Zimmerman et al., 2009; Brzezina et al., 2016), core farm processes involve strategic decisions about why to produce, and investment decisions about how to produce and what to produce. Each of these decisions in a farm is essentially based on the farming budget – the accumulation of generated on-farm and off-farm income minus production costs that originate from production factors. At the end of the year, the farmer makes up the balance and calculates if he came off with a profit or a loss. The resulting budget reflects the money available to invest in production factors like labour, capital, external inputs and land. Production factors determine production and subsequently consumption and in the end feed back into the farming budget. Most decisions made in a farm primarily follow an annual cycle in which a farm improves its resilience (Maes and Van Passel, 2017). A simplified CLD of interactions in the farming system, rooted in academic literature, is found in Figure 7 and explained in the remainder of this paragraph. Connections between the farming system CLD and the CLD of the Euroean scenarios of socioeconomic pathways are detailed in Annex 3.

A farmer's success is the basis for his strategic decisions. In case the farm has a prospective successor, the farmer has an incentive to reinvest his profit in farm development (Zimmerman et al., 2009), which is a reinforcing process given the likelihood that it results in even more profit the next year (R1a – Success to the Successful). If no profit, or even a loss, is made, the farmer experiences pressure to minimise costs by improving his production efficiency (Sustainability Institute, 2003), which is a vicious, reinforcing process of increasing production and reducing prices that does not generate profit (R1b – Efficiency Treadmill). According to the Sustainability Institute (2003), farmers who are not able to minimise costs to turn their loss into profit again may decide to quit the business.

A farmer's strategic decisions determine his investment decisions about how to produce. Reinvestments for farm development are put into growth of the farm business (Zimmerman et al., 2009), for example through acquisition of farming capital or addition of agricultural land. In principle, investments in land directly result in higher production levels. However, intensive land use without regeneration causes soil pollution and thereby reduces the availability of quality land (B2a – Degradation) and thus decreases the marginal benefit from investments in land (e.g., Conacher and Sala, 1998; Ibanez et al., 2008). Investments in capital result in higher production efficiency, but such an investment substitutes investments in farming labour and external inputs (Levers et al., 2016; Rotz and Fraser, 2015). At the same time, acquisition of capital reinforces the

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

development of mechanisation technology and in the long run improves the availability of mechanisation technology for future reinvestments (R2a – Mechanisation).

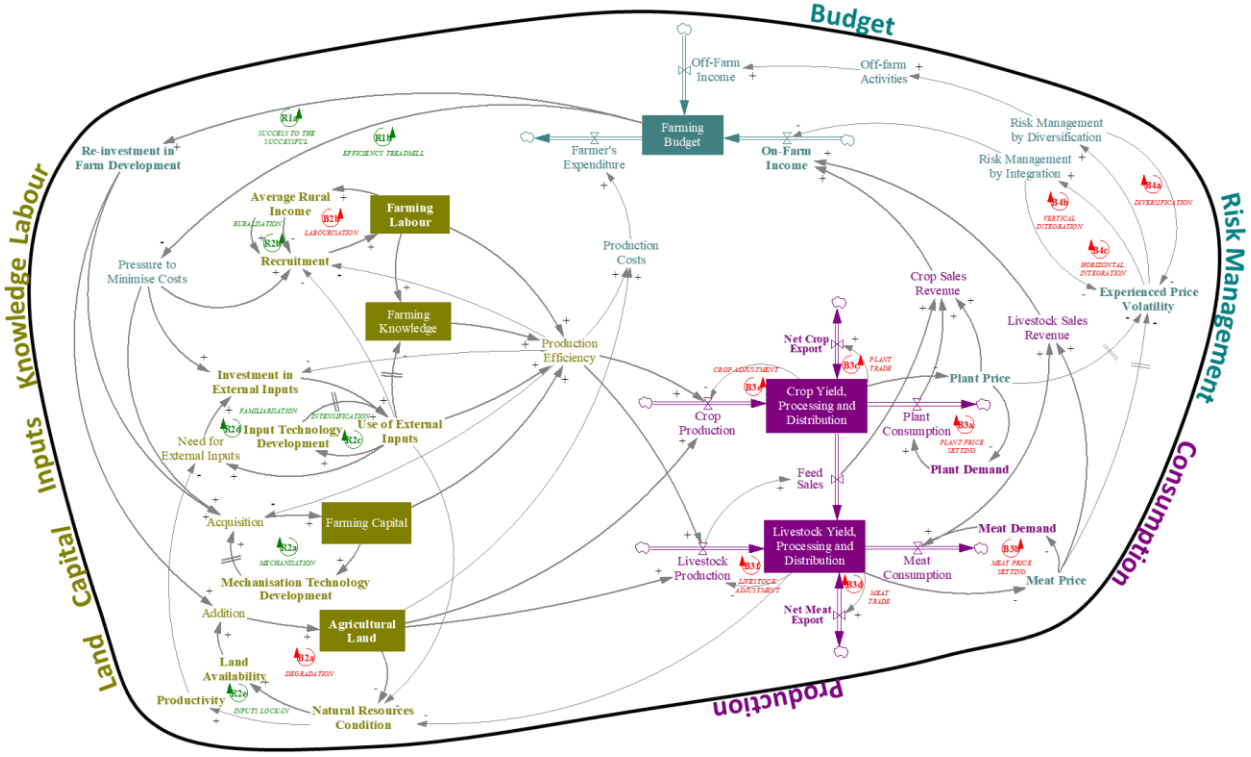


Figure 7: Simplified CLD of the farming system

Notes : Annex 3 provides a comprehensive guide on how to read causal loop diagrams and on the color coding of the variables. The different colors in Figure 7 refer to different elements of farming systems. Direct connections between the simplified farming system CLD and the simplified CLD of the Eur-SSPs in Figure 6 are : «average rural income » and « natural resource condition ». « International trade » from the Eur-SSPs corresponds to « net crop export » and « net meat export » ; « Sustainability of lifestyles » corresponds to « meat demand » and « plant demand » ; « Rural employment » corresponds to « farming labor » ; and « Land use intensity » corresponds to « use of external inputs ».

A pressure to minimise costs is translated into a targeted production efficiency that can be reached in multiple ways, namely by investments in farming labour, external inputs or farming capital (Brzezina et al., 2016). The associated costs and the availability of a production factor are found to be the most important factors that determine the production factor in which is invested (Godfray et al., 2010; Hazell and Wood, 2008; La Trobe et al., 2000; Levers et al., 2016; Rotz and

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Fraser, 2015). According to these researchers, low costs and high availability of a production factor relative to high costs and low availability of other production factors creates high attractiveness for investing in that one production factor. Just as with investments in capital (R2a – Mechanisation), investments in external inputs reinforce the development of external inputs and in the long run thereby both increase the availability and decrease the costs of external inputs (R2c – Intensification). Investments in labour recruitment balance recruitment of labour by increased average incomes resulting from scarcity in the labour market (B2b – Labourisation), but they also reinforce rural labour availability by increased attractiveness (R2b – Ruralisation) resulting from higher employment rates and average incomes in rural areas (Harrington and Reinsel, 1995).

An investment in one of the production factors substitutes investments in production factors, depending on the desired production efficiency relative to the actual production efficiency. Next to the trade-off in which production factor to invest, most farmers also consider important side-effects that go beyond the consideration of costs and availability of a production factor. Side-effects are particularly important for farmers that investment in external inputs as these may cause water pollution (e.g., Tilman et al., 2002) and loss of biodiversity (Geiger et al., 2010; Mclaughlin and Mineau, 1995), causing decreased productivity and thus increased dependency on external inputs for production efficiency (R2e – Input Lock-in) (Stave and Kopainsky, 2015; Goodman et al., 1987). Moreover, the use of external inputs has a negative effect on tacit farming knowledge – knowledge about land quality that has been obtained through years of experience (Sundkvist et al., 2005; Morgan and Murdoch, 2000). In addition, Morgan and Murdoch (2000) warn that the use of external inputs promotes standardised knowledge, which also creates dependency on external inputs for production efficiency (R2d – Familiarisation). In contrast, investments in labour improve the stock of farming knowledge, thereby having a positive side-effect on production efficiency (Morgan and Murdoch, 2000). Altogether, agricultural land and production efficiency have a positive influence on the production levels (e.g., Morgan and Murdoch, 2000).

The farmer's investment decisions about how to produce over an extended period of time determine his investment decisions about what to produce. Consumption patterns and production profitability are found to be the most important factors that determine a farmer's choice of crop or livestock on a piece of agricultural land (Kopainsky et al., 2015). The underlying indicators of price and demand are influenced by the stock of crop in processing and distribution (B3a – Plant Price Setting; B3b – Meat Price Setting), which can be managed with exports and imports (B3c – Plant Trade; B3d – Meat Trade) depending on respectively surplus and scarcity (Brzezina et al., 2016). Farmers try to avoid imports and resolve scarcity by adjusting their

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

production levels, using their agricultural land and production efficiency as input (B3e – Crop Adjustment; B3f – Livestock Adjustment).

In principle, the price of crops and meat is the outcome of a ratio between supply of and demand for crops and meat (Brzezina et al., 2016). The price development over an extended period of time shows periods of high prices and periods of low prices – indicating the price volatility experienced by farmers (Brzezina et al., 2016). Farmers who experience high price volatility seek for ways to manage the risk of having to sell their produce against a too low price by restructuring their market (Zimmerman et al., 2009). Goddard et al. (1993) argue that they do so by vertical supply chain coordination (B4b – Vertical Integration) or horizontal coordination through, for example, local collaboration (B4c – Horizontal Integration). This generally results in more stable price development, but a lower per unit revenue. Another strategy is to diversify by broadening the product portfolio (B4a – Diversification). This results in mixed farming and off-farm activities by which income can be generated and risks are reduced (Rotz and Fraser, 2015). Altogether, this feeds into the farming budget again and determines the farmer's decisions in the year that follows (Sustainability Institute, 2003).

5.3 The influence of socioeconomic developments on the farming system

The dynamic representation of the (Eur-)SSPs exposes three areas in socioeconomic developments that demand close attention, namely demographics, governance and environmental policy. The reinforcing structure underlying rural demographics points out that properly designed policies can make rural areas flourish with high employment rates and incomes, but that malfunctioning policies can push rural areas in a vicious cycle of social degradation. Similarly, the governance structure points out that collaboration reinforces good governance by improving effectiveness of institutions, increasing policy budget and expanding policy planning horizon. However, malfunctioning governance can push nations apart instead of bringing them together. The balancing structure underlying environmental policy implementation (e.g., regulation, subsidies and taxes) points out that, as long as natural resources keep degrading, increasingly more regulations, subsidies and taxes are introduced to push citizens to a more sustainable lifestyle and organisations to a less energy, resource and land intensive business model. But the priority for such policies slowly fades away when – after a significant number of years – the condition of natural resources starts to improve because of regeneration.

Also the dynamic representation of the farming system exposes three areas in farming systems that demand close attention, namely adoption of technology, agricultural production and risk management. The structure underlying the adoption of technology points out that acquisition of capital and use of external inputs is an investment that further reinforces the development of technology, thereby improving its availability and reducing its price. Reinforcing side-effects,

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

however, are the increase in a farmer's dependence on technology when intensification and mechanisation result in degradation of soil, water, biodiversity and air. The balancing structure underlying agricultural production indicates how – regardless of the particular crop or livestock central in the farming system – a farmer is heavily subjected to developments in international trade (i.e., chances for export; threats of import), market competition and changing consumer preferences (e.g., shifting away from meat rich diets) for adjusting his production levels because of the influence on price developments and thus his profitability. Furthermore, the higher the price volatility experienced by farmers, the more effort is put into managing the risks involved in farming. The balancing structure underlying risk management indicates that in a context of increasing price volatility, farmers either choose to specialise into a product type by vertical integration in an existing supply chain or choose to diversify their product portfolio and potentially seek collaboration with local farmers. Such a development in the farming landscape may result in a few large specialised farms next to many small collaborating farms with a diversity of products and services.

The farming system is a very diverse governance system that relates to nearly every aspect of society. The bold indicators in Figure 6 and Figure 7 highlight the indicators of the 'macro environment' that relate with the farming system. Although the collective of farming systems can make a difference in society, the influence of society on a farming system in general is far more dominant. Reflecting on the areas described above that demand close attention, it is particularly interesting to consider the dominating influence of the Common Agricultural Policy on farmer's income, of market regulation and integration of international markets on price developments, of environmental subsidies and taxes and integration of international markets on changes in crop and meat demand, the effect of rural demographics on recruitment of rural labour and vice versa, the effect of environmental degradation and subsequently regulation on the availability of land and the adoption of technology and vice versa and the effect of environmental degradation and subsequently environmental crises on contracting weather insurances. These and other relationships between the 'macro environment' and the farming system can be studied in further detail using the comprehensive CLDs in Annex 3.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

6 CONCLUSIONS

We have developed European contextual scenarios in order to contribute to the resilience of EU farming systems. As these are long-run scenarios, they are most suited to analyse strategic decisions enhancing long-term resilience through adaptation or transformation at the level of the farming system. Scenarios are less useful to analyse short-run strategies enhancing short-term resilience through robustness at the level of the farm. This has implications for the use of the scenarios in the various workpackages, as the focal point of the different workpackages differs.

Direct and specific use of the scenarios is foreseen in WP3, WP5 and WP6. WP3 aims to assess farm demographics for different scenarios and policy measures. The scenarios we developed can be used directly for this task by making the link between the factors influencing farm demographics and the variables described in the scenarios. WP5 aims to assess the performance of farming systems under different scenarios. The quantitative assumptions made in the SSPs underlying our scenarios can be used as a starting point for developing assumptions for the integrated assessment exercise. These assumptions will have to be translated into the local conditions of each case study. WP6 aims to develop guiding principles for resilience-enabling governance and roadmaps towards their implementation in the various EU contexts. The scenarios will be used here to investigate to what extent these guiding principles are robust under different future conditions.

The use of scenarios is not mentioned specifically in WP2 and WP4. The aim of WP2 is to develop and test risk management strategies and decision support tools that farmers can use to cope with increasing economic, environmental and social uncertainties and risks. While the scenarios we developed provide a coherent set of such uncertainties and risks, but they are likely to be more useful to test combinations of risk management strategies at the level of the farming system than to analyse individual instruments at farm level. The aim of WP4 is to provide recommendations for the CAP to be more resilience-enhancing. The scenarios offer a framework to test whether the CAP will be resilience-enhancing under different future conditions. As the CAP itself is object of analysis, the CAP was not explicitly part of the scenario exercise aiming at characterizing the external environment of farming systems.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

7 REFERENCES

Alba, J.W., Williams, E.F., 2013. Pleasure principles: A review of research on hedonic consumption. Journal of Consumer Psychology 23, 2-18.

Amato, M., Caruso, M. C., Guzzo, F., Glagano, F., Commisso, M., Bochicchio, R., Labella, R., Favati, F., 2015. Nutritional quality of seeds and leaf metabolites of Chia (Salvia hispanica L.) from Southern Italy. European Food Research and Technology 241 (5), 615-625.

Andersen, D.L., Luna-Reyes, L.F., Diker, V. G., Black, L., Rich, E., Andersen, D.F., 2012. The disconfirmatory interview as a strategy for the assessment of system dynamics models. System Dynamics Review 28, 255-275.

Bauer, N. et al., 2017. Shared Socio-Economic Pathways of the Energy Sector – Quantifying the Narratives. Global Environmental Change 42, 316-330.

Boyd, E., Nykvist, B., Borgström, S., Stacewicz, I.A., 2015. Anticipatory governance for social-ecological resilience. AMBIO 44(Suppl 1): 149-161.

Brunner, T. A., van der Horst, K., Siegrist, M., 2010. Convenience food products. Drivers for consumption. Appetite 55, 498-506.

Brzezina, N., Kopainsky, B., Mathijs, E., 2016. Can Organic Farming Reduce Vulnerabilities and Enhance the Resilience of the European Food System? A Critical Assessment Using System Dynamics Structural Thinking Tools. Sustainability 8 (10), 1-32.

Conacher, A.J., Sala, M., 1998. Land Degradation in Mediterranean Environments of the World. Wiley, Chichester.

Duden, 2017. Trend, der. URL: https://www.duden.de/rechtschreibung/Trend [accessed 9 January 2018].

Ebi, K.L., et al., 2014. A new scenario framework for climate change research: background, process, and future directions. Climatic Change 122(3), 363-72.

Fink, A., Siebe, A., Kuhle, J.-P., 2004. How scenarios support strategic early warning processes. Foresight 6(3), 173-185.

Ford, A., 2009. Modeling the Environment, 2nd edition. Island Press, Washington, DC, USA.

Garnett, T., 2011. Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain). Food Policy 36, 23-32.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Geiger, F. et al., 2010. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic Applied Ecology 11, 97-105.

Goddard, E., Weersink, A., Chen, K., Turvey, C.G., 1993. Economics of structural change in agriculture. Canadian Journal of Agricultural Economics 41, 475-486.

Godfray, H.C.J., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Nisbett, N., Pretty, J., Robinson, S., Toulmin, C., Whiteley, R, 2010. The future of the global food system. Philosophical Transactions of the Royal Society London B: Biological Sciences 365, 2769-2777.

Goodman, D., Sorj, B., Wilkinson, J., 1987. From Farming to Biotechnology: A Theory of Agro-Industrial Development. Basil Blackwell, Oxford, UK.

Gracia-Arnaiz, M., 2010. Fat bodies and thin bodies. Cultural, biomedical and market discourses on obesity. Appetite 55, 219-225.

Harrington, D.H., Reinsel, R.D., 1995. A synthesis of forces driving structural change. Canadian Journal of Agricultural Economics 43, 3-14.

Hazell, P., Wood, S, 2008. Drivers of change in global agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences 363, 495-515.

Horx, M., 2010. Trend-Definitionen. Zukunftsinstitut Horx GmbH, Frankfurt. URL: http://www.horx.com/zukunftsforschung/Docs/02-M-03-Trend-Definitionen.pdf [accessed 8 January 2018].

Horx, M., Huber, J., Steinle, A., Wenzel, E., 2007. Zukunft machen: Wie Sie von Trends zu Business-Innovationen kommen. Ein Praxis-Guide. Campus-Verlag, Frankfurt.

Ibanez, J., Martinez Valderrama, J., Puigdefabregas, J., 2008. Assessing desertification risk using system stability condition analysis. Ecological Modelling 213, 180-190.

Jurack, A., Karmann, A., Lukas, D., Werblow, A., 2012. Gesundheitsökonomie: Nachfrage nach Gesundheitsleistungen. In S. Hoffmann, U. Schwarz, & R. Mai (Hrsg.), Angewandtes Gesundheitsmarketing (pp. 15-29). Springer Fachmedien, Wiesbaden.

Kearney, J., 2010. Food consumption trends and drivers. Philosophical Transactions of the Royal Society 365, 2793-2807.

Kok, K., Pedde, S., 2016. IMPRESSIONS socio-economic scenarios. Wageningen University, Wageningen, The Netherlands.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Kopainsky, B., Huber, R., Pedercini, M., 2015. Food provision and environmental goals in the Swiss agri-food system: System dynamics and the social-ecological systems framework. Systems Research and Behavioral Science 32, 414-432.

La Trobe, H.L., Acott, T.G., 2000. Localising the global food system. International Journal of Sustainable Development & World Ecology 7, 309-320.

Lavini, A., Pulvento, C., d'Adriana, R., Riccardi, M., Choukr-Allah, R., Belhabib, O., Yazar, A., Incekaya, C., Metin Sezen, S., Qadir, M., Jacobson, S.-E., 2014. Quinoa's potential in the Mediterranean Region. Journal of Agronomy and Crop Science 200 (5), 344-360.

Lester, R., Waters, J., 1989. Environmental scanning and business strategy. University Press, Cambridge.

Levers, C., Butsic, V., Verburg, P.H., Müller, D., 2016. Drivers of changes in agricultural intensity in Europe. Land Use Policy 58, 380-393.

Maes, D., Van Passel, S., 2017. An agent-based model of farmer behaviour to explain the limited adaptability of Flemish agriculture. Environmental Innovation and Societal Transitions 22, 63-77.

Mclaughlin, A., Mineau, P., 1995. The impact of agricultural practices on biodiversity. Agriculture, Ecosystems & Environment 55, 201-212.

McMichael, A. J, Powles, J. W., Butler, C. D., Uauy, R., 2007. Food, livestock production, energy, climate change, and health. Lancet 370, 1253-1263.

Meeuwissen, M. et al., 2018. A framework to analyse the resilience of EU farming systems. Deliverable 1.1, SURE-Farm project.

Morgan, K., Murdoch, J., 2000. Organic vs. conventional agriculture: Knowledge, power and innovation in the food chain. Geoforum 31, 159-173.

Mora, O., 2016. Scenarios of land use and food security in 2050. Agrimonde-Terra foresight, Working Paper.

Mylona, K., Maragkoudakis, P., Bock, A.-M., Wollgast, J., Caldeira, S., Ulberth, F., 2016. Delivering on EU Food Safety and Nutrition in 2050 – Future challenges and policy preparedness. Publications Office of the European Union, Luxembourg.

O'Neill, B.C., Kriegler, E., Riahi, K., Ebi, K.L., Hallegatte, S., Carter, T.R., Mathur, R., Vuuren, D.P., 2014. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Climatic Change 122, 387–400

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

O'Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., Van Ruijven, B., Van Vuuren, D., Birkmann, J., Kok, K., Levy, M., Moss, R., Solecki, W., 2017. The Roads Ahead: Narratives for Shared Socioeconomic Pathways describing World Futures in the 21st Century. Global Environmental Change 42, 169-180.

Otto, R., 1993. Industriedesign und qualitative Trendforschung. Akad. Verlag, München.

Pfadenhauer, M., 2004. Wie forschen Trendforscher? Zur Wissensproduktion in einer umstrittenen Branche. Forum Qualitative Sozialforschung 5 (2), URL: http://www.qualitative-research.net/fqs-texte/2-04/2-04pfadenhauer-d.htm [accessed 7 January 2018].

Pillkahn, U., 2007. Trends und Szenarien als Werkzeuge zur Strategieentwicklung. Publicis Corporate Publishing, Erlangen.

Popp, A. et al., 2017. Land-use futures in the shared socio-economic pathways. Global Envrionmental Change 42, 331-345.

Riahi, K. et al., 2017. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change 42, 153-168.

Rotz, S., Fraser, E.D.G., 2015. Resilience and the industrial food system: Analyzing the impacts of agricultural industrialization on food system vulnerability. Journal of Environmental Studies and Sciences 5, 459-473.

Rützler, H., 2017. Meet Food – Die neue Nähe zum Produkt. Zukunftsinstitut, Frankfurt. URL: https://www.zukunftsinstitut.de/artikel/food/meet-food-die-neue-naehe-zum-produkt/ [accessed 6 January 2018].

Schmitt Olabisi, L.K., Kapuscinski, A.R., Johnson, K.A., Reich, P.B., Stenquist, B., Draeger, K. J., 2010. Using scenario visioning and participatory system dynamics modeling to investigate the future: Lessons from Minnesota 2050. Sustainability 2(8), 2686-2706.

Schoemaker, P.J.H., 1995. Scenario planning: a tool for strategic thinking. Sloan Management Review 36(2), 25-40.

Schütt, P., 1972. Weltwirtschaftspflanzen, Pareys Studientexte 2. Verlag Paul Parey, Berlin/Hamburg.

Scientific Advisory Board of the Federal Ministry of Food and Agriculture for Agricultural Policy, Nutrition and health-related Consumer Protection & Scientific Advisory Board of the Federal Ministry of Food and Agriculture for Forest Policy, 2016. Klimaschutz in der Land- und

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Forstwirtschaft sowie den nachgelagerten Bereichen Ernährung und Holzverwendung. URL: http://www.bmel.de/SharedDocs/Downloads/Ministerium/Beiraete/Agrarpolitik/Klimaschutzgutachten_2016.pdf?__blob=publicationFile [accessed 6 January 2018].

Sharangi, A.B., 2009. Medicinal and therapeutic potentialities of tea (Camellia sinensis L.) – A review. Food Research International 42, 529-535.

Stave, K.A., Kopainsky, B., 2015. A system dynamics approach for examining mechanisms and pathways of food supply vulnerability. Journal of Environmental Studies and Sciences 5(3), 321-336.

Sterman, J., 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. McGraw-Hill Higher Education, Toronto, ON, Canada.

Sundkvist, Å., Milestad, R., Jansson, A., 2005. On the importance of tightening feedback loops for sustainable development of food systems. Food Policy 30, 224-239

Sustainability Institute, 2003. Commodity systems challenges: Moving sustainability into the mainstream of natural resource economies. Sustainability Institute, Hartland, Vermont.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agriculture sustainability and intensive production practices. Nature 418, 671-677.

Vervoort, J., Helfgott, A., Brzezina, N., Moragues-Faus, A., Lord, S., Avermaete, T., Mathijs, E., 2016. Explorative EU Scenarios. Deliverable 5.3., TRANSMANGO project.

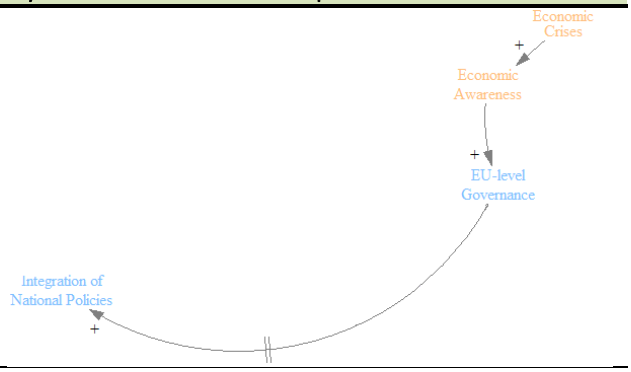
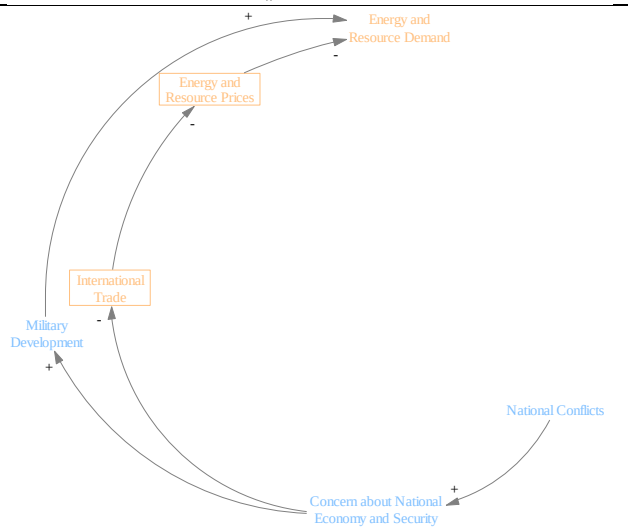
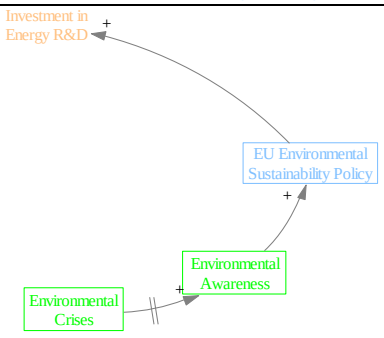
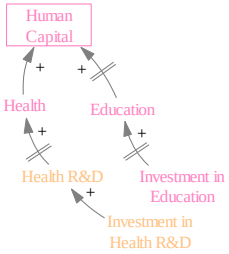
WHO, 2000. Obesity. Preventing and managing the global epidemic. WHO Technical Report Series 894, WHO, Geneva.

Williams, L. A., 2017. Top 10 Trends 2017 by Innova Market Insights. URL: http://www.enfasis.com/Presentaciones/FTSMX/2017/Summit_Food_Tech/FRIDA_KAHLO-TOP_TEN_TRENDS-LU_ANN_WILLIAMS.pdf [accessed 5 January 2018].

Zimmerman, A., Heckelei, T., Dominguez, I.P., 2009. Modelling farm structural change for integrated ex-ante assessment: review of methods and determinants. Environmental Science and Policy 12, 601-618.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Annex 1: From narrative to diagram (examples)

Scenario narrative	Dynamic causal relationships
We are the World *"The financial crisis continues to have strong repercussions and EU leaders are forced towards further integration of European financial and fiscal policies"* (Kok and Pedde, 2016, p. 12)	
Icarus *"The persistence of conflicts and decline in trade also substantially increases energy and food prices, while initiating a massive build-up of the military industry, which is resource hungry but not resource efficient"* (Kok and Pedde, 2016, p. 13)	
Riders on the Storm *"Sparked by the economic crisis and extreme weather events, the EU increases commitment to find innovative solutions to the depletion of natural resources and climate change"* (Kok and Pedde, 2016, p. 13)	
Fossil-fuelled Development *"There are also strong investments in health, education, and institutions to enhance human and social capital"* (Kok and Pedde, 2016, p. 14)	

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Annex 2: From narrative to diagram (references)

LEGEND			
P	Relationship polarity	SSP4	Eur-SSP4: Riders on the Storm
D	Significant delay (Y = Yes)	SSP5	Eur-SSP5: Fossil-fueled Development
SSP1	Eur-SSP1: We are the World	wSSP	One of the world SSPs (O'Neill et al., 2015)
SSP3	Eur-SSP3: Icarus		Relationship supported by narrative

Human Development, Demographics and Consumer Preferences

RELATIONSHIP				SCENARIO-NARRATIVE				
Cause	Effect	P	D	SSP1	SSP3	SSP4	SSP5	wSSP
Average Rural Income	Economic Equality Within Countries	+						
Average Rural Income	Gross Domestic Product in EU	+						
Average Rural Income	Net Labour Migration to EU	+	Y					
Average Rural Income	Purchasing Power	+						
Average Rural Income	Urbanisation	-						
Access to Private Goods and Services	Purchasing Power	+						
Economic Equality Within Countries	Economic Uncertainty	-	Y					
Economic Equality Within Countries	Economic Crises	-	Y					
Economic Equality Within Countries	Socio-Economic Cohesion	+	Y					
Economic Uncertainty	Fertility	-						
Education	Human Capital	+	Y					
Education	Socio-Economic Cohesion	+	Y					
Fertility	Total Population Size	+						
Food and Nutrition Security	Social Welfare in EU	+						
Health	Human Capital	+						
Human Capital	Fertility	-						
Human Capital	Mortality	-						
Human Capital	Public Access to Labour Market	+						
Human Capital	Social Welfare in EU	+						
Impact of Environmental Crises	Social Welfare in EU	-						
Investment in Education	Education	+	Y					
Investment in Social Support	Public Access to Credit	+	Y					
Net Labour Migration to EU	Total Population Size	+						
Net Refugee Migration to EU	Total Population Size	+						
Mortality	Total Population Size	-						
Public Access to Credit	Economic Equality Within Countries	+						
Public Access to Labour Market	Economic Equality Across EU Countries	+						

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Public Access to Labour Market	Net Labour Migration to EU	+						
Purchasing Power	Energy and Resource Demand	+						
Purchasing Power	Job Availability	+	Y					
Purchasing Power	Social Welfare in EU	+						
Rural Employment	Average Income	+	Y					
Rural Job Availability	Rural Employment	+						
Rural Population Size	Rural Employment	-	Y					
Social Awareness	EU Human Development Budget	+						
Social Crises	Social Awareness	+	Y					
Social Welfare in EU	Net Refugee Migration to EU	+						
Social Welfare in EU	Social Crises	-	Y					
Societal Participation	Public Access to National Institutions	+						
Societal Participation	Social Welfare in EU	+						
Socio-Economic Cohesion	Societal Participation	+						
Sustainability of Lifestyles	Energy and Resource Demand	-	Y					
Sustainability of Lifestyles	Food and Nutrition Security	+						
Total Population Size	Rural Population Size	+						
Urbanisation	Rural Population Size	-						

Economic Development and Technology

RELATIONSHIP				SCENARIO-NARRATIVE				
Cause	Effect	P	D	SSP1	SSP3	SSP4	SSP5	wSSP
Economic Awareness	EU Economic Development Budget	+						
Economic Awareness	EU-level Collaboration	+						
Economic Crises	Economic Awareness	+						
Economic Equality Across EU Countries	Economic Crises	-	Y					
Economic Equality Across EU Countries	GDP in EU	+	Y					
Energy and Resource Demand	Conventional Energy and Resource Extraction	+						
Energy and Resource Prices	Energy and Resource Demand	-						
Energy and Resource Use Efficiency	Conventional Energy and Resource Extraction	-						
Energy R&D	Energy and Resource Use Efficiency	+	Y					
Energy R&D	Green Energy Production	+	Y					
Health R&D	Health	+	Y					
Gross Domestic Product in EU	Access to Private Goods and Services	+						
Gross Domestic Product in EU	EU Policy Budget	+						
Gross Domestic Product in EU	Urbanisation	+						
Green Energy Production	Land Use Intensity	+						
Green Energy Production	Investment in Energy R&D	+						

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Integration of International Markets	Economic Equality Across EU Countries	+						
Integration of International Markets	International Trade	+						
Integration of International Markets	Public Access to Labour Market	+						
International Trade	Economic Equality Across EU Countries	+						
International Trade	Energy and Resource Prices	-						
International Trade	Access to Private Goods and Services	+						
Investment in Energy R&D	Energy R&D	+						
Investment in Health R&D	Health R&D	+						
Investment in Technological Innovation	Skill Based Technology	+						
Investment in Technological Innovation	Technology Transfer Pace	+						
Market Competition	Economic Equality Across EU Countries	-						
Market Competition	GDP in EU	+						
Demand for High-Skilled Labour	Public Access to Labour Market	-						
Skill Based Technology	Demand for High-Skilled Labour	+						
Technology Transfer Pace	Investment in Technological Innovation	+						

Governance Development and Policy

RELATIONSHIP				SCENARIO-NARRATIVE				
Cause	Effect	P	D	SSP1	SSP3	SSP4	SSP5	wSSP
Concentration of Power, Wealth, and Income	EU Governance Capacity	-						
Concentration of Power, Wealth, and Income	National Conflicts	+						
Concern about National Economy and Security	Environmental Vulnerability	+						
Concern about National Economy and Security	International Trade	-						
Concern about National Economy and Security	Military Development	+						
Concern about National Economy and Security	EU Policy Planning Horizon	-						
Effectiveness of EU Institutions	EU Policy Effectiveness	+						
Environmental Subsidies and Taxes	Energy and Resource Prices	+						
Environmental Subsidies and Taxes	Sustainability of Lifestyles	+	Y					
Environmental Sustainability Regulation	Conventional Energy and Resource Extraction	-	Y					

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Environmental Sustainability Regulation	Land Use Intensity	-	Y					
EU Economic Development Budget	Investment in Technological Innovation	+						
EU Economic Development Budget	Market Regulation and Trade Barriers	-						
EU Environmental Sustainability Budget	Environmental Sustainability Regulation	+						
EU Environmental Sustainability Budget	Environmental Subsidies and Taxes	+						
EU Environmental Sustainability Budget	Investment in Energy R&D	+						
EU Institutional Power	EU Governance Capacity	+	Y					
EU Institutional Power	National Institutional Power	-						
EU Governance Capacity	Effectiveness of EU Institutions	+						
EU Human Development Budget	Investment in Education	+						
EU Human Development Budget	Investment in Health R&D	+						
EU Human Development Budget	Investment in Social Support	+						
EU-level Collaboration	International Cooperation	+						
EU-level Collaboration	Integration of National Policies	+	Y					
EU Policy Effectiveness	EU Economic Development Budget	+						
EU Policy Effectiveness	EU Environmental Sustainability Budget	+						
EU Policy Effectiveness	EU Human Development Budget	+						
EU Policy Effectiveness	EU-level Collaboration	+						
EU Policy Planning Horizon	EU Policy Effectiveness	+						
EU Policy Budget	EU Policy Effectiveness	+						
Integration of National Policies	Market Regulation and Trade Barriers	+						
International Collaboration between Institutions	EU Institutional Power	+						
International Collaboration between Institutions	Technology Transfer Pace	+						
International Cooperation	Integration of International Markets	+	Y					
International Cooperation	International Collaboration between Institutions	+	Y					
Market Regulation and Trade Barriers	International Trade	-						
Market Regulation and Trade Barriers	Market Competition	-						
Market Regulation and Trade Barriers	Public Access to Labour Market	+						
Military Development	Energy and Resource Demand	+						
National Conflicts	Concern about National Economy and Security	+						
National Conflicts	EU Governance Capacity	-						
National Institutional Power	EU Governance Capacity	-						

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

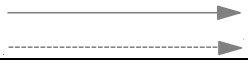
National Institutional Power	National Conflicts	+						
Public Access to National Institutions	Concentration of Power, Wealth, and Income	-						
Public Access to National Institutions	EU Human Development Budget	+						

Environmental Development and Climate

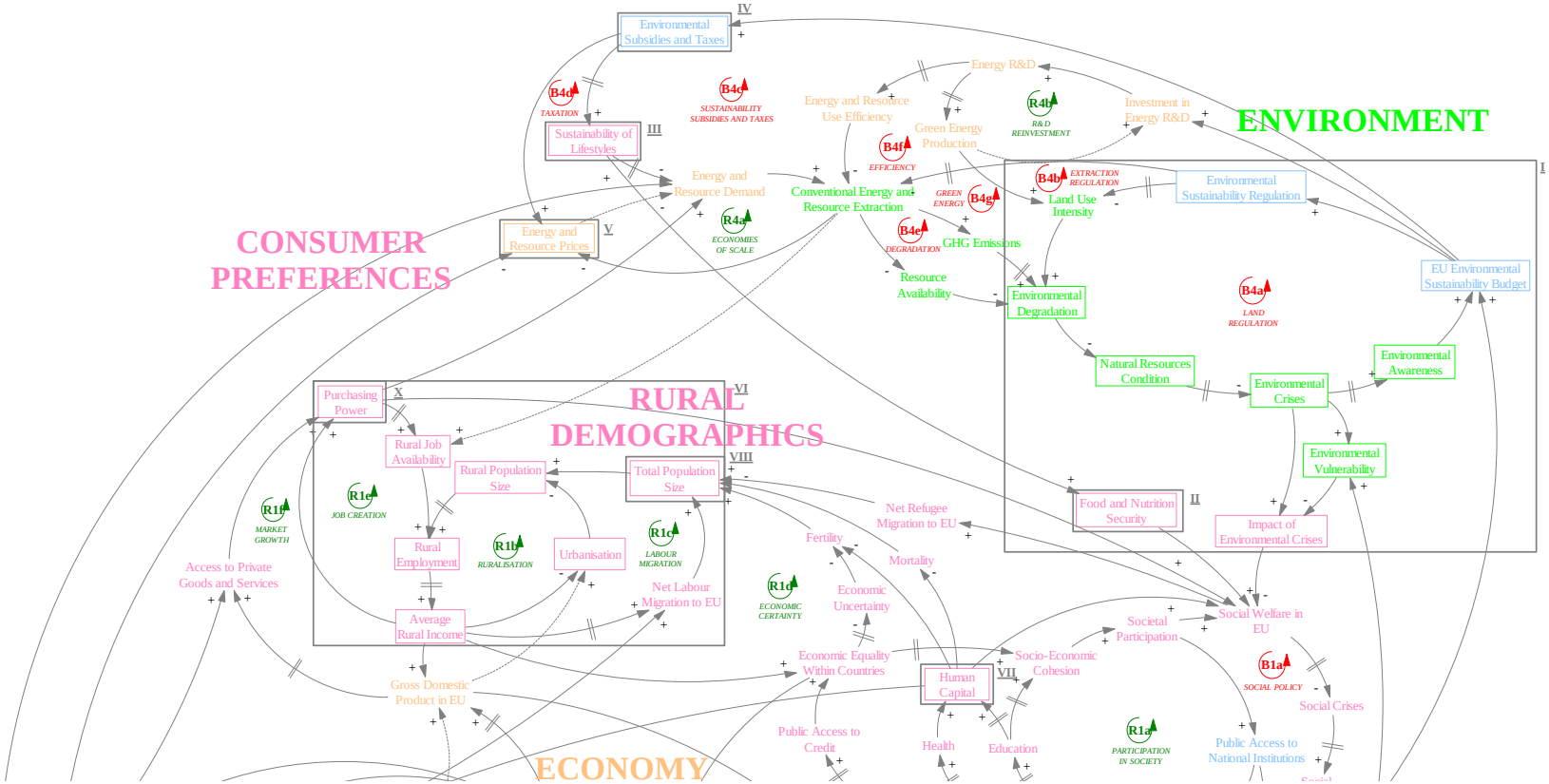
RELATIONSHIP				SCENARIO-NARRATIVE				
Cause	Effect	P	D	SSP1	SSP3	SSP4	SSP5	wSSP
GHG Emissions	Environmental Degradation	+	Y					
Conventional Energy and Resource Extraction	GHG Emissions	+						
Conventional Energy and Resource Extraction	Energy and Resource Prices	-						
Conventional Energy and Resource Extraction	Resource Availability	-						
Conventional Energy and Resource Extraction	Rural Job Availability	+						
Environmental Awareness	EU Environmental Sustainability Budget	+						
Environmental Crises	Environmental Awareness	+	Y					
Environmental Crises	Environmental Vulnerability	+						
Environmental Crises	Impact of Environmental Crises	+						
Environmental Degradation	Natural Resources Condition	-						
Environmental Vulnerability	Impact of Environmental Crises	-						
Land Use Intensity	Environmental Degradation	+						
Natural Resources Condition	Environmental Crises	-	Y					
Resource Availability	Environmental Degradation	-						

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

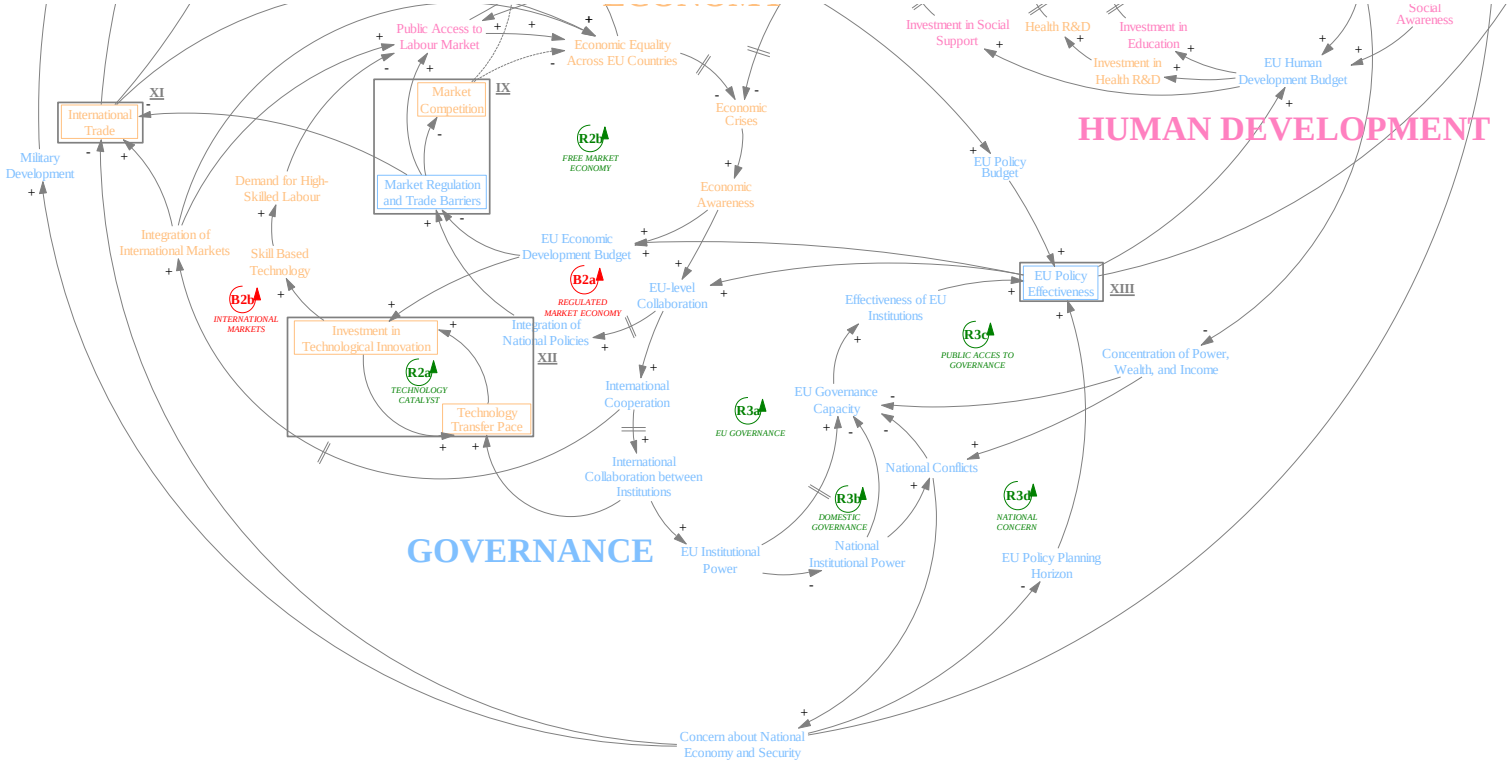
Annex 3: Comprehensive CLDs of Eur-SSPs and farming system

LEGEND	
Causal relationship based on narrative or literature Causal relationship based on expert knowledge	
Negative relationship Positive relationship Significant delay	- + ||
Balancing feedback loop and name – labelled with track number Reinforcing feedback loop and name – labelled with track number	
Indicator in the 'macro environment' that is (in)directly related with the farming system	Rural Population Size
Area of indicator(s) is related to a particular area in the farming system – labelled with track number	EU Policy Effectiveness XIII
Indicator related to Human Developments, Demographics & Consumer Preferences Indicator related to Economic Developments & Technology Indicator related to Governance Developments & Policy Indicator related to Environmental Developments & Climate	Average Income Farming Knowledge Availability Policy Effectiveness Conventional Energy and Resource Extraction
Indicator related to budget and risk management Indicator related to production efficiency and productivity Indicator related to production and consumption	Investment in Labour Production Costs Crop Sales

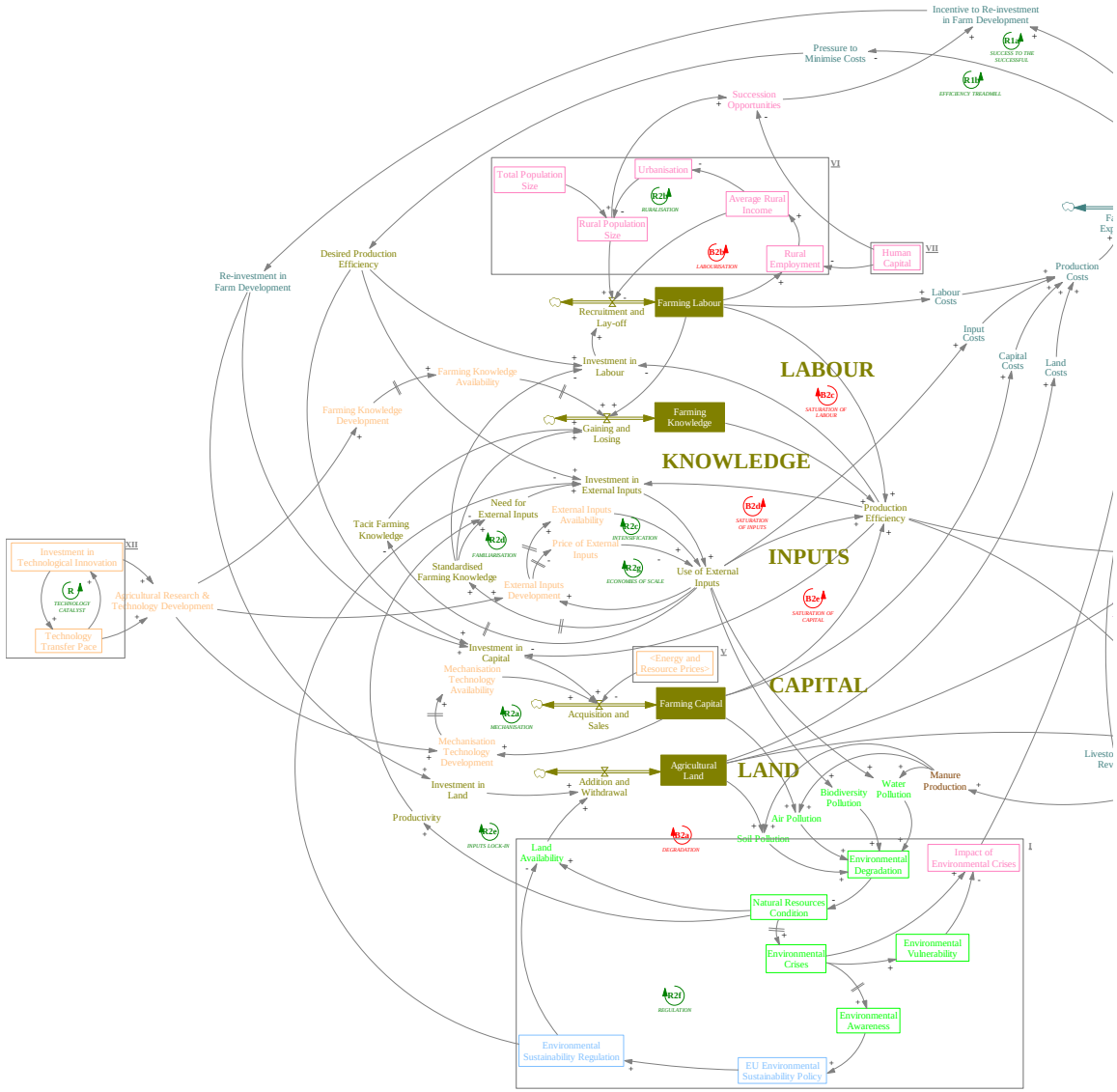
This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



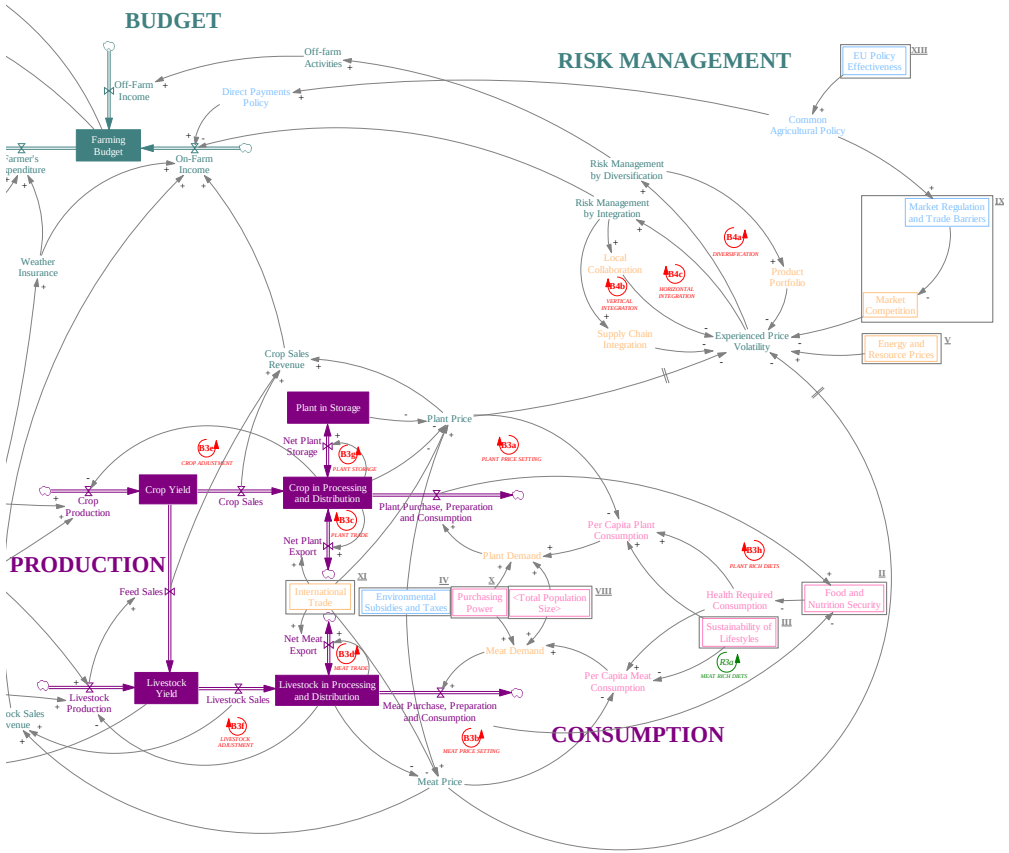
This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Annex 5: Characterization of Shared Socio-economic Pathways

	SSP1 Sustainability	SSP2 Middle of the road	SSP3 Regional rivalry	SSP4 Inequality	SSP5 Fossil-fueled development
Growth per capita	High in LICs, MICs; medium in HICs	Medium, uneven	Slow	Low in LICs, medium in other countries	High
Inequality	Reduced across and within countries	Uneven moderate reductions across and within countries	High, especially across countries	High, especially within countries	Strongly reduced, especially across countries
International trade	Moderate	Moderate	Strongly constrained	Moderate	High, with regional specialization in production
Globalization	Connected markets, regional production	Semi-open globalized economy	De-globalizing, regional security	Globally connected elites	Strongly globalized, increasingly connected
Consumption & diet	Low growth in material consumption, low-meat diets, first in HICs	Material-intensive consumption, medium meat consumption	Material-intensive consumption	Elites: high consumption lifestyles; Rest: low consumption, low mobility	Materialism, status consumption, tourism, mobility, meat-rich diets
International cooperation	Effective	Relatively weak	Weak, uneven	Effective for globally connected economy, not for vulnerable populations	Effective in pursuit of development goals, more limited for envt. goals
Environmental policy	Improved management of local and global issues; tighter regulation of pollutants	Concern for local pollutants but only moderate success in implementation	Low priority for environmental issues	Focus on local environment in MICs, HICs; little attention to vulnerable areas or global issues	Focus on local environment with obvious benefits to well-being, little concern with global problems
Policy orientation	Toward sustainable development	Weak focus on sustainability	Oriented toward security	Toward the benefit of the political and business elite	Toward development, free markets, human capital
Institutions	Effective at national and international levels	Uneven, modest effectiveness	Weak global institutions/ natl. govts. Dominate societal decision-making	Effective for political and business elite, not for rest of society	Increasingly effective, oriented toward fostering competitive markets

Source: O'Neill et al. (2017)

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Annex 6: Overview on land use description for the 5 SSP scenarios

	SSP 1 Sustainability	SSP 2 Middle of the raod	SSP 3 Regional rivalry	SSP 4 Inequality	SSP 5 Fossil-fueled devevelopment
Land-use change regulation	Strong regulation to avoid environmental tradeoffs	Medium regulation; slow decline in the rate of deforestation	Limited regulation; continued deforestation	Highly regulated in MICs and HICs; lack of regulation in LICs lead to high deforestation rates	Medium regulation; slow decline in the rate of deforestation
Land productivity growth	High improvements in agricultural productivity; rapid diffusion of best practices	Medium pace of technological change	Low technology development	Productivity high for large scale industrial farming, low for small-scale farming	Highly managed, resource-intensive; rapid increase in productivity
Environmental Impact of food consumption	Low growth in food consumption, low-meat diets	Material-intensive consumption, medium meat consumption	Resource-intensive consumption	Elites: high consumption lifestyles; Rest: low consumption	Material-intensive consumption, meat-rich diets
International Trade	Moderate	Moderate	Strongly constrained	Moderate	High, with regional specialization in production
Globalization	Connected markets, regional production	Semi-open globalized economy	De-globalizing, regional security	Globally connected elites	Strongly globalized
Land-based mitigation policies	No delay in international cooperation for climate change mitigation. Full participation of the land use sector	Delayed international cooperation for climate change mitigation. Partial participation of the land use sector	Heavily delayed international cooperation for climate change mitigation. Limited participation of the land use sector	No delay in international cooperation for climate change mitigation. Partial participation of the land use sector	Delayed international cooperation for climate change mitigation. Full participation of the land use sector

Source: Popp et al. (2017)

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Annex 7: TRANSMANGO Scenarios (Vervoort et al., 2016)

	Consumption Patterns	Environmental Degradation	Poverty and Economic Inequality	Social and Technical Innovation	Urban and Rural Population Dynamics	Power and Market Concentration	Trade Agreements	Resource Use
Fed up Europe	High animal products, high sugar/processed food (unhealthy meat eaters)	Biodiversity loss, water pollution, soil degradation etc. continued environmental decline	Low poverty high inequality – few are truly poor, but some are extremely rich	Low innovation, private sector driven – public and private sectors are inert, despite interest in change among a minority in the private sector	Increase in both urban and rural populations	Extreme concentration: several companies dominate the entire market worldwide	Free markets (more free trade agreements, removal of subsidisation)	Resource crisis
The Retrotopia	Low animal products, high sugar/processed food (unhealthy vegans and vegetarians)	Environmental degradation is reversed	Low poverty, low inequality	High innovation, public sector driven	Decrease in both urban and rural populations	Healthy competition exists in all sectors – significant role for SMEs	Protected markets (less free trade more subsidies)	Significant reduction in resource use/demand
The Protein Union	Meat consumption, low sugar/processed food – strong innovation on animal proteins, e.g. insects	Environment is stabilized but at lower levels than today	High poverty, low inequality – people have less assets but strong state support.	High innovation, public sector driven – the public sector stimulates innovation, but there is an important role for the private sector	Decrease in rural, increase in urban	Some sectors dominated by a few global players, others less concentrated	Protected markets (less free trade more subsidies)	Resource scarcity
The Price Of Health	Low animal products, low sugar/processed food (healthy vegans and vegetarians)	Environment is stabilized	High poverty, high inequality – incomes are low, but quality of life has been decoupled from income through other means of subsistence; the rich lead very different lives	High innovation, needs driven, bottom-up – local initiatives, local businesses and local governments	Increase in rural decrease in urban	Extreme decentralisation dominated by SMEs	Protected markets (less free trade more subsidies)	Significant reduction in resource use/demand

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

	Consumption Patterns	Environmental Degradation	Poverty and Economic Inequality	Social and Technical Innovation	Urban and Rural Population Dynamics	Power and Market Concentration	Trade Agreements	Resource Use
The Gravy Train	High animal products, high sugar/processed food (unhealthy meat eaters)	Biodiversity loss, water pollution, soil degradation etc. Continued environmental decline	Low poverty high inequality	High innovation, bottom up and needs driven	Rural and urban populations stabilized	Extreme decentralisation, dominated by SMEs	Protected markets (less free trade more subsidies)	Resource scarcity
Goodbye to All That	Low animal products, high sugar/processed food (unhealthy vegans and vegetarians)	Biodiversity loss, water pollution, soil degradation etc. Continued environmental decline	High poverty, high inequality	Low innovation, private sector driven	Reruralisation	Some sectors dominated by a few global players, others less concentrated	Protected markets (less free trade more subsidies)	Resource scarcity
Too Busy to Cook	Low animal products, high sugar/processed food (unhealthy vegans and vegetarians)	Environment is revived	Low poverty high inequality	High innovation, private sector driven	Rural and urban populations stabilized	Extreme decentralisation, dominated by SMEs	Free markets (more free trade agreements, removal of subsidisation)	Decoupled economies
The Grass is Greener	Low animal products, low sugar/processed food (healthy vegans and vegetarians)	Environment is stabilized worldwide but at lower levels than today	High poverty, high inequality	Low innovation, public sector driven	Decrease in urban and rural populations	Competitive markets, mix of larger and smaller companies	Free markets (more free trade agreements, removal of subsidisation)	Resource scarcity

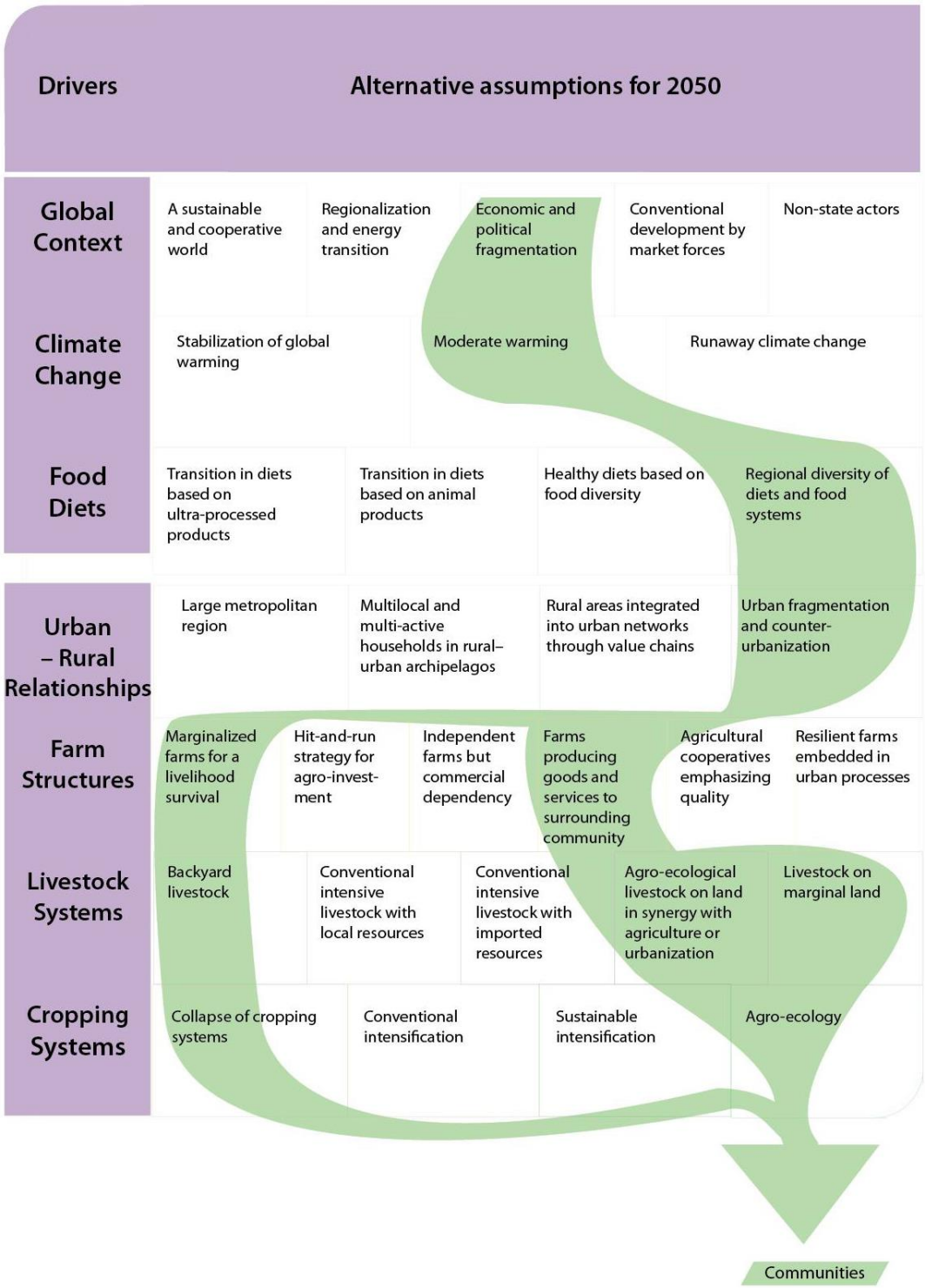
This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Annex 8: DG SANTE Scenarios (Mylona et al., 2016)

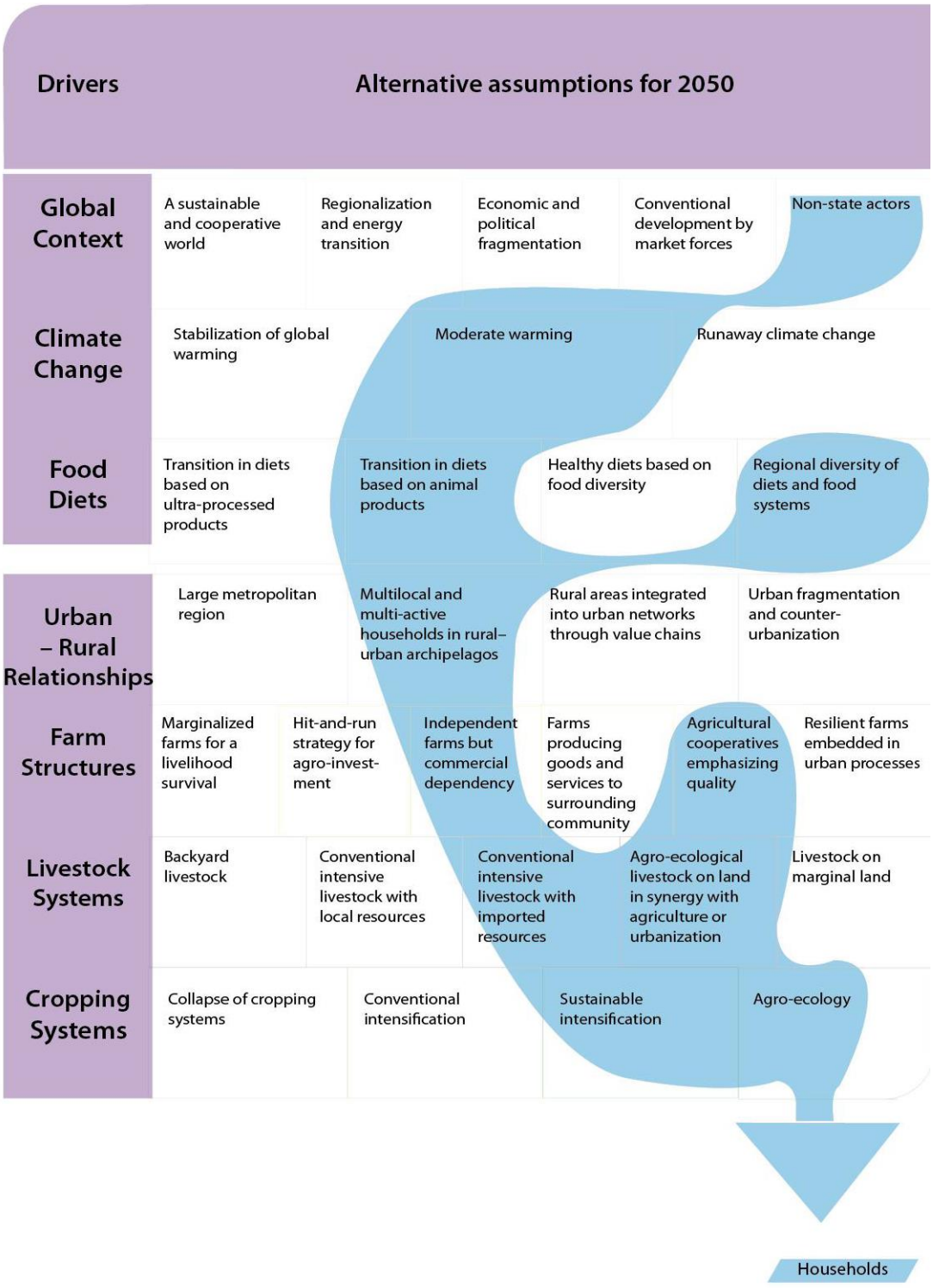
Driver	"Global Food"	"Regional Food"	"Partnership Food"	"Pharma Food"
Global trade	Full liberalisation	Disrupted and fragmented	EU trade focus on the US & Canada	Full liberalisation
EU economic growth	Medium	Decoupled, GDP no longer used as indicator	Stagnation	High
Agro-food chain structure	Concentration	Diversification, alternative food chains	Concentration	Concentration
Technology uptake	High	High with focus on environmental sustainability	High	High with focus on nutrition & health
Social cohesion	Low	High	Limited to local community	High
Food values	Low	High with focus on local production & quality	Low	High with focus on nutrition & health
Climate change	2°C threshold of temperature increase will be reached by 2050			
Depletion of natural resources	Progressive natural resource depletion towards 2050			
World population growth	World population will increase to about 9 billion by 2050			

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

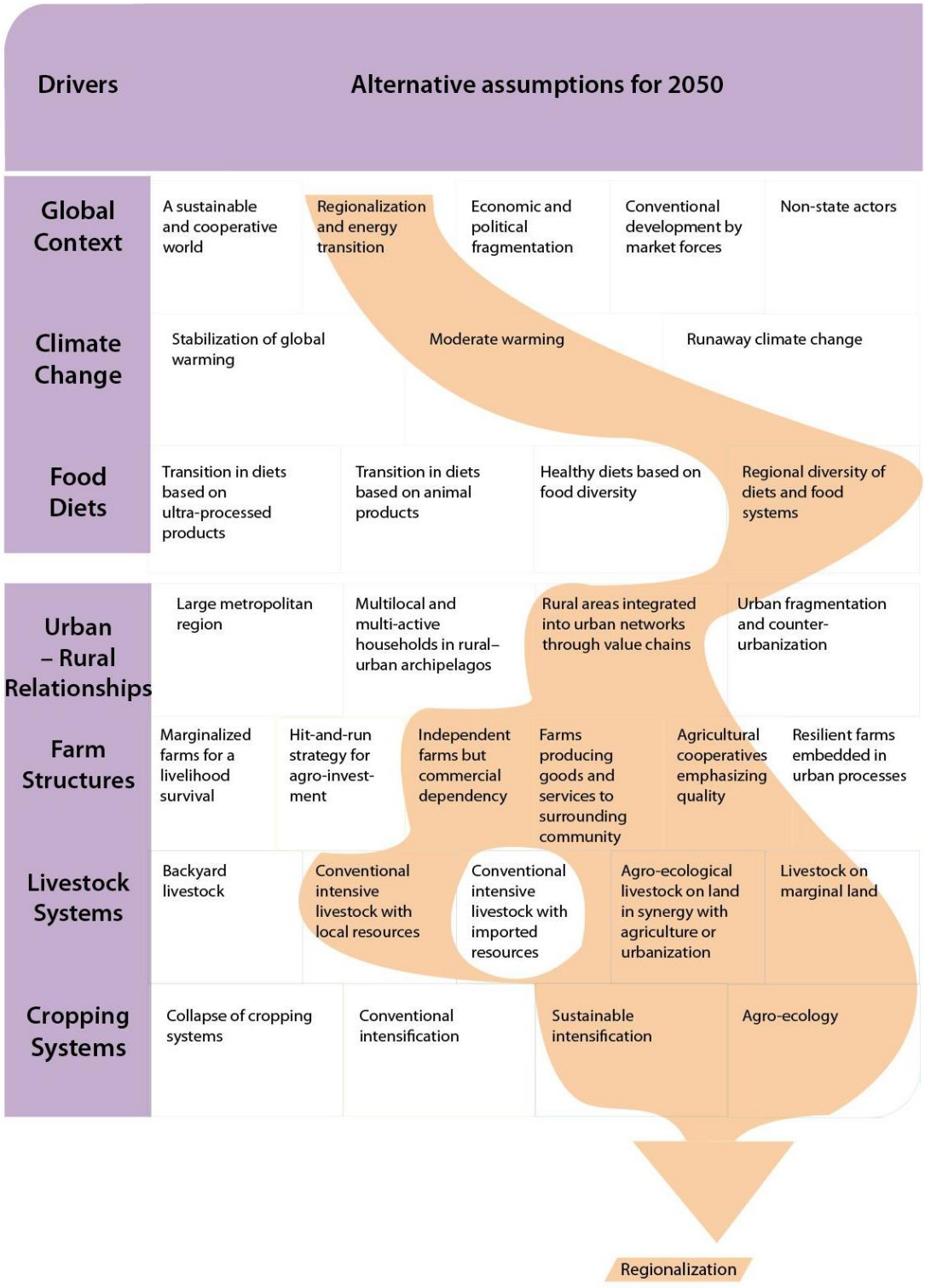
Annex 9 : Agrimonde-TERRA scnearios (Mora, 2016)



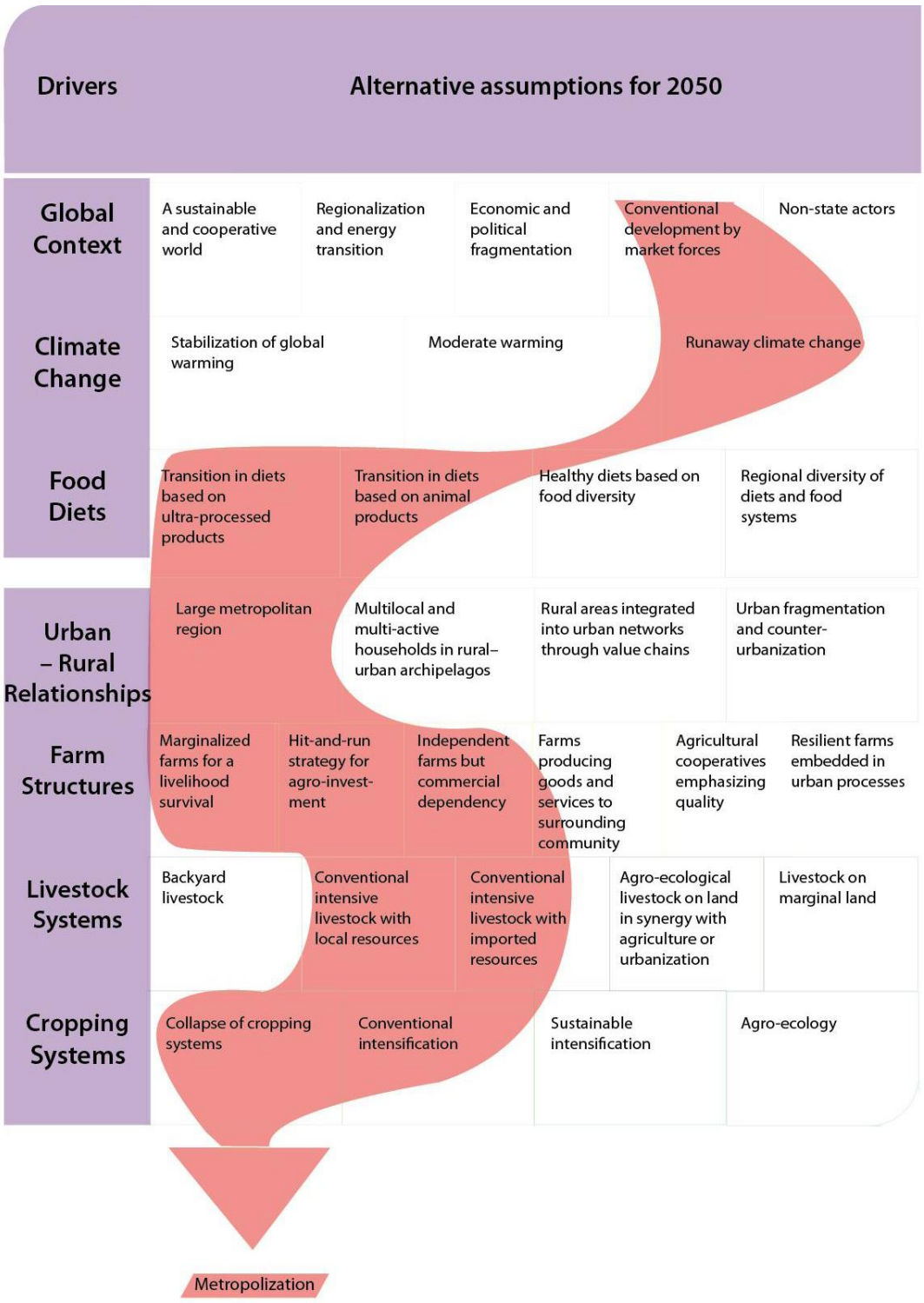
This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



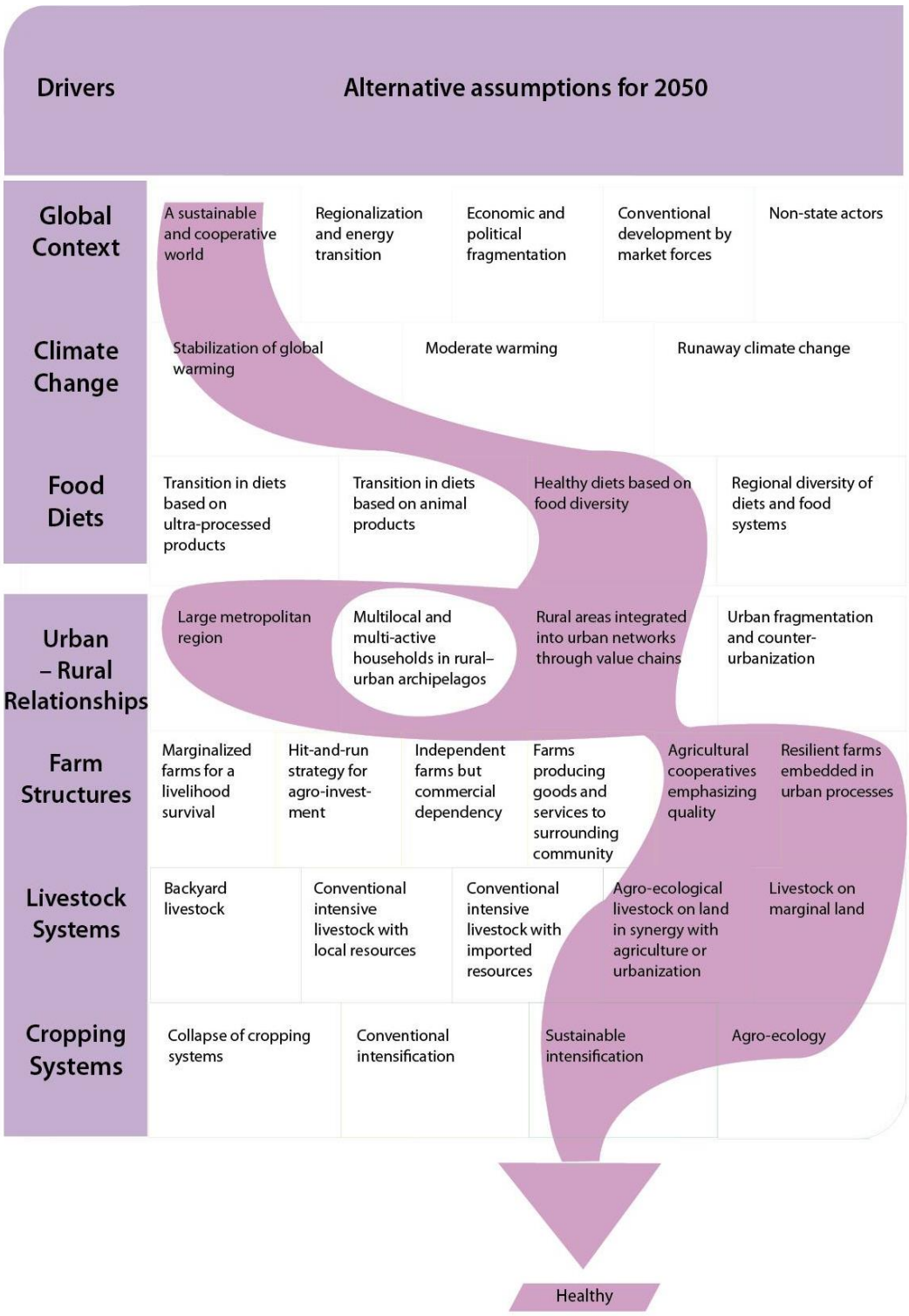
This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520



This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Annex 10: Quantitative assumptions of SSPs (Popp et al., 2017)

Demand for meat

	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
IMAGE	Meat&dairy consumption 5%, 10%, 20% and 30% lower than endogenous outcome, in 2020, 2030, 2050, and 2100 respectively	-	meat&dairy consumption 5%, 10%, 20% and 30% higher than endogenous outcome, in 2020, 2030, 2050, and 2100 respectively	-	-
GCAM	Future projections linked to income, using historical income-calorie relationships. Meat demand limited to 1000kcal/per/day. Growth in meat demand limited to 2% per year	Future projections linked to income, using historical income-calorie relationships. Meat demand limited to 1100kcal/per/day. Growth in meat demand limited to 2% per year	Future projections linked to income, using historical income-calorie relationships. Meat demand limited to 1400kcal/per/day. Growth in meat demand limited to 2% per year	Future projections linked to income, using historical income-calorie relationships. Meat demand limited to 1100kcal/per/day. Growth in meat demand limited to 2% per year	Future projections linked to income, using historical income-calorie relationships. Meat demand limited to 1400kcal/per/day. Growth in meat demand limited to 2% per year
AIM-CGE	Low meat demand. Low income elasticity of meat consumption.	Income elasticity derived from income and meat consumption and best fitted case is adopted as medium	High meat demand. High income elasticity of meat consumption.	Settings of SSP1, 2 and 3 were applied to high-, med- and low-income groups, respectively.	Income elastisity same as SSP2 and as a result of the combination of high income and medium elasticity, the meat consumtpion becomes high.
MESSAGE-GLOBIOM	Animal protein demand is reduced in regions where more than 75 g prot/cap/day are consumed for animal and vegetal products. A minimum consumption of 25 g prot/cap/day of animal calories is ensured but red meat consumption	Income elasticities calibrated to FAO AT2050 (Alexandratos & Bruinsma, 2012).	SSP2 elasticities used, difference in demand is due to the difference in GDP	-	-

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
	is reduced to 5 g prot/cap/day				
REMIND-MAGPIE	Food demand sytem leading to medium food demand and low demand for livestock products. Additionally, food waste is strongly reduced, leading to a maximum demand of 3000kcal/capita/day.	Food demand sytem leading to medium food demand and low demand for livestock products. Livestock share in rich countries not falling below 15%.	-	-	Food demand sytem leading to high food demand and high demand for livestock products. Liivestock share in rich countries not falling below 15%.

Yield increase

	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
IMAGE	Yield increase as a function of GDP increase as e.g. suggested by Powell et al. 2013, and see IMAGE paper	Yield increase as a function of GDP increase as e.g. suggested by Powell et al. 2013, and see IMAGE paper	Yield increase as a function of GDP increase as e.g. suggested by Powell et al. 2013, and see IMAGE paper	-	
GCAM	Annual growth rates 1.5x FAO estimates	Based on FAO estimates for all regions.	Annual growth rates 1/2 of FAO estimates	Based on FAO estimates for all regions	Growth rates are double FAO estimates
AIM-CGE	20% increase in an annual growth ratio from a baseline assumption in low- and medium-regions.	10% decrease in an annual growth ratio from a baseline assumption	70% decrease in an annual growth ratio from a baseline assumption	Settings of SSP1, 2 and 3 were applied to high-, med- and low-income groups, respectively.	same as SSP1
MESSAGE-GLOBIOM	Technological change as a function of GDP.	Technological change as a function of GDP.	Technological change as a function of GDP.	-	-
REMIND-MAGPIE	Endogenous yield increase	Endogenous yield increase	-	-	Endogenous yield increase

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520

Agricultural trade barriers

	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
IMAGE	Export subsidies and import tariffs reduction for all sectors, in 2020 50% reduction compared with 2010, 2030 abolished.	-	-	-	
AIM-CGE	Agricultural trade barriers decline; 0.2%/year increase in price elasticity of trade.	Trande tariff and price elasticities are same as base year	Agricultural trade barriers decline; 0.2%/year decrease in price elasticity of trade.	Settings of SSP1, 2 and 3 were applied to high-, med- and low-income groups, respectively.	same as SSP1
REMIND-MAGPIE	Agricultural trade barriers decline by 1% per year	Agricultural trade barriers decline by 0.5% per year	-	-	Agricultural trade barriers decline by 1% per year

Regional preferences

	SSP 1	SSP 2	SSP 3	SSP 4	SSP 5
IMAGE	Preference for products from own region: Implemented by the introduction of an import taxes for all agri products. 2030: 5%, 2050: 10%, 2100 10%	-	Food security concerns: Implemented by the introduction of an import taxes for all agri products. 2030: 5%, 2050: 10%, 2100 10%.	-	-

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 727520