17 Integrated Assessment of the Sustainability and Resilience of Farming Systems

Lessons from the Past and Ways Forward for the Future

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17.1 Introduction

European agriculture is coping with economic, environmental, social and institutional challenges that are expected to further accumulate in the future. Identifying strategies to cope with these challenges requires understanding of the mechanisms that make farming systems resilient. Following the definition adopted in SURE-Farm, a resilient farming system continuously provides economic (e.g., assuring economic viability), environmental (e.g., maintenance of natural resources), and social (e.g., ensuring a good quality of life) functions, even in the face of multiple challenges. These functions include ecosystem services, i.e., the goods and services that ecosystems provide to humans (Daily, 1997). The integration of economic, environmental, and social functions resonates with the concept of sustainability (Schader et al., 2016). We hypothesized a reinforcing interaction between sustainability and resilience. We argue that when dimensions of food production, environment, economy, and society are well and equally addressed, a farming system strengthens its ability to cope with challenges (Walker and Salt, 2012).

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We first studied the levels of sustainability and resilience of current European farming systems in the past and present, and used insights derived from this to imagine the future. This has methodological difficulties. First, farming systems consist of multiple technical, ecological, economic, and social elements interacting in a non-linear way (Fischer et al., 2015). We took into account the multi-dimensional aspects of farming systems with an integrated system approach (van Ittersum et al., 2008). We further used the resilience framework of Meuwissen et al. (2019), presented in Chapter 1, to navigate the complex issue of farming systems' sustainability and resilience in five steps: identification of (1) the system, (2) the main challenges, (3) the main functions, (4) the resilience capacities and (5) the main resilience attributes. For operationalizing these steps, we used an Integrated Assessment (IA) (see Rotmans and van Asselt, 1996), consisting of an interdisciplinary mix of qualitative and quantitative methods, involving participatory approaches with stakeholders, models, and data analysis.

Second, Europe presents a wide heterogeneity of farming systems: from extensive ruminant systems in less favoured areas to intensive systems relying on feed imports; from integrated crop-livestock systems to monocultures. We selected eleven case studies with different characteristics in terms of geographic location, typology (arable, livestock, permanent crops, mixed crop-livestock), social, economic and historical context. Although not completely representative of Europe's farming system heterogeneity, the selection of eleven different farming systems supported the generalization of results and the formulation of policy recommendations. In the chapter, these case studies are referred to with abbreviations: arable system in Bulgaria (BG-Arable), mixed and arable system in Germany (DE-Mixed&Arable), arable system in the United Kingdom (UK-Arable), dairy system Belgium (BE-Dairy), extensive beef cattle system in France (FR-Beef), extensive sheep system in Spain (ES-Sheep), horticulture system in Poland (PL-Horticulture), hazelnut system in Italy (IT-Hazelnut), starch potato system in the Netherlands (NL-Arable), mixed smallholder farms system in Romania (RO-Mixed) and poultry system in Sweden (SE-Poultry).

In this chapter, we present an assessment of the eleven SURE-Farm case studies aimed at exploring linkages between sustainability and resilience. The narrative is primarily based on a selection of methods that allow for comparisons across case studies. Generalizable findings are given priority over farming-system-specific details. These

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details can be found in the case study chapters (Chapters 6–16) and in SURE-Farm deliverables (Paas et al., 2019; Reidsma et al., 2019; Accatino et al., 2020).

17.2 Contribution of Qualitative and Quantitative Methods to Resilience Assessment

In this section, we present how the three steps of the resilience assessment framework presented in Chapter 1 were operationalized: (i) identifying the key challenges that could impede the ability of the farming systems to deliver the desired functions, (ii) assessing the importance and performance of the functions provided by the farming systems, (iii) investigating the resilience-enhancing attributes, i.e., the characteristics of the systems that are likely to enhance resilience.

17.2.1 A Toolbox for Resilience Assessment

In SURE-Farm we assembled an IA toolbox with complementary qualitative and quantitative methods (see Herrera et al., 2018). The qualitative methods consisted of two participatory workshops with representatives of different stakeholder groups (e.g., farmers, food chain actors, NGOs, government) and were conducted in each farming system. The first workshop (FoPIA-SURE-Farm 1; Paas et al., 2019, 2021a) was focused on the resilience of current systems: we assessed the main challenges, the perceived importance and performance of functions, the strategies adopted to cope with past challenges, and the resilience attributes. The second workshop (FoPIA-SURE-Farm 2; Accatino et al., 2020; Paas et al., 2021b; 2021c) was focused on the resilience of future, hypothetical, systems. The quantitative methods included the assessment of current and future ecosystem services based on data and models and the simulation of farming system behavior based on system dynamics modelling.

17.2.2 Assessing Challenges (Resilience to What)

During the activities of the SURE-Farm projects (participatory workshops, focus groups, interviews), we identified and discussed key challenges in interaction with stakeholders in the case studies. For future resilience we assessed in interaction with stakeholders the closeness of

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the most important challenges to critical thresholds, whose exceedance would have a drastic impact on farming system functioning. This assessment was done in all case studies except two (BE-Dairy and FR-Beef, due to the COVID-19 crisis). Closeness of challenges to critical threshold was classified into 'not close', 'somewhat close', 'close', and 'at or beyond'.

17.2.3 Assessing Functions (Resilience for Which Purpose)

Eight farming system functions were identified and categorized as providing private or public goods. The provision of private goods includes (1) producing food, (2) producing other bio-based resources, (3) ensuring economic viability and (4) providing quality of life for people involved in farming. The provision of public goods includes (1) maintaining natural resources (2) maintaining biodiversity in good condition, (3) ensuring animal welfare and (4) ensuring that rural areas are attractive places for residence and tourism. In participatory workshops, stakeholders were asked to individually assess the importance and performance of the eight functions. Importance was assessed by letting stakeholders divide 100 points over the functions. Assessing performance was based on stakeholders' scores on a scale: (1) very low, (2) low, (3) moderate, (4) good and (5) very good performance.

The participatory assessment of functions was complemented with an ecosystem services assessment based on quantitative data, mostly related to the biophysical components of the system. For ecosystem services, the considered private goods were food crop production, fodder crop production, energy crop production, grazing livestock density, and timber removal. The considered public goods were carbon storage, habitat quality, atmospheric pollutant deposition, topsoil organic matter concentration, relative pollination potential, recreation potential, soil erosion control, and water retention. The assessment was based on gridded ecosystem service maps at the European scale made publicly available by the Joint Research Centre of the European Commission (see Maes et al., 2015). We calculated the average grid value of the ecosystem services in the farming systems as well as in the sub-national regions surrounding them (Nomenclature of Territorial Units for Statistics 3; NUTS 3). This allowed for comparing each farming system with the surrounding region in terms of ecosystem service provision.

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In order to explore future sustainability and resilience, stakeholders were asked to determine critical thresholds for main challenges, functions, and resilience attributes, and, next, assess system performance in case critical thresholds would be exceeded (Accatino et al., 2020; Paas et al., 2021b; 2021c). Impacts on performance were classified as strongly negative (−2), moderately negative (−1), no trend (0), moderately positive (+1), and strongly positive developments (+2). As a baseline reference, researchers also assessed the development of farming system performance based on current levels and trends of functions and resilience attributes. Subsequently, stakeholders identified possible alternative configurations of the farming systems. Alternative systems were generated based on individual input and elaborated in small group discussions of three to eight stakeholders moderated by a researcher. In these discussions, stakeholders were invited to elaborate how an alternative system would perform regarding system functions and resilience attributes.

The assessment of future systems was completed with system dynamics modelling, which is based on a causal-loop diagram able to represent the cause–effect relationship present in the farming systems (Richardson, 2011). The advantage of this approach is that cause-effect relationships can be mapped coherently, which is otherwise challenging during a participatory assessment due to the limits of mental capabilities of researchers and stakeholders (e.g., bounded reality). Therefore, in a sense, the modelling approach can extend the reach of our mind (Sterman, 2000).

17.2.4 Assessing Resilience Attributes (What Enhances Resilience)

Resilience attributes are characteristics of the farming system or its surrounding environment which enhance resilience (Cabell and Oelofse, 2012; Paas et al. 2021a; see a complete list in Chapter 1). An example of a resilience attribute is 'ecologically self-regulated' which promotes resilience because it is argued that a system relying on natural regulation processes is more likely to withstand shocks due to input shortage. Based on input from FoPIA-SURE-Farm workshops, we assessed the presence of resilience attributes in the farming systems by looking at the strategies that farming system actors have already adopted and the strategies that are proposed to realize potential future

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systems. Strategies are linked to resilience attributes (see Reidsma et al., 2020a) as we argue that a strategy can be seen as a concrete example of supporting a certain resilience attribute. For example, if farmers aim to diversify their production, they are supporting the attribute 'functional diversity'. In this chapter we specifically reflect on those resilience attributes that were supported in the past and those that are likely to be supported in potential future systems. In addition to this, we used system dynamics to explore the relationships between functions and resilience attributes. Based on the results of the participatory workshops we built causal-loop diagrams, describing cause–effect relationships among system components, including system functions and resilience attributes. More details are available in Reidsma et al. (2020a).

17.3 Challenges of Farming Systems

The studied farming systems face a wide array of challenges in the environmental, economic, social and institutional domain (Table 17.1). Some challenges were common to a large number of farming systems, while other challenges were context dependent. Stakeholders perceived that some challenges were close to or have even already exceeded critical thresholds. It should be noted, however, that the actual position of critical thresholds may be different from the perceived position. In any case, a challenge whose intensity is perceived to be beyond a critical threshold needs to be regarded as of particular concern.

Low profitability and price volatility were identified as an economic challenge for all the farming systems. In addition, in some farming systems, low profitability was marked as close to or beyond critical thresholds. It was linked to context-specific factors: low margins (DE-Arable&Mixed), high production and labour costs (ES-Sheep), competition with foreign markets (FR-Beef, IT-Hazelnut, RO-Mixed), and possible production failures (SE-Poultry). In BE-Dairy low profitability was caused by a combination of increasing costs and high price volatility due to market liberalization. Specific economic challenges regarded the Russian embargo in PL-Horticulture and BG-Arable, and the weak position of the farmers in the value chain (IT-Hazelnut, FR-Beef, RO-Mixed).

Climate change was the environmental challenge mentioned in all case studies, and manifested itself in different ways: increasing drought frequency and changing rainfall patterns, harming grassland and crop

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Table 17.1. *Overview of the main challenges in the SURE-Farm case studies and their closeness to critical thresholds according to stakeholders' perception*

Type	Challenge	BG-Arable	DE-Mixed&Arable	UK-Arable	BE-Dairy	FR-Beef	ES-Sheep	PL-Horticulture	IT-Hazelnuts	NL-Arable	RO-Mixed	SE-Poutlry
Economic	Low prices and price fluctuation	**C**	**A**	**C**	**P**	**P**	**P**	**S**	**S**	**P**	**N**	**P**
	High production costs			**C**			**A**			**C**		
	Unbalanced value chain		**P**	**P**	**P**	**P**		**P**	**P**		**P**	**P**
	Competition with foreign markets		**P**	**P**	**P**	**P**		**P**	**P**		**P**	
	Technology adaptation			**P**								**P**
	Limited use of insurance	**P**		**P**				**P**				
	Dependency on alternative off-farm income			**P**				**P**			**P**	
	Import competition			**P**				**P**			**P**	
	Production failure											**P**
Environmental	Climate change (extreme weather events)	**C**	**C**	**P**	**P**	**P**	**P**	**S**	**N**	**S**	**A**	**V**
	Plant or cattle diseases			**P**		**P**		**P**	**S**	**C**	**V**	
	Conflicts with wild fauna						**N**					
	Low soil fertility quality		**P**	**P**	**P**							
	Water scarcity		**P**		**P**			**P**	**P**			
	Excess of nutrients	**P**			**P**							**P**
	Soil erosion							**P**		**P**		**P**

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Table 17.1. (*cont.*)

Type	Challenge	BG-Arable	DE-Mixed&Arable	UK-Arable	BE-Dairy	FR-Beef	ES-Sheep	PL-Horticulture	IT-Hazelnuts	NL-Arable	RO-Mixed	SE-Poutlry
Social	Depopulation/lack of labour	**C**	**P**	**P**			**A**	**S**			**P**	**P**
	Changing consumer preferences	**P**	**P**	**P**			**A**	**P**				**P**
	Low attractiveness		**A**									
	Poor infrastructure		**A**									
	Change in technology											**C**
	Lack of successors	**P**	**P**	**P**		**P**	**P**	**P**			**P**	**P**
	High societal expectations	**P**	**P**		**P**	**P**						
	Poor quality of life		**P**				**P**					
Institutional	Continuous change of laws and regulations	**S**	**S**	**P**	**P**	**P**	**P**	**C**	**S**	**C**	**P**	
	Economic laws and regulations			**A**					**S**		**S**	**A**
	Environmental and animal welfare regulations			**S**				**P**	**C**		**P**	**A**
	Complicated administrative procedures		**P**			**P**		**P**				**P**
	Lack of long-term vision in policy	**P**		**P**	**P**			**P**				
	High land prices		**P**		**P**		**P**					

	Agricultural trade and regulation	**P**						**P**				
	Delay in rural development policies								**P**			
	Brexit (uncertainty and loss of subsidies)			**P**								
	Unequal aids distribution						**P**					

Empty cells indicate that the challenge is not perceived a major in the farming system. A “P” indicates the Presence of the challenge as major in the farming system, but its proximity to the threshold was not assessed by the stakeholders. Other letters indicate the level of proximity to thresholds as indicated by stakeholders, namely: Not close to critical threshold (“N”); Somewhat close to critical threshold (“S”); Close to critical threshold (“C”); At or beyond critical threshold (“A”). For BE-Dairy the relationships of challenges with critical thresholds were not assessed, for FR-Beef they were assessed with a desk study (i.e., without stakeholder involvement).
Source: Reidsma et al. (2019); Accatino et al. (2020); Paas et al. (2021c) and elaboration from chapter authors.

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productivity in extensive livestock, permanent, mixed, and arable systems; heat waves, harming chicken health and egg quality (SE-Poultry); and out-of-season frosts (PL-Horticulture). Stakeholders mentioned diseases as a major concern in both arable (especially NL-Arable and BG-Arable) and livestock systems (especially FR-Beef and DE-Arable&Mixed). Specific environmental challenges regarded, for example, conflicts with wild faunas (attack by wolves in ES-Sheep, although not close to critical threshold), excess of nutrients, soil erosion, low soil fertility, and water scarcity.

Social challenges regarded both internal (e.g., ageing of the farmers and difficulty to find successors) and external processes (high societal expectation about practices, social distrust, and changing of consumer preferences). The lack of successors was linked to the lack of attractiveness of farming (FR-Beef, ES-Sheep), because of high workload, unfavourable work-life balance, low attractiveness of the area, poor infrastructure (BG-Arable, ES-Sheep), poor cultural and social opportunities (DE-Arable&Mixed, even deemed at or beyond critical threshold). In BG-Arable, stakeholders pointed out the difficulty to transfer knowledge and technology: workers, due to ageing, might be reluctant to learn about new technologies. In RO-Mixed, young people often go abroad to work in the agricultural sector of western European countries. Some farming systems were subject to increasing public distrust regarding farming practices (FR-Beef), with a special attention to animal welfare (SE-Poultry). In DE-Arable&Mixed some farmers showed their discomfort about the very high societal expectations. Changes in consumer preferences consisted, e.g., in the lowering of lamb meat consumption (ES-Sheep). For SE-Poultry, change in technology was mentioned as a challenge of concern (close to critical threshold).

Institutional challenges regarded strict regulations, the administrative and bureaucratic burden, and the frequent changes in the rules. Frequent changes in regulations were widely mentioned and considered at least somewhat close to critical threshold in four case studies (BG-Arable, DE-Mixed&Arable, PL-Horticulture, IT-Hazelnut, NL-Arable). Strict regulations were mentioned, e.g., in SE-Poultry especially in relation to animal welfare standards. Administrative and bureaucratic burden was perceived as a cost by farmers in terms of money and time. In IT-Hazelnut the inefficiencies in the regional system were mentioned to cause delays in the CAP payments; in PL-Horticulture, bureaucracy added complication in regard to the

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many workers coming from Ukraine and agricultural land trade. For UK-Arable, the main institutional challenge was BREXIT, an overarching challenge bringing other issues such as uncertainty about the future regulations and loss of the EU subsidies.

17.4 Functions of Farming Systems

In this section we present the assessment of functions in current systems, the identification of alternative systems, and the performance of functions in alternative systems. Regarding these assessments we present the higher-level principles emerging from a comparison across all farming systems, occasionally discussing particularities of specific farming systems.

17.4.1 Functions in Current Systems

Beyond the marked differences among case studies (Figure 17.1), we observed some common elements. First, in all case studies functions were perceived to have different performances and were assigned different importance. Second, stakeholders perceived food production to perform moderate to high in all case studies, while functions related to the social domain ('Quality of life' and 'Attractiveness of the area') performed consistently low to moderate. Two exceptions were observed in which policy changes led to lower economic viability and finally to lower food production: for ES-Sheep the decoupling of payments from production pushed non-land-owning farmers to rent hectares for maintaining payment rights; for PL-Horticulture the access to the EU provoked a lowering of product prices. Third, stakeholders tended to assign a higher importance to economic viability but, at the same time, they considered this function to perform poor to moderately. Exceptions were IT-Hazelnut and RO-Mixed: for IT-Hazelnut the reason was found in the high profitability of hazelnuts, produced in high quantities in the region. For RO-Mixed the reason was found in the subsidies, which covered an important share of costs in small farms.

Different relative performances were observed, across farming systems, among 'Food production'; 'Economic viability' and environment-related functions ('Natural resources' and 'Biodiversity and habitat'). In the arable systems the perceived performance of

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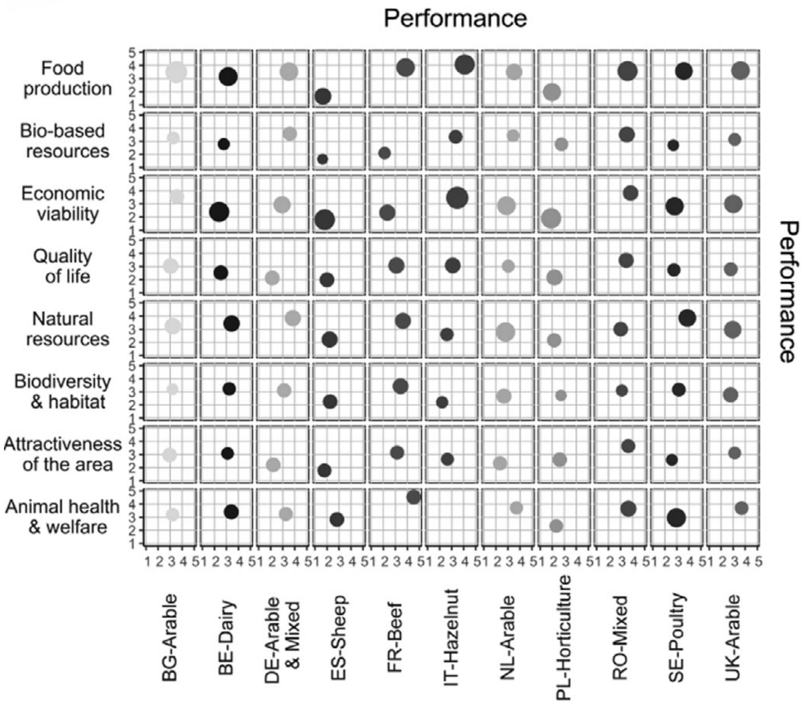

Figure 17.1 Perceived performance and importance of functions as assessed by stakeholders in the SURE-Farm case studies. Perceived performance is indicated on both the x- and y-axis to allow comparability among functions within a case study (vertically), and among case studies for a function (horizontally). The radius of the circles is proportional to the importance assigned. *Source*: Elaborated from Reidsma et al. (2020b).

'Food production' and 'Economic viability' was on average higher than in other systems, while environment-related functions were perceived to perform lower. The studied arable systems of western Europe (NL-Arable, UK-Arable, DE-Arable&Mixed) have historically invested more in the improvement of food production and economic viability, than in the improvement of public functions. In BG-Arable, stakeholders stated that food production was generally perceived not compatible with the conservation of natural resources in general, and nature conservation was considered more under the responsibility of policy-making rather than being a farmers' goal. In other cases, both 'Food production' and environment-related functions performed relatively well. In RO-Mixed

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this was favoured by the access of Romania to the EU in synergy with local policies and awareness about the importance of public goods. For FR-Beef the farming system is built upon a synergy between extensive beef production and maintenance of the landscape. In the ES-Sheep, the low performance of private functions, especially 'Food production', linked to the reduction of the number of sheep in the region, has decreased the contribution of the sector to nature conservation.

In our ecosystem service data assessment, we compared the multifunctionality of farming systems with the multifunctionality of their surrounding regions. We identified two groups: (i) farming systems that enriched the multifunctionality of the region providing a relatively rich array of ecosystem services and (ii) farming systems that were mostly focused on food production and reduced the diversity of ecosystem services provided in the region. Within group (i), IT-Hazelnut brought ecosystem services intrinsically connected to the presence of permanent crops (e.g., carbon storage, recreation potential); extensive livestock systems (ES-Sheep and FR-Beef) provided ecosystem services related with recreation potential and, in the case of FR-Beef, also erosion control. Within group (ii), BG-Arable was formed by monocultures poor in habitat quality and decreasing organic matter in soils; RO-Mixed decreased most of the public goods of the surrounding region (especially carbon storage, pollutant removal, habitat quality); NL-Arable, PL-Horticulture, DE-Arable&Mixed removed public goods to the surrounding region already poorly multifunctional; and SE-Poultry was clearly disconnected from the surrounding region which was mostly occupied by forests; UK-Arable was classified into group (ii) according to data analysis, but in participatory workshops stakeholders reported practices aimed at increasing some ecosystem services, such as carbon sequestration (e.g., practices of no-tillage, cover crops).

Participatory workshops and the ecosystem service assessment provide complementary information. For FR-Beef and RO-Mixed the multifunctionality of ecosystem services is confirmed by stakeholder perception, while this is not the case for ES-Sheep. For SE-Poultry, stakeholders perceive good performance of 'Natural resources'; however, elaboration of data suggests a separation between the broiler system and the surrounding forest. In DE-Arable&Mixed, data indicate poor performance of ecosystem services, but from a local stakeholder perspective, the presence of mixed crop–livestock systems are argued to ensure the maintenance of natural resources. For IT-Hazelnuts the

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system performs well with ecosystem services, but the intensive character of the system causes concerns among system actors. Results from the two methods align for PL-Horticulture and the arable systems. Overall, the participatory workshops provided information that is missing in satellite data about ecosystem services such as management practices that might contribute to ecosystem services provision.

17.4.2 Alternative Systems

For each farming system, three particular cases were considered in interaction with stakeholders: maintenance of the *status quo*, system decline when critical thresholds would be exceeded, and alternative systems for the future that could enhance sustainability and resilience. For each case study, at least one type of proposed alternative system was characterized by an increased use of technology. Examples are the investment in precision agriculture for NL-Arable, shelter farming in PL-Horticulture, technological innovation in IT-Hazelnut, use of robots in SE-Poultry, precision farming in BG-Arable, and advanced practices of pasture management in ES-Sheep. In many cases, the proposed alternative systems were related to organic and/or nature-inclusive agriculture (NL-Arable, UK-Arable, DE-Arable&Mixed, RO-Mixed, PL-Horticulture, IT-Hazelnut) and enhancement of diversification such as diversification of crops in BG-Arable, development of alternative crops in NL-Arable and RO-Mixed, and the achievement of fodder self-sufficiency in SE-Poultry. Other alternative systems were mostly specific to case studies, such as different forms of collaborations within the farming system (BG-Arable, NL-Arable, RO-Mixed), the valorization of products (BG-Arable, IT-Hazelnut), improvement of the attractiveness of the region (DE-Arable&Mixed), and valorization of the products locally processed and transformed (IT-Hazelnut).

17.4.3 Functions in Future Systems

In case the *status quo* is maintained in the future, no significant improvements were expected in functions' performances and some function indicators were perceived to likely decrease, such as 'Quality of life' (UK-Arable) and 'Economic viability' (BE-Dairy, ES-Sheep). However, in some case studies (IT-Hazelnut, SE-Poultry, NL-Arable), a moderate improvement was expected for the functions that are already performing moderately to well (especially 'Food production').

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Stakeholders indicated that when critical thresholds are exceeded, most of the functions might worsen their performance. The most critical function was 'Economic viability': it was seen as the most urgent to improve, as in the longer term it may cause lower 'Attractiveness of the area' and therefore decrease the availability of labor to realize 'Food production'. In regard to 'Natural resources', UK-Arable and NL-Arable were perceived close to thresholds concerning soil quality, which directly affects the production of food.

Function performances were perceived to be different depending on the alternative systems. Still, some commonalities were observed: (i) Stakeholders were aware of the existence of trade-offs, i.e., not all functions could be improved at the same time. (ii) In many alternative systems, food production was expected not to change or only moderately improve, meaning that this function was not targeted as a priority to improve. (iii) 'Economic viability' and, when discussed, also 'Other bio-based resources', 'Attractiveness of the area', 'Animal health & welfare' were often expected to improve from moderately to strongly; 'Natural resources' and 'Biodiversity & habitat' were often expected not to change or moderately improve.

17.5 Generic Resilience in Farming Systems

17.5.1 Resilience Attributes and Capacities in Current Systems

When linking the strategies implemented in the current systems to resilience attributes, we observed that 38% of the strategies positively contributed to the resilience attribute "Reasonably profitable" (Figure 17.2). Many strategies also contributed to "Building human capital", "Socially self-organized", "Infrastructure for innovation", "Response diversity", "Functional diversity" and "Coupled with local and natural capital (production)". There seems to have been a lack of attention for improving "Optimal redundancy of crops, nutrients, and water", and for the "Spatial heterogeneity at landscape level".

17.5.2 Resilience Attributes and Capacities in Future Systems

The strategies identified by stakeholders to reach alternative systems were relatively more focused on strengthening "coupled with local and natural capital", both regarding production and legislation. Strategies to improve these resilience attributes include improving soil quality, improving circularity, reducing inputs, using varieties adapted to local

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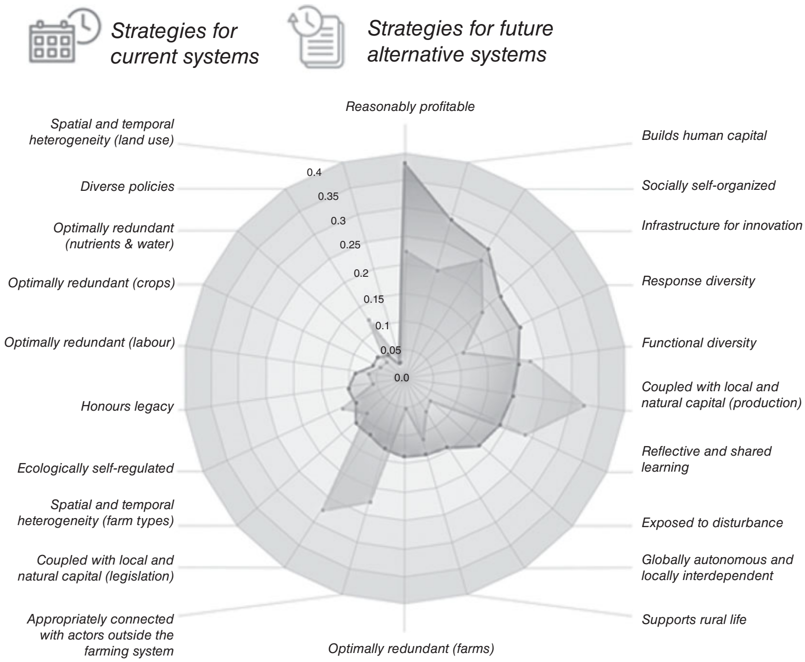

Figure 17.2 The contribution to resilience attributes of the identified strategies implemented and proposed in farming systems. The darker line shows the ratio of (past) strategies implemented for current systems contributing to an attribute, and the lighted line the ratio of future strategies for alternative systems contributing to an attribute. Attributes are ordered, starting with the attribute to which most past strategies contributed (based on Reidsma et al., 2020a).

climatic conditions, local branding, and policies that support this. The following attributes were more often strengthened when compared to strategies already implemented: "diverse policies" (although on average not mentioned often), "coupled with local and natural capital (legislation)", "appropriately connected with actors outside of the farming system", "coupled with local and natural capital (production)", "functional diversity", and "ecologically self-regulated".

17.6 Link among Functions and Resilience Attributes with System Dynamics

Causal-loop diagrams confirmed an alignment among functions and resilience attributes with the same goals. For instance, an improvement

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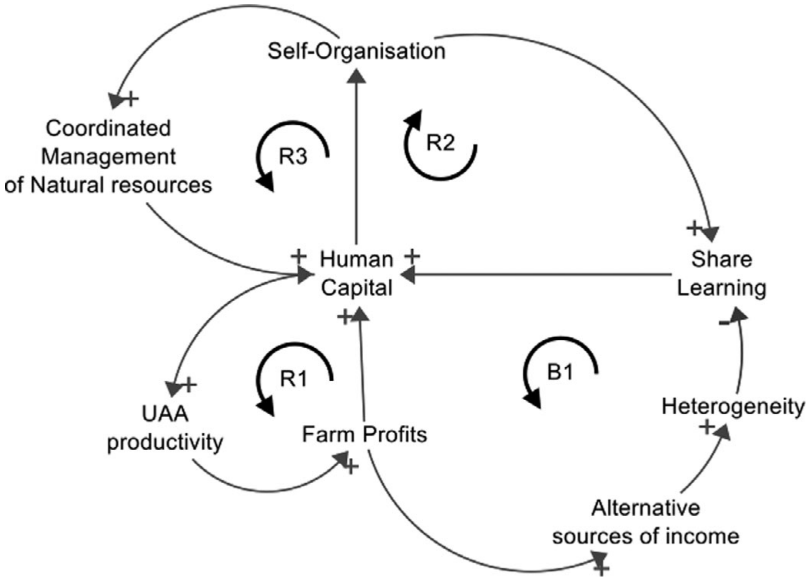

Figure 17.3 A causal loop diagram showing how economic, social, and environmental functions and attributes are related. An R refers to reinforcing and a B to balancing feedback loop. *Source*: Reidsma et al. (2020a).

of economic functions mainly enhanced "reasonably profitable", and social functions enhanced "supports rural life". Some cross-dimension relationships were observed. For example, "reasonably profitable" would benefit not only economic functions but also social and environmental functions (R1 in Figure 17.3). Similarly, "building human capital" would benefit not only social functions but also economic and environmental functions (R2 and R3 in Figure 17.3). However, economic functions could harm "Supports rural life" and "Spatially and temporally heterogeneity" (B1 in Figure 17.3).

17.7 Insights from the Integrated Resilience Assessment of Current and Future Systems

We explored the linkage between resilience and sustainability. Insights from our analysis showed that current systems are on average characterized by poor to moderate resilience and poor to moderate sustainability, whereas visions for future systems enhance the role of sustainability as a condition for achieving resilience.

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17.7.1 Sustainability Dimensions Are Currently Not Addressed in a Balanced Way

Our assessment revealed that the main focus of our case studies was on food production, whereas other environmental, economic, and social functions were often overlooked. Strategies implemented in the past revealed that much attention was given to the attribute "reasonably profitable": while this led to an increase in food production, it did not improve economic viability for the farmers. The strategies ensured a certain robustness in the past, but economic viability remained close to perceived critical thresholds in many farming systems. The need to ensure economic viability induces myopia among farming system actors, as long as performance in the environmental and social domain is considered to be acceptable.

17.7.2 Lack of Sustainability Corresponds to a Lack of Resilience

Insights from our assessment suggested that the unbalanced attention to sustainability dimensions corresponds to poor resilience. First, according to stakeholders' input, the *status quo* is not resilient: if it is maintained for the future, most functions would likely not improve or deteriorate; in the case of exceeding critical thresholds, most functions are expected to strongly worsen. Second, in a current situation where sustainability dimensions are not equally addressed, challenges are currently present and most of them are close to critical thresholds (Table 17.1). The existence of common challenges raises concern about the resilience of European agriculture: current farming systems are under stress. Above all, economic issues are perceived as extremely critical by stakeholders. In addition, some of the challenges are internally generated (e.g., lack of successors and workforce), meaning that the current configurations generate problems. Third, the system dynamics analysis assessed that focusing on production and economic functions would erode resilience attributes.

17.7.3 Sustainability and Resilience for the Future

The view of stakeholders for future systems was clearly characterized by a joint improvement of sustainability and resilience, especially in

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regard to environmental and social aspects. The analysis performed with system dynamics showed that functions promote resilience attributes and *vice versa*. This suggests that there are pathways towards the joint improvement of sustainability and resilience. In the literature some studies highlighted the linkage among environmental and social functions and resilience. According to Altieri et al. (2015), resilience to extreme climate events is higher for systems that integrate ecological processes in their configuration and practices via, e.g., diversification, polycultures, crop-livestock systems, and organic soil management. Concerning the social component, studies highlight the importance of, e.g., creating a learning environment, enhancing the capacity of community self-organization (Berkes, 2007), and ensuring a good quality of life (Darnhofer, 2010) to promote resilience.

17.8 Improving the Sustainability and Resilience of European Farming Systems

We cannot consider farming systems as places for food production only. This is recognized in the literature (see Darnhofer et al., 2010), in our SURE-Farm approach, and also by the stakeholders involved in our study. Local stakeholders showed awareness about the importance of all the aspects of sustainability for promoting resilience. The functions enhanced in future systems were first of all economic viability, but also attractiveness of the region, natural resources and biodiversity, habitat quality, and animal welfare. The enhancement of resilience attributes such as "coupled with the local and natural capital" and "ecologically self-regulated" in future systems showed the importance of integrating ecosystem services into farm management.

Our assessment suggested that economic problems hinder the promotion of sustainability and resilience (Reidsma et al., 2020b). Although farmers are exposed to both economic and social challenges, they assigned a high importance to the function "Economic viability" and a low importance to social functions ("Attractiveness of the area" and "Quality of life"), revealing that economic issues are perceived as most urgent. Helping farmers with economic problems is therefore surely recommendable, but in the light of our findings also very challenging. The analysis of the challenges points out that all farming

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systems experience economic problems, but these have different context-specific origins and are ruled by different mechanisms. It is important to design diagnosis tools that monitor specific farming systems and study value chains, effects of subsidies, and other elements that might be important factors that help explain the low profitability of farming. When the burden of low profitability is removed, farmers are expected to be able to change their view from short-term to long-term and promote local solutions aimed at improving environmental and social aspects (Darnhofer, 2010).

Climate change was highlighted as a serious challenge, assuming different forms in the different case studies. Insurance schemes mostly provide only a temporary solution, without really transforming the system. Resilience-thinking and a number of resilience attributes enhanced in the alternative systems proposed by stakeholders suggest that promoting ecosystem services and nature-based solutions can make farming systems more robust to climate change (see also Altieri et al., 2015). For all of this, research needs to be supported and accelerated, as well as the spread of innovation practices (Herrero et al., 2020).

To cope with societal issues, it is of course of primary importance to promote practices among farmers that meet the consumer expectations, are environment-friendly and good for society. In this regard, we especially mention the continuous improvement of animal welfare, which is at the core of both consumer and producer values, even if our analysis denoted different perceptions about the performance of this function. Initiatives should promote communication and dialogue with the civil society. Moreover, some action should be taken to improve the attractiveness of the areas and of farming. Last but not least, the institutional context was often seen as a source of stress for farmers. Strict regulations, frequently changing regulations, excessive administrative burden are all things that can be directly addressed by governments and policy-makers.

17.9 Conclusion

We aimed at identifying factors that promote resilience and sustainability of farming systems, focusing on the link between the two. Our results show that sustainability and resilience are related and strengthening their link improves both. In the current systems,

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strategies were mainly focused on increasing economic functions, leading to trade-offs in the environmental and social domain. For the future of European farming, systems resilience can be improved when synergies are searched, identified, and enhanced, so that environmental, economic, and social aspects can sustain one another.

References

Accatino, F., Paas, W., Herrero, H., et al. 2020. D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods. Sustainable and resilient EU farming systems (SURE-Farm) project report, EU Horizon 2020 Grant Agreement No. 727570.

Altieri, M. A., Nicholls, C. I., Henao, A. and Lana, M. A. 2015. Agroecology and the design of climate change-resilient farming systems. *Agronomy for Sustainable Development* 35, 869–890.

Berkes, C. 2007. Understanding uncertainty and reducing vulnerability: Lessons from resilience thinking. *Natural Hazards* 41, 283–295.

Cabell, J. F. and Oelofse, M. 2012. An indicator framework for assessing agroecosystem resilience. *Ecology and Society* 17, 18.

Daily, G. C. (ed.). 1997. *Nature's Services*, vol. 3. Washington, DC: Island Press.

Darnhofer, I. 2010. Strategies of family farms to strengthen their resilience. *Environmental Policy and Governance* 20, 212–222.

Darnhofer, I., Fairweather, J. and Moller, H. 2010. Assessing a farm's sustainability: Insights from resilience thinking. *International Journal of Agricultural Sustainability* 8, 186–198.

Fischer, J., Gardner, T. A., Bennett, E. M., et al. 2015. Advancing sustainability through mainstreaming a social-ecological systems perspective. *Current Opinion in Environmental Sustainability* 14, 144–149.

Herrera, H., Kopainsky, B., Appel, F., et al. 2018. D5.1 Impact assessment tool to assess the resilience of farming systems and their delivery of private and public goods Sustainable and resilient EU farming systems (SURE-Farm) project report, EU Horizon 2020 Grant Agreement No. 727570.

Herrero, M., Thornton, P. K., Mason-P'Croz, D., et al. 2020. Innovation can accelerate the transition towards a sustainable food system. *Nature Food* 1, 266–272.

Kinzig, A. P., Ryan, P., Etienne, M., et al. 2006. Resilience and regime shifts: Assessing cascading effects. *Ecology and Society* 11, 20.

https://doi.org/10.1017/9781009093569.018 Published online by Cambridge University Press

Lebacq, T., Baret, P. V. and Stilmant, D. 2013. Sustainability indicators for livestock farming. A review. *Agronomy for Sustainable Development* 33, 311–327.

Maes, J., Fabrega, N., Zulian, G., et al. 2015. Mapping and assessment of ecosystems and their services: Trends in ecosystems and ecosystem services in the European Union between 2000 and 2010. Luxembourg: Publications Office.

Meuwissen, M. P. M., Feindt, P. H., Spiegel, A., et al. 2019. A framework to assess the resilience of farming systems. *Agricultural Systems* 176, 102656.

Paas, W., Accatino, F., Antonioli, F., et al. 2019. D5.2 Participatory impact assessment of sustainability and resilience of EU farming systems. Sustainable and resilient EU farming systems (SURE-Farm) project report. EU Horizon 2020 Grant Agreement No. 727570.

Paas, W., Coopmans, I., Severini, S., van Ittersum, M., Meuwissen, M. and Reidsma, P. 2021a. Participatory assessment of sustainability and resilience of three specialized farming systems. *Ecology and Society* 26, 2.

Paas, W., San Martín, C., Soriano, B., van Ittersum, M. K., Meuwissen, M. P. M. and Reidsma, P. 2021b. Assessing future sustainability and resilience of farming systems with a participatory method: A case study on extensive sheep farming in Huesca, Spain. *Ecological Indicators* 132, 108236.

Paas, W., Accatino, F., Bijttebier, J., et al. 2021c. Participatory assessment of critical threshold for resilient and sustainable European farming systems. *Journal of Rural Studies* 88, 214–226. https://doi.org/10.1016/j.jrurstud.2021.10.016

Reidsma, P., Spiegel, A., Paas, W., et al. 2019. D5.3 Resilience assessment of current farming systems across the European Union. Sustainable and resilient EU farming systems (SURE-Farm) project report, EU Horizon 2020 Grant Agreement No. 727570.

Reidsma, P., Paas, W., Accatino, F., et al. 2020a. D5.6 Impacts of improved strategies and policy options on the resilience of farming systems across the EU Sustainable and resilient EU farming systems (SURE-Farm) project report, EU Horizon 2020 Grant Agreement No. 727570.

Reidsma, P., Meuwissen, M. P. M., Accatino, F., et al. 2020b. How do stakeholders perceive sustainability and resilience of EU farming systems? *EuroChoices* 19, 18–27.

Richardson, G. P. 2011. Reflections on the foundations of system dynamics. *System Dynamics Review* 27, 219–243.

Rotmans, J. and van Asselt, M. 1996. Integrated assessment: A growing child on its way to maturity. *Climatic Change* 34, 327–336.

Schader, C., Baumgart, L., Landert, J., et al. 2016. Using sustainability monitoring routine (smart) for the systematic analysis of trade-offs

https://doi.org/10.1017/9781009093569.018 Published online by Cambridge University Press

and synergies between sustainability dimensions and themes at the farm level. *Sustainability* 8, 274.

Sterman, J. (ed.). 2000. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston: Irwin/McGraw-Hill.

van Ittersum, M. K., Ewert, F., Heckelei, T., et al. 2008. Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS). *Agricultural Systems* 96, 150–165.

Walker, B. and Salt, D. (eds.). 2012. *Resilience Practice: Building Capacity to Absorb Disturbance and Maintain Function*. Washington, DC: Island Press.

https://doi.org/10.1017/9781009093569.018 Published online by Cambridge University Press