SUSTAINABLE AND RESILIENT FARMING SYSTEMS IN THE EUROPEAN UNION

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Abstract

Farming systems in Europe face a variety of environmental, economic, social and institutional challenges, such as volatile producer prices, extreme weather events, dependence on landowners and financial institutions, organizational changes in value chains, competing policy objectives and changing consumer preferences. Resilience theory provides an integrated framework to analyze the capacity of social-ecological systems to cope with these changes, and resilience is defined as the maintenance of essential functions of farming systems in the face of increasingly complex economic, social and environmental challenges, thus farming systems include interactions between farms, technologies, stakeholders, consumers, decision makers and the environment, and vulnerabilities such as intergenerational transfer and declining attractiveness of farming affect the demographic stability of rural areas. The paper explores the resilience of farming systems in the European Union in the face of growing economic, social, environmental and institutional challenges. The study identifies a wide range of risks to EU farming systems, from extreme weather events and price volatility to demographic and institutional changes, thus through dynamic scenarios, it provides a picture of the possible future of European agriculture, taking into account socio-economic, environmental and technological developments. The scenarios developed are used to test resilience strategies at the level of farming systems and to make recommendations for the Common Agricultural Policy and governance to support the long-term resilience of these systems.

Key words: farming systems, sustainability, resilience, adaptability, efficiency

INTRODUCTION

The concept of resilience for farming systems is based on their ability to adapt and transform to cope with external challenges, thus farming systems are exposed to risks from multiple domains including economic, environmental, social and institutional. In the face of these risks, systems go through different stages, known as adaptive cycles (Andersen E., 2017).

Adaptive cycles include phases of growth, equilibrium, collapse and reorientation, thus in the growth phase, the agricultural system grows and expands, in the equilibrium phase, it reaches stabilization after having gone through the previous phases (De Kraker J., 2017). However, under certain circumstances, the system may collapse due to major disturbances, and after a collapse, the system may go through a reorientation stage, where it restructures itself to cope with new conditions (Cabell J.F. and Oelofse M., 2012).

These adaptive cycles are influenced by interlinked processes, these include governance, which refers to the role of institutions and policies, farm demography, i.e. changes in the farm population, and agricultural production, which is the process by which agricultural products are produced (Andersen E. *et al*, 2007).

To survive and thrive, agricultural systems must maintain their essential functions, which include private goods, which provide individual benefits, and public goods, which provide benefits to society as a whole, such as environmental protection and biodiversity conservation (Fath B.D. *et al*, 2015).

Research examining the resilience of farming systems mainly focuses on agricultural production processes (Urruty N. *et al*, 2016) and generally shows that different systems are better able to cope with variability (Mathijs E., 2018). However, in practice, changes in technology, markets and policies have led to larger and more specialized farms (Andersen E., 2017; Bullock J.M. *et al*, 2017). Thus, to fully understand developments in agriculture, it is necessary to consider several simultaneous processes. In this context, we highlight three key processes of the adaptive cycle that are central to farming systems

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in the EU: agricultural production processes, farm demographics and governance.

Agricultural production is the set of agricultural and multifunctional activities carried out by farms, leading to the provision of public and private goods. These goods include food and fiber, but also regulatory services, such as climate change mitigation and provision of clean water, as well as cultural services, such as landscape creation and maintenance (Binder C.R. *et al*, 2010).

Farm demography refers to the labor force required to operate agricultural systems, including both farm populations and hired labor.

Governance is defined as the process of organizing and leading society, which is based on a mix of economic, communication and regulatory mechanisms, all aimed at achieving collective goals (Darnhofer I., 2010). Thus, governance includes elements of the Common Agricultural Policy (CAP) and its national implementations, as well as public and private regulations that influence agricultural production chains and risk management strategies in the agricultural sector. Other processes such as infrastructure and local culture, which affect the performance of farming systems, are integrated as features of the farming system.

MATERIAL AND METHOD

In this study, a farm's resilience is defined as its ability to maintain essential functions, such as the provision of private and public goods, in the face of increasingly complex economic, social, environmental and institutional shocks and pressures. This capacity is based on three essential elements: robustness, adaptability and transformability (Darnhofer I., 2010). Although other external actors such as local government, NGOs and banks play a role in ensuring the essential functions of agriculture. Thus robustness is the ability of the farm to cope with shocks and stresses (predictable or unpredictable), adaptability refers to the ability to adjust inputs, production, marketing strategy and risk management to respond to shocks and pressures without changing the fundamental structures of the farm, and transformability is the ability to radically change the structure and internal mechanisms of the farm in the face of severe shocks or persistent pressures that make it impossible to continue activities in their current form. Based on these we assess the attributes that underpin resilience, following five general principles proposed by the Resilience Alliance (Folke C. *et al*, 2010): i) diversity, ii) modularity, iii) openness, iv) robust feedbacks and v) system buffers. Diversity, both functional and response diversity, tends to support system resilience, while modularity involves the division of the system into independent but interconnected units that may have different functions. Openness refers to the connectivity of systems to each other. Robust feedbacks allow parts of a system to react quickly to changes in other parts. System buffers, such as stocks of natural, economic, and social capital, provide redundancy and function as a form of „insurance” that allows the system to cope with losses or failures (Cumming G.S., Peterson G.D., 2017). These principles provide a framework for understanding how agricultural systems can become more resilient and better prepared to cope with the complex and changing challenges in the current environment.

RESULTS AND DISCUSSIONS

Resilience of farming systems is a key concept in the current context of climate change, population growth and increasing pressure on natural resources. It refers to the ability of these systems to cope with and adapt to various risks and disturbances while maintaining essential functions such as food production and environmental protection. Agricultural systems face multiple challenges, including economic, environmental, social and institutional risks, which can take the form of sudden shocks or long-term pressures. In this context, assessing the resilience of an agricultural system involves analyzing its capacity to withstand, adapt and transform when necessary (Figure 1).

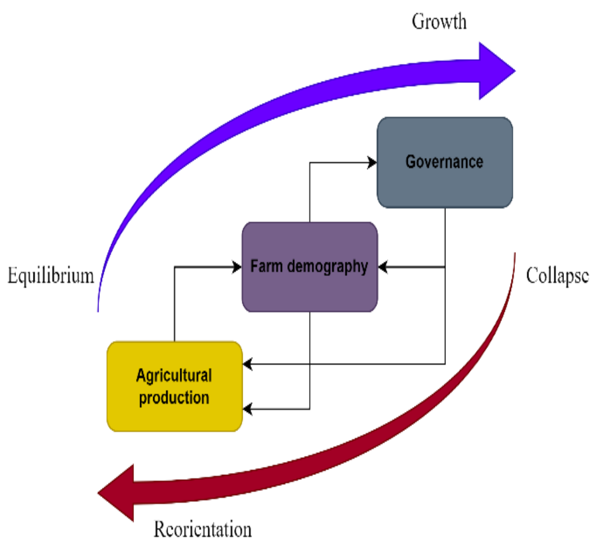

Figure 1 **The concept of resilience for farming systems**

To analyze the diversity of challenges facing farming systems, they can be classified into four main categories: economic, environmental, social and institutional risks (Giller K.E., 2013). There are also two ways in which these challenges can affect farming systems: either as sudden shocks or as long-term pressures accompanied by uncertainty (Figure 2).

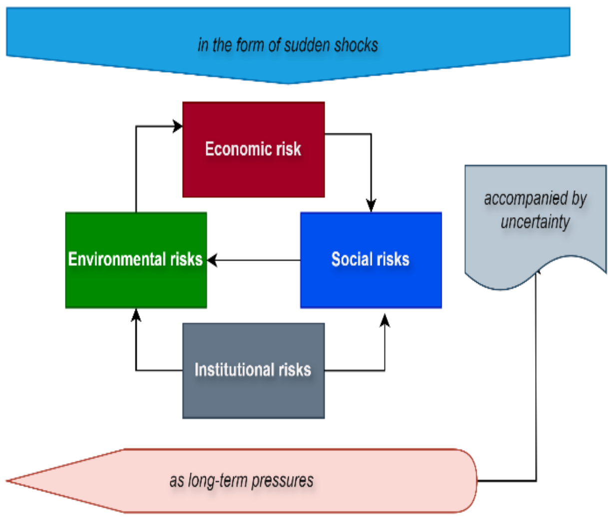

Figure 2 **Challenges facing farming systems**

Adapting the concepts proposed by Quinlan A.E. *et al*, (2016), a shock is defined as „a rapid and unexpected change in the risk environment of an agricultural system that affects part or all of the system in the short term, with negative effects on people's well-being, production levels, livelihoods or ability to cope with future shocks." Examples of shocks include price crashes (economic risk), extreme weather events (environmental risk), rapid social change at the farm level such as loss of social capital due to illness, divorce or conflicts over property or inheritance (social risk) and geopolitical crises such as embargoes (institutional risk).

Long-term pressures, on the other hand, refer to factors that slowly change the context of an agricultural system, leading to new uncertainties, e.g. reduced access to finance (economic risk), hydro-geological disturbances (environmental risk), demographic changes such as rural out-migration (social risk) and changes in public policy directions (institutional risk).

Impact studies often tend to focus on long-term pressures, such as the effects of climate change (Andersen E., 2017), while shocks can have more devastating short-term effects, such as extreme weather events (Giller K.E., 2013). Although the distinction between shocks and long-term pressures is somewhat arbitrary, this categorization can be used as a useful assessment tool, thus the main challenges are highlighted in Table 1.

Table 1

Main challenges for farming systems

Challenges	Shocks	Long-term pressures
Environmental challenges	Extreme weather events: droughts, excessive rainfall, hail, frosts, floods. Outbreaks of diseases, pests or weeds (epidemics). Food or feed security crises.	Reduced soil fertility (soil mineralization, nutrient depletion). Deforestation. Heavy metal pollution. Hydrogeological changes. Species decline, including pollinators. Antimicrobial resistance. Changes in nutrient cycling (e.g. phosphorus and nitrate cycling).
Economic challenges	Sharp falls in agricultural commodity prices. Input price volatility. Market access crises (e.g. Russian embargo or Brexit).	Reduced access to bank finance. Rising costs of hired labor. Increased competition in international markets. Reallocation of infrastructure (transportation, information technology). Increased start-up costs for new agribusiness. 'Bottleneck' situation due to resource fixity.
Social challenges	Sudden media attention on a food or safety crisis. Rapid social change on the farm, such as illness, death or divorce. Insufficient seasonal labor availability.	Rural migration, emigration and ageing rural population. Reduced access to social services (health, education). Demographic changes (urbanization, rural population decline). Changes in household structure and labor markets. Increasing gender gaps in agricultural labor. Changing consumer preferences (demand for local, organic products). Public distrust of industrial agriculture.
Institutional challenges	Sudden changes in access to international markets (e.g. embargoes). Rapid changes in food safety regulations and export markets.	Sudden changes in access to international markets (e.g. embargoes). Rapid changes in food safety regulations and export markets.

These challenges highlight the varied impact that external factors have on agriculture and provide a basis for developing resilience strategies in the face of risks and uncertainties. Thus the functions that an agricultural system performs may vary according to its geographical location (e.g. near a city or in a remote area). In addition, different institutional frameworks for sustainable development promote different principles, although a general consensus remains the Brundtland Report (1987), which defines sustainable development as „development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland G., 1987). This concept is important in agricultural systems to understand the range of „essential functions". To maintain their functionality, agricultural systems need to provide two types of essential functions: the production of private goods and public goods (Figure 3). Private goods, such as agricultural products, benefit individuals, while public goods, such as maintaining biodiversity and protecting the environment, benefit the whole community. Thus the sustainability of farming systems depends on their ability to balance these essential functions in the face of risks and change.

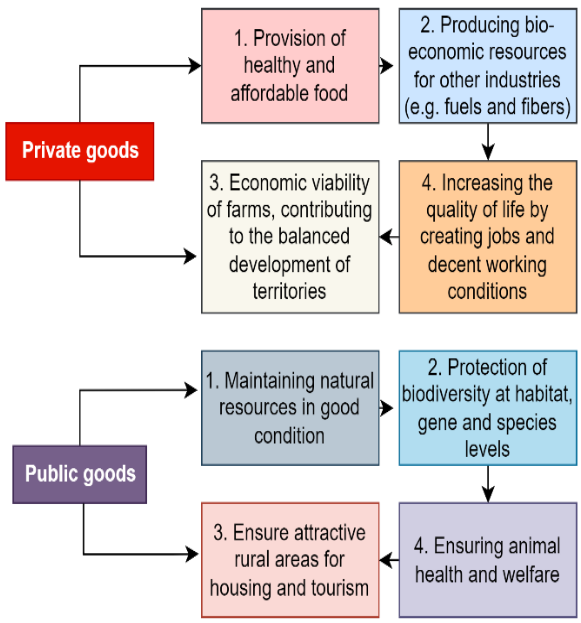

Figure 3 **Essential functions of farming systems**

These functions are defined at the farming system level, not at the individual farm level, which means that the objective is not primarily the preservation of individual farms. Although there are synergies between the provision of different functions of a farming system, not all of them are mutually supportive. Conflicts can arise between social, economic and environmental objectives, leading to trade-offs. The degree of interdependence between these functions varies according to the specificity of each farming system.

Each farming system has a level of sustainability that is linked to its specific functions and interactions within the system. For assessing the performance of an agricultural system in providing essential functions, various indicator frameworks exist (Andersen E. *et al*, 2007; Binder C.R. *et al*, 2010; Urruty N. *et al*, 2016).

The selection of indicators for assessing the performance of an agricultural system in providing essential functions is done in two steps:

1. Identification and prioritization of functions related to the provision of private and public goods.

2. Associating the functions with relevant indicators, which are specific to each agricultural system and the function they fulfill.

To select the relevant indicators, three principles can be applied:

1. The type of challenge affecting the agricultural system: different challenges can have a short- or long-term impact, and the indicators need to be tailored to measure these effects. For example, in the case of shocks such as extreme weather events, an indicator such as productivity (t/ha) would be appropriate. In contrast, for long-term pressures such as climate change, indicators such as soil erosion or water quality might be more appropriate.

2. Use of resources (human, natural and economic): each agricultural system uses different resources, and these can be assessed through specific indicators. For example, for large-scale agricultural production in the East of England, the key resources might be labor, land and technology. Indicators could include landscape maintenance (for rural attractiveness), water and soil quality (for conservation of natural resources) and percentage of land owned (as an indicator of economic viability).

3. Efficiency of agricultural system outputs: for arable crops, efficiency indicators for resilience could be the number of jobs created (quality of life), populations of key animal and plant species (biodiversity) and economic indicators such as farm liquidity and profitability.

The key functions of an agricultural system may change over time and vary according to the context. Some functions may also be taken over by other systems, depending on the interactions and specificities of each farming system.

Assessing the resilience of an agricultural system or subsystem involves a complex approach, as the stages of robustness, adaptability and transformability cannot be categorized simply (Urruty N. *et al*, 2016). An effective way to start the analysis is to explore the following elements:

1. The dynamics of the essential functions (robustness) of an agricultural system refers to its ability to maintain its essential functions, such as the production of private goods (e.g. food) and public goods (e.g. environmental protection), in the

face of disturbances. Robustness assessment focuses on how the system withstands shocks and how it recovers from disturbances

2. The relationship between risks and responses (adaptability) is the capacity of an agricultural system to respond and adjust to risks, which may be economic, environmental, social or institutional. This includes responses to sudden shocks (e.g. extreme weather events) and long-term pressures (e.g. climate change), involving adjustments in farming practices and policies.

3. Tipping points and transformation (transformability) describes the ability of an agricultural system to make fundamental changes when necessary, especially when it reaches critical points. These tipping points may force the system to transform and adapt to new conditions or evolve into a new structure in order to remain viable in the long term.

Resilience attributes play a key role in enhancing the capacity of farming systems to cope with challenges and contribute directly to improving resilience indicators. These attributes influence, for example, the rate of recovery after a shock, the diversity of responses available within a safe operating space, or the speed with which a system can transform after a collapse

Cabell and Oelofse (2012) identified 13 general attributes that support agroecosystem resilience, namely:

1. Self-organizing networks (farmers, consumers and cooperating communities).

2. Ecological self-regulation (farmers maintaining vegetation and using perennials).

3. Appropriate connectivity (polyculture and collaboration between value chain actors).

4. Functional and response diversity (heterogeneous landscapes and diverse farms).

5. Optimal redundancy (growing multiple varieties and recycling nutrients from different sources).

6. Spatial and temporal diversity (mosaics of differently managed land and varied farming practices).

7. Exposure to disturbance (pest management and positive selection).

8. Use of local natural capital (minimizing the need for imports and reducing waste exports).

9. Reflective and shared learning (record keeping and knowledge sharing between farmers).

10. Global self-reliance and local interdependence (reducing dependence on global markets and increasing local collaboration).

11. Respecting heritage (integrating traditional knowledge into modern practices).

12. Building human capital (investment in education and support for social events).

13. Reasonable profitability (farmers and laborers earn a decent income and agriculture is not overly dependent on market-distorting subsidies).

Attributes become more complex and intense when we refer to transformability versus robustness, e.g. learning is an important attribute for building resilience. Depending on the phases of the adaptive cycle, learning can range from incremental innovation („single-loop learning”) in periods of growth, to radical innovation in the face of crises („double-loop learning”) and transformation to new farming practices („three-loop learning”). Another example is related to the organization of agricultural production, here attributes may include resources for sustainable production, diversity of farms and technologies, as well as biodiversity and resource redundancy at the regional level, thus diversity and redundancy contribute to diverse and stable ecosystem services. In addition, social networks are essential for collaboration and innovation, they can support the exchange of resources between farmers and government institutions, as well as experimentation with new processes and entering new markets.

Finally, governance plays a major role in facilitating resilience, this can include financial support for farmers, access to credit and subsidies, knowledge management through dialog between formal and informal institutions, and regulatory flexibility to allow innovation and adaptation to new circumstances.

CONCLUSIONS

Farming systems are characterized by high complexity, reflected in the interaction between institutions and the agro-ecological context. Previous resilience analysis frameworks have not fully captured this complexity, and many of them have not clearly distinguished between different types of resilience, thus reducing the range of solutions available to improve resilience. In this study, we identify three main processes of adaptive cycles relevant to agricultural systems: agricultural, demographic and governance processes. We develop a framework that is based on three types of resilience: robustness, adaptability and transformability.

Exploring resilience starts with defining the spatial, functional and temporal boundaries of the system, e.g. risks and key functions vary according to the perspectives of different stakeholders and recent events, which emphasizes the need for clarity in defining the spatial, functional and temporal boundaries of the system under study.

Another challenge is to identify meaningful indicators that reflect the performance of key functions over the long term. The use of simple indicators may omit the complexity of farming systems, which may require the adoption of composite indicators or the analysis of several indicators simultaneously.

Another aspect to consider is the risk that the attributes mentioned are taken for granted without yet being empirically verified, although attribute diversity has frequently been associated with resilience to climate variability and change, this is not true in all cases. Resilience to climate change does not automatically imply resilience to technological change, thus the attributes proposed in this framework are useful for prototyping, but require further clarification and evidence in different contexts. This clarification is, however, a major challenge, as most of these attributes (especially those related to adaptability and transformability) are slow changing variables. Learning about these slow variables can take a long time, with the risk of ignoring important processes or paying attention to wrong assumptions.

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