# Appendix

Table A1. Used concepts and their explanations and main references. Adapted from Paas et al. (In Review)

|  |  |  |
| --- | --- | --- |
| Concept | Explanation | References |
| Sustainability | An adequate performance of all system functions across the environmental, economic and social domain. Obviously adequate is normative and depends on environmental thresholds and societal constraints and objectives. | See e.g. Morris et al. (2011) and König et al. (2013) |
| Resilience capacities | Robustness, adaptability and transformability potential of systems in the face of shocks and stresses. The explanation of the resilience capacities follows below and is influenced by the mentioned sources. | Walker et al. (2004), Folke et al. (2010), Anderies et al. (2013), Meuwissen et al. (2019) |
| Robustness | Robustness is the capacity to resist to and endure shocks and stresses. |  |
| Adaptability | Adaptability is the capacity to actively respond to shock and stresses without changing farming system structures and feedback mechanisms |  |
| Transformability | Transformability is the capacity of a system to reorganize its structure and feedback mechanisms in response to shocks and stresses. |  |
| Specific resilience | Resilience specified with regard to answering the questions "resilience of what, to what and for what purpose?" | Carpenter et al. (2001), Quinlan et al. (2016) |
| General resilience | General resilience is related to a system's robustness, adaptability and transformability, regardless the type of challenge or shock. | Resilience Alliance (2010), Walker and Salt (2012), Meuwissen et al. (2019) |
| Farming system | The basis of a farming systems consists of farms producing the main products of interest in a regional context. Social actors included in the farming systems are the producers of main products and other actors that mutually influence one another. In the context of resilience, the farming system relates to the question “Resilience of what?” | Meuwissen et al. (2019) |
| Challenges | Shocks or stresses that constrain farming system functioning. In the context of resilience, challenges relate to the question “Resilience to what?”. | Meuwissen et al. (2019) |
| Functions | Delivery of public and private goods from the farming system to society (categorized according to domain they belong to): production of food (economic), bio-based resources (economic), economic viability (economic), quality of life (social), maintenance of natural resources (environmental), bio-diversity & habitat (environmental), attractiveness of the area (social), and animal health & welfare (environmental). In the context of resilience, functions relate to the question “Resilience for what purpose?” | Meuwissen et al. (2019) |
| Indicators | Indicators that represent farming system functions in the absence of a unique metric for these functions. Indicators with high allocated importance are assumed to represent the identity of the farming system. | Reidsma et al. (2019), Meuwissen et al. (2019) |
| Resilience attributes | Specific system characteristics that are supposedly contributing to general resilience of farming systems. For the resilience attributes that are treated in this study, see also Table A1.2. | Cabell & Oelofse (2012), Meuwissen et al. (2019) |
| Critical thresholds | Levels at which system challenges, indicators or resilience attributes are expected to cause large and permanent system change. | Adapted from Kinzig et al. (2006) and Biggs et al. (2018). |
| Enabling conditions | Conditions around the farming system that enable the maintenance of the current system or realization of alternative systems in the future. | This study |
| Interacting thresholds | Critical thresholds, when exceeded, leading to the exceedance of another critical threshold. | Kinzig et al. (2006) |

Table A2. Resilience attribute definitions and implications. Source: Paas et al. (In Press) adapted from Cabell & Oelofse et al. (2012).

| Resilience attribute | Definition | Implications | Explanation statement | Link with resilience principle  |
| --- | --- | --- | --- | --- |
| Reasonably profitable | Persons and organizations in the farming system are able to make a livelihood and save money without relying on subsidies or secondary employment | Being reasonably profitable allows participants in the system to invest in the future; this adds buffering capacity, flexibility, and builds wealth that can be tapped into following release | Farmers and farm workers earn a livable wage while not depending heavily on subsidies | Systems reserves (economic capital) |
| Production coupled with local and natural capital  | The system functions as much as possible within the means of the bio-regionally available natural resource base and ecosystem services | Responsible use of local resources encourages a system to live within its means; this creates an agroecosystem that recycles waste, relies on healthy soil, and conserves water | Soil fertility, water resources and existing nature are maintained well | Systems reserves (natural capital), tightness of feedbacks |
| Functional diversity | Functional diversity is the variety of (ecosystem) services that components provide to the system | Diversity buffers against perturbations (insurance) and provides seeds of renewal following disturbance | There is a high variety of inputs, outputs, income sources and markets | Diversity |
| Response diversity | Response diversity is the range of responses of these components to environmental change | Diversity buffers against perturbations (insurance) and provides seeds of renewal following disturbance | There is a high diversity of risk management strategies, e.g. different pest controls, weather insurance, flexible payment arrangements | Diversity |
| Exposed to disturbance | The system is exposed to discrete, low-level events that cause disruptions without pushing the system beyond a critical threshold | Such frequent, small-scale disturbances can increase system resilience and adaptability in the long term by promoting natural selection and novel configurations during the phase of renewal; described as “creative destruction” | The amount of year to year economic, environmental, social or institutional disturbance is small (well dosed) in order to timely adapt to a changing environment | Openness |
| Spatial and temporal heterogeneity of farm types | Patchiness across the landscape and changes through time | Like diversity, spatial heterogeneity provides seeds of renewal following disturbance | There is a high diversity of farm types with regard to economic size, intensity, orientation and degree of specialization | Modularity, diversity |
| Optimally redundant farms | Critical components and relationships within the system are duplicated in case of failure | Redundancy may decrease a system’s efficiency, but it gives the system multiple back-ups, increases buffering capacity, and provides seeds of renewal following disturbance | Farmers can stop without endangering continuation of the farming system and new farmers can enter the farming system easily | Modularity |
| Supports rural life | The activities in the farming system attract and maintain a healthy and adequate workforce, including young, intermediate and older people. | A healthy workforce that includes multiple generations will ensure continuation of activities and facilities in the area, and the timely transfer of knowledge. | Rural life is supported by the presence of people from all generations, and also supported by enough facilities in the nearby area (e.g. supermarkets, hospital, shops) | Systems reserves (social capital) |
| Socially self-organized | The social components of the agroecosystem are able to form their own configuration based on their needs and desires | Systems that exhibit greater level of self-organization need fewer feedbacks introduced by managers and have greater intrinsic adaptive capacity | Farmers are able to organize themselves into networks and institutions such as co-ops, community associations, advisory networks and clusters with the processing industry | Tightness of feedbacks, system reserves (social capital) |
| Appropriately connected with actors outside the farming system | The social components of the agroecosystem are able to form ties with actors outside their farming system | In case self-organization fails, signals can be send to actors that indirectly influence the farming system | Farmers and other actors in the farming system are able to reach out to policy makers, suppliers and markets that operate at the national and EU level | Tightness of feedbacks |
| Legislation coupled with local and natural capital | Regulations are developed to let the system function as much as possible within the means of the bio-regionally available natural resource base and ecosystem services | Responsible use of local resources encourages a system to live within its means; this creates an agroecosystem that recycles waste, relies on healthy soil, and conserves water | Norms, legislation and regulatory frameworks are well adapted to the local conditions | Systems reserves (social capital) |
| Infrastructure for innovation | Existing infrastructure facilitates diffusion of knowledge and adoption of cutting-edge technologies (e.g. digital) | Through timely adoption of new knowledge and technologies, a farming system can better navigate in a changing environment | Existing infrastructure facilitates knowledge and adoption of cutting-edge technologies (e.g. digital) | Openness, system reserves |
| Diverse policies | Various policy instruments stimulate different mechanisms that improve different resilience capacities. | Policies addressing all three resilience capacities avoid situations in which farming systems are permanently locked in a robust but unsustainable situation. Or situations in which adapting and transforming systems are increasingly vulnerable | Policies stimulate all three capacities of resilience, i.e. robustness, adaptability, transformability | Diversity |