Project acronym: SURE-Farm
Project no.: 727520

Start date of project: June 2017
Duration: 4 years

Guidelines for the Framework of Participatory Impact Assessment of SUstainable and REsilient EU FARMing systems (FoPIA-Surefarm)

Work Performed by Partner 1, WU

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Due date	31 May 2019
Version/Date	31 May 2019
Work Package	WP5
Task	T5.2
Task lead	Wageningen University (WU, P1)
Dissemination level	Public

INDEX

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Please, cite this FoPIA-Surefarm workshop guideline as:

Reidsma, P., Paas, W., Spiegel, A., Meuwissen, M., 2019, 'Guidelines for the Framework of Participatory Impact Assessment of Sustainable and Resilient FARMing systems (FoPIA-Surefarm)'. In: Paas, W., Accatino, F., Antonioli, F., Appel, F., Bardaji, I., Coopmans, I., Courtney, P., Gavrilescu, C., Heinrich, F., Krupin, V., Manevska-Tasevska, G., Neumeister, D., Peneva, M., Rommel, J., Severini, S., Soriano, B., Tudor, M., Urquhart, J., Wauters, E., Zawalinska, K., Meuwissen, M., Reidsma, P. D5.2 Participatory impact assessment of sustainability and resilience of EU farming systems. Sustainable and resilient EU farming systems (SURE-Farm) project report.

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1 Introduction

SURE-Farm Working Package 5 (WP5) aims to analyse the integrated impact of resilience-enhancing strategies on the selected farming systems in the 11 SURE-Farm case studies, in particular regarding their delivery of private and public goods. In WP5, existing models (static and dynamic, quantitative and qualitative) are incorporated in an integrated assessment (IA) tool (D5.1 Herrera et al., 2018). The IA-tool includes the agent-based model of farm structural change AgriPoliS, the Farm System SIMulator (FSSIM), statistical models, stochastic models, a spatially explicit model to assess ecosystem services, a system dynamic model, and the Framework for Participatory Impact Assessment adapted for SURE-Farm (FoPIA-Surefarm). To serve the general aim of WP5, the IA tool will be specifically used to: 1) assess the current resilience and delivery of private and public goods for selected farming systems across the EU; 2) assess the impact of future challenges, and 3) assess the expected impact of resilience-enhancing strategies (and combinations of resilience-enhancing strategies) on the selected farming systems.

The quantitative models cannot be applied to all case studies because of 1) low data availability, 2) the level of model expertise of local partners and 3) model incompatibility with the type of farming system under study. Therefore, it is proposed in the IA-tool to use FoPIA-Surefarm as a participatory, semi-quantitative approach in all case studies, as 1) the approach can be applied in all case studies, 2) it allows comparability among case studies, and 3) it complements (or in some cases replaces) the quantitative assessments. With regard to the latter: some indicators are difficult to measure (mainly social ones), and therefore participatory assessments are needed to assess these. In addition, sustainability and resilience of farming systems partly depend on the perceived importance of different indicators. While changes in indicators may be measured and/or modelled, the perceived importance can only be understood when involving stakeholders in a participatory approach. Overall, in alignment with the aims of WP5 and its IA-tool, the participatory impact assessment aims to get a semi-quantitative overview of the sustainability and resilience of a farming system.

The guidelines in this report aim to explain the Framework for Participatory Impact Assessment of SUstainable and REsilient EU FARMing systems (FoPIA-Surefarm). Section 2 provides an overview of the theoretical framework of SURE-Farm, which provides the steps for the whole project, and in which FoPIA-Surefarm is embedded. Section 3 explains FoPIA-Surefarm and how it should be applied in the case studies. We expect the first workshop regarding past and current resilience to be held in autumn/winter of 2018/2019, and the second workshop on future scenarios in autumn/winter of 2019/2020. Results from the first workshops will be synthesized in D5.2, which is due in June 2019. These results will also complement quantitative results in D5.3 on current resilience and sustainability. Results of the second workshop will be included in D5.5

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and D5.6 on future scenarios and resilience-enhancing strategies. Appendix A includes summaries of the frameworks used as a basis: the original FoPIA methodology, the Resilience Assessment Framework (RAF) and the participatory approach used in system dynamics modelling.

2 Framework to assess resilience of EU farming systems

In D1.1 a framework for assessing the resilience of EU farming systems was developed (Figure 1; based on Meuwissen et al., 2018).

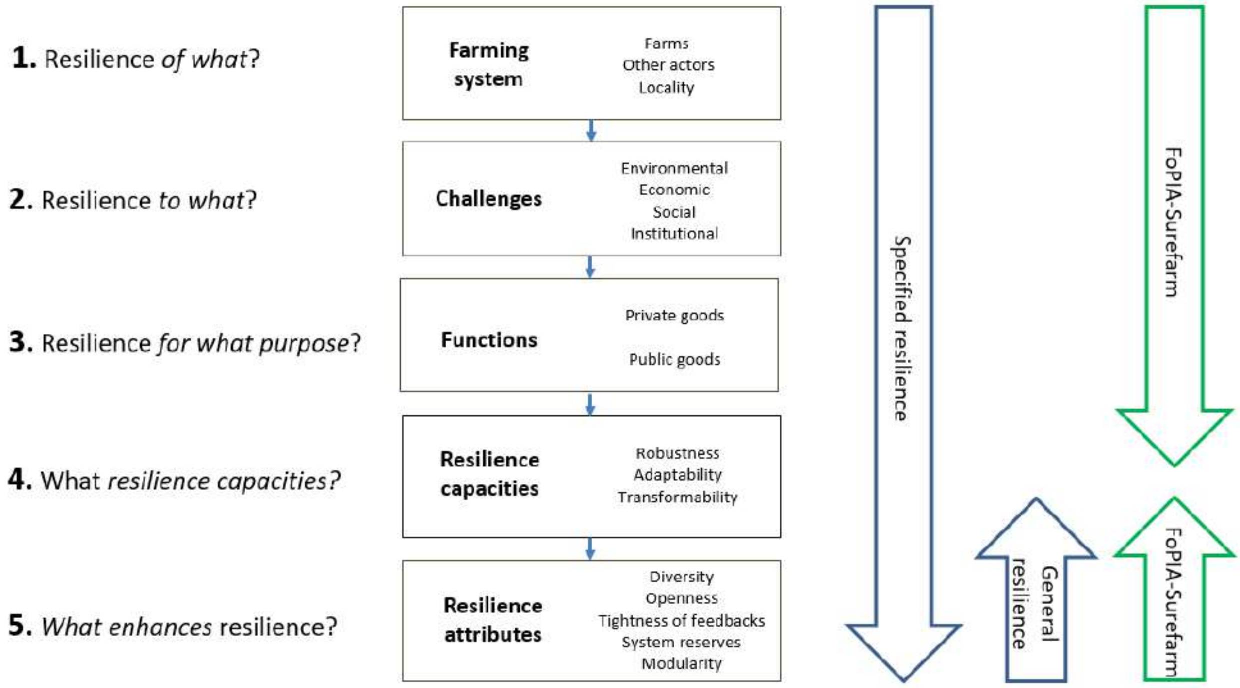

Figure 1. **Framework to analyse the resilience of farming systems, including resilience capacities and attributes. Source: adapted from Meuwissen et al. (2018).**

In Figure 1, the first three boxes refer to the delineation of the research and describing the dynamics of the subjects under study: resilience of what (farming system), to what (challenges) and for what purpose (essential functions) (Carpenter et al., 2001; Herrera, 2017; Quinlan et al., 2016). Next steps are to define and explain resilience capacities and resilience attributes. The resilience of farming systems and their essential functions depends on their robustness, adaptability and transformability. Resilience capacities narrate the dynamics of essential functions, and resilience attributes are relative easily measurable proxies that positively relate to at least one of the resilience capacities.

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The social boundary of a farming system is such that we include actors who influence farms in a specified region, and, conversely, farms in that region also influence these actors. In some cases, the processing industry is part of the farming system, while on others not. D1.3 (Unay-Gailhard et al., 2018) provides guidelines for developing a farm typology including interactions with the farming system, based on data and expert interviews. D3.1 (Bijttebier et al., 2018) describes the current farm demographics and trends per case study. With regard to the next step, general challenges have been synthesized in D1.1 (Meuwissen et al., 2018), and scenarios based on Shared Socio-Economic Pathways (SSPs) have been developed for EU farming systems in D1.2 (Mathijs et al., 2018). All case studies should consider these, but main risks differ per case study. Also for essential functions, an overview has been provided in D1.1, but the importance of different functions may differ per case study.

As farming systems, challenges, and essential functions differ, resilience capacities and attributes also differ per case study. In addition, resilience capacities can differ per essential function. For example, recovery rate (or return time) is often ascribed to robustness (e.g. Scheffer et al., 2009), and it is appropriate for continuous processes like soil respiration (Todman et al., 2016), but it is less appropriate for essential functions related to annual processes, like crop yield. In ecology, lakes have often served as example to explain resilience theory (Carpenter et al., 2001; Scheffer et al., 2001). It has been shown that the slow changing variable 'sediment phosphorus' is a useful surrogate for resilience (or 'attribute'), when assessing the resilience of a clear-water or turbid water state. Dynamics of the fast variable 'water phosphorus' provide more direct information, but are more difficult to measure. In our terminology, 'sediment phosphorus' is the resilience attribute. It is however clear that this attribute refers to a specific system. Cabell and Oelofse (2012) defined 13 attributes for the resilience of agro-ecosystem resilience. In their paper, Cabell & Oelofse (2012) focus on "a scale greater than the individual farmer and his or her farm, but a scale small enough that an individual's voice can still make a difference". This is aligned with the social boundary setting of farming systems of FoPIA-Surefarm as described in the previous paragraph. While the attributes of Cabell & Oelofse (2012) are argued to be generally applicable, the relation between attributes and resilience, may differ per farming system, challenge and essential function. It is therefore important to keep in mind the resilience of what, to what and for what purpose.

As quantitative tools cannot address all steps in the framework, participatory tools are needed. In the next sections we will provide details on the tools we build on, and propose steps for FoPIA-Surefarm.

3 Participatory impact assessment

FoPIA-Surefarm builds on three frameworks that have been applied before: 1) The Framework for Participatory Impact Assessment (FoPIA; Morris et al., 2011), 2) Resilience Assessment Framework (RAF; Resilience Alliance, 2010) and 3) the participatory approach used for system dynamics modelling by the University of Bergen (Herrera, 2017) . All methods have in common that they seek to support discussions among participants to understand the system under study.

FoPIA was developed within the EU5 project SENSOR. After that it was used in many other case studies, mainly in the EU6 project LUPIS (König et al., 2013; Reidsma et al., 2011). The aim of the original FoPIA is to assess the impact of policies on a set of indicators, encompassing sustainability. In FoPIA, a semi-quantitative approach is taken to quickly summarize judgments of participants on performance of sustainability indicators. As FoPIA does not address dynamics in these indicators, and hence does not address resilience, we also use RAF (Resilience Alliance, 2010) to complement our participatory method. The resilience assessment is more in line with the SureFarm framework, addressing questions like resilience of what, to what and for what purpose. It does not include a semi-quantitative assessment of the impact of changes on indicators reflecting sustainability (the essential functions), and therefore both building blocks are needed. Lastly, the participatory approach used for system dynamics modelling by the University of Bergen (Herrera, 2017) also includes aspects (causal loop diagram, sketches of past and future developments) that are useful for FoPIA-Surefarm. Details on these three participatory assessment frameworks that were used as building blocks for FoPIA-Surefarm are provided in Appendix A.

4 The FoPIA-Surefarm approach

4.1 Introduction

To fulfil the aims of FoPIA-Surefarm (section 1), two workshops are planned in all case studies: a first workshop regarding past and current resilience to be held in autumn/winter of 2018/2019, and the second workshop on future scenarios and strategies in autumn/winter of 2019/2020. Each workshop has a preparation phase.

Parts of the preparation may be performed in other SURE-Farm WPs or with quantitative models. In the guidelines, we refer to related tasks in the SURE-Farm project as much as possible. The more that is prepared by researchers, including interviews by experts, the more efficient a stakeholder workshop will be. Under the guiding questions, questions in italic refer to questions that are ideally answered, but can be excluded because of time issues.

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In brief, the first stakeholder workshop will focus on the past and current resilience and sustainability of the farming system, focusing on 1) ranking the importance of essential functions and selecting representative indicators for these functions, 2) scoring the current performance of the representative indicators, 3) sketching dynamics of representative indicators of essential functions, 4) linking these dynamics to challenges and resilience enhancing strategies, 5) relating this to the robustness / adaptability and/or transformability of the farming system, and 6) linking this to resilience attributes. Guidelines for this workshop are detailed in this report, including guidelines for analysis and reporting.

The second workshop will focus on the future resilience and sustainability. This includes 1) scoring the impact of scenarios on essential functions, 2) scoring the impact of scenarios on resilience attributes, 3) discuss the implications of the scoring for robustness / adaptability / transformability. D1.2 forms a basis for this assessment, but more detailed EU-Agri-SSP scenarios are currently being developed in an international collaboration process. Guidelines for this workshop to be held during autumn/winter 2019/2020 will therefore be improved after the first workshops have been held.

4.2 Phases in FoPIA-Surefarm

FoPIA-Surefarm consists of three phases: the preparation phase, the stakeholder workshop and the evaluation phase. Table 1 presents an overview of the steps to take in each of the three phases. Guidelines for the two workshops are presented separately. In the follow-up sections, more detail is provided.

The first stakeholder workshop has an estimated time of 270 minutes, excluding breaks. This is 4.5 hours, so including breaks and some extra time, 6 hours are needed. The workshop could be organized from 10.00-16.00.

For the second workshop some preliminary guidelines are provided, but these will be updated next year, after the evaluation of the first workshops, and further developments of future scenarios.

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Table 1. Phases in FoPIA-Surefarm. R = Researcher, E=Expert, S = Stakeholder.

Phase	Step	Activities	Who*	Time
Preparation phase	Farming system	Define main actors in the farming system, using guidelines from D1.1.	R, E	
		Identify mutual dependence between actors.	R, E	
		Identify farm types based on D1.3 and D3.1.	R, E	
	Challenges	Define main challenges using list in D1.1, and information from D3.1 and D2.1.	R, E	
	Essential functions	Select indicators per essential function starting with list in D1.1. Define for which stakeholders indicators are important.	R, E	
		Evaluate whether indicators reflect identity of the farming system.	R	
		Prepare worksheets to evaluate ranking of essential functions and indicators, and current performance of indicators, on a scale from 1 to 5.	R	
	Resilience capacities	If possible, collect data on historical dynamics of indicators of essential functions, analyse resilience capacities, and identify data gaps to prepare questions for stakeholders.	R	
	Resilience attributes	Collect literature on resilience attributes, in relation to main indicators to prepare questions for stakeholders.	R	
		Identify strategies that are currently implemented to cope with main challenges.	R, E	
Stakeholder workshop	Introduction	Use PowerPoint template to give an introduction to the workshop.	R	10 min
	Farming system	Present actors, relationships and farm types.	R	5 min
		Confirm main actors and mutual relationships.	S	10 min
		Confirm main farm types.	S	5 min
	Essential functions	Present essential functions and indicators.	R	5 min
		Rank importance of essential functions, using 100 points divided over 8 functions. Rank indicators, 100 points divided per function. Per stakeholder.	S	20 min
		Assess current performance of indicators, scoring from 1 to 5. Per stakeholder.	S	20 min
		Evaluate ranking and select up to 6 indicators that reflect identity, and need to be evaluated to assess resilience.	R, S	25 min
	Resilience capacities	Present (adaptive cycles and) the meaning of robustness, adaptability and transformability.	R	10 min
		Make groups of at least 3 persons (per indicator; main farming system functions) and continue in these groups throughout the workshop.	R	5 min
		Sketch dynamics of indicators over time.	S	15 min
(Table continues on next page)		Show, in the graphs, which challenges have influenced historical dynamics of the indicator.	S	10 min

Phase	Step	Activities	Who*	Time
		Identify strategies that have been implemented to reduce or benefit from the impact of a challenge.	S	10 min
		Identify whether an indicator was robust, adaptive and/or transformed.	S	10 min
		Plenary discussion: compare historical dynamics of groups; identify alternate states of farming systems.	R, S	30 min
	Resilience attributes	Present general resilience attributes and explain.	R	5 min
		Assess level of implementation of identified strategies from 1 to 5; score impact of strategy on resilience from -3 to +3. Only for strategies related to the same indicator as discussed before in group; filling in forms is done individually	S	10 min
		Assess level of presence of general resilience attributes from 1 to 5; score impact of strategy on resilience from -3 to +3. For the whole farming system; per stakeholder.	S	20 min
		Provide examples for most important resilience attributes in relation to robustness, adaptability and transformability	S	15 min
		Plenary discussion: evaluate robustness, adaptability and transformability of the indicators and the farming system in general; how do farming system level resilience attributes relate to farm level resilience attributes?	R, S	30 min
Evaluation phase	System description	Update description of farming system, challenges and essential functions.	R	
		Process results on ranking and scoring of essential functions, and definition of farming system identity based on main functions	R	
	Resilience capacities & attributes	Compare stakeholder sketches on indicator development with data.	R	
		Compare stakeholder defined relationships between resilience attributes and indicators with data.	R	
		Evaluate robustness, adaptability and transformability of the farming system	R	
	Reporting	Write chapter for D5.2, based on template	R	
		Use results for D5.3, in comparison with quantitative information.	R	

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5 Guidelines for stakeholder workshop on past and current resilience and sustainability

5.1 Introduction to stakeholder workshop

A general PowerPoint template will be prepared, which can be used as format in all case studies when organizing stakeholder workshops. Each slide in the template is accompanied with comments on 1) what to prepare for that slide, 2) what to do during the workshop and 3) what to say to introduce the slide. All the worksheets used in the preparation phase and the stakeholder workshops will also be included in an Excel file. The Excel file will also include sheets that can be used for summarizing results, e.g. mean, median, tables and graphs. These summarizing results will be used during the workshop for evaluation with the participants. For the worksheets and the PowerPoint, a clean version will be provided. For the Excel-sheets also a version is provided with preliminary or randomly generated results for the case study in the Netherlands. An overview of the materials needed for the workshop are presented in Appendix B. Guidelines for selecting and inviting stakeholders are presented in Appendix C.

5.2 Farming system

5.2.1 Introduction

The type of challenges a system is facing, as well as its response are largely affected by the characteristics of the system. Characterising the system is therefore the first step in our framework presented in Figure 1. This entails a description of key system characteristics such as farm types (Andersen, 2017; Andersen et al., 2007; Bijttebier et al., 2018), institutions in place, the agro-ecological context, (dis)connects related to the system's essential functions (Cumming et al., 2014), and the identity of the system (Cumming and Peterson, 2017).

Key actors within the system boundary are identified using the following selection criteria, i.e. *the boundary of a farming system is such that we include actors who influence farms, and, conversely, farms also influence these actors.* In contrast, we exclude actors who influence the farming system, but who are themselves scarcely influenced by the system. Figure 2 provides an example farming system.

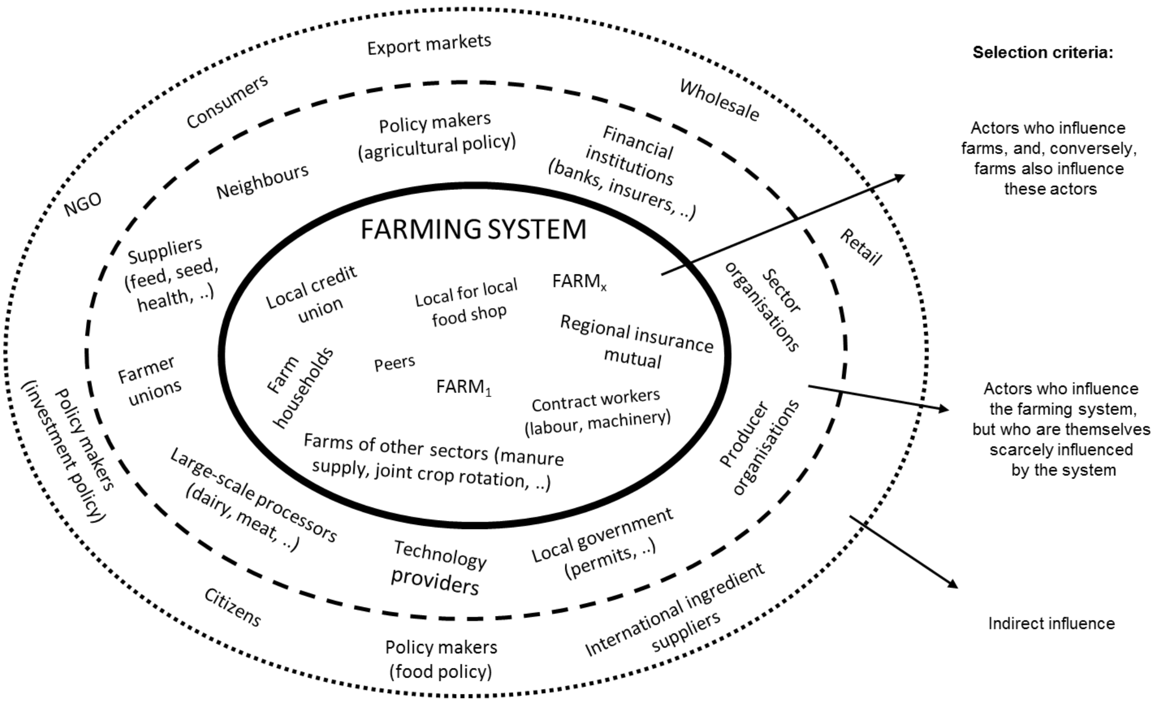

Figure 2. Selection criteria to identify actors within the system boundary of a farming system, incl. example actors (Source: Meuwissen et al., 2018).

Regarding the identity of the system, Cumming and Peterson (2017) refer to a system's identity as "key actors, system components, and interactions". They also mention the subjective nature of it ("[..] although subjective, it is not arbitrary; it requires establishment of key criteria [..]"). In the workshop, stakeholders will be asked to confirm main actors and their mutual dependence, i.e. the level of influence that they have on each other (see also Figure 2). In addition, the identity will be discussed in the step 'essential functions' (section 5.3), where the importance of essential functions will be ranked, and representative indicators will be selected for impact assessments in subsequent steps. It assumed that the most representative indicators for most important essential functions shape the identity of the system, in addition to main actors responsible for the provision of these functions.

5.2.2 Guiding questions

a. What are the main **actors/stakeholders** in the farming system?

b. For which of these actors/stakeholders there is strong **mutual dependence** (actors influence farms, and conversely, farms also influence these actors)?

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5.2.3 Preparation phase

The farming system needs to be defined in the preparation phase, by the research team, using the guiding questions. Experts can be interviewed. D8.2 and D3.1 provide a first overview. The social network may be mapped and analysed (Resilience Alliance, 2010). Worksheet P1 can be used to construct the list of stakeholders, describe their mutual dependence, and to describe the main farm types. You can include farm types with another orientation than the ones under study when there are strong interactions. For instance when the case-study is about dairy farming and dairy and crop farmers are exchanging land, manure etc. than the crop farmers are part of the farming system. It would be good if some of them are also invited to the workshop.

5.2.4 Stakeholder workshop

During the workshop, the farming system, including 1) main actors, 2) their mutual dependence, and 3) main farm types, is presented to the stakeholders. No specific questions will be asked, but stakeholders can provide comments for improvement.

5.3 Challenges

5.3.1 Introduction

To identify the variety of challenges farming systems are confronted with, we categorise the challenges along four dimensions, i.e. economic, environmental, social and institutional risks. Also, we distinguish two ways of how these challenges affect farming systems: as a shock, or as a long-term pressure with inherent uncertainties. Agro-ecological conditions that are static in nature are not seen as challenges, e.g. low water holding capacity is not seen as a challenge, but an incident of drought is. Adapted from Zseleczky and Yosef (2014), we define a shock as a sudden change in the risk environment of a farming system that influences (part of) the farming system on the short term through negative effects on people's current state of well-being, level of assets, livelihoods, or safety, or their ability to withstand future shocks. Shocks can be permanent or non-permanent. Examples of shocks are extreme price drops (economic risk), extreme weather events (environmental risk), sudden changes to on-farm social capital due to illness, divorce, or stress regarding ownership or succession (social risk), and geopolitical issues such as the Russian boycot (institutional risk). In contrast, long-term pressures refer to stressors slowly changing the context of a farming system, inherently leading to new uncertainties (Zseleczky and Yosef, 2014). Distinction between various dimensions and sub-classifications (shock, long-term pressure) is somewhat arbitrary, but the classification can be useful as a 'checklist' (see Annex 1 of Meuwissen et al. 2018).

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5.3.2 Guiding questions

a. What are the main economic, social, environmental and institutional **challenges** in the region? Group them as either shocks or long-term challenges.

5.3.3 Preparation phase

Use the list with main challenges (4 dimensions, 2 types) for EU farming systems as presented in Annex II of D1.1 (Meuwissen et al., 2018). Use literature and expert interviews to identify main challenges for the case study. D8.2 provided a basis, and the questionnaire on the farm typology in D1.3 included a question on this. The response of the experts is included in D3.1, and can be used as a basis here. Fill in worksheet P2 (Table 2).

Table 2. Worksheet P2. Main challenges in the farming system.

	Economic	Environmental	Social	Institutional
Shocks				
Long-term pressures				

5.3.4 Stakeholder workshop

Identified challenges are not presented during the stakeholder workshop, but an overview is relevant to guide the discussions. Challenges will later be linked to dynamics of essential functions, and if not mentioned by stakeholders, they could be asked about the influence of specific challenges.

5.4 Essential functions

5.4.1 Introduction

Depending on a system's location (e.g. close to a city centre, or remote), system functions may differ. Furthermore, institutional discourses on sustainable development espouse different sustainable development principles even though the general consensus as quoted in the Brundtland Report (United Nations, 1987), i.e. 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' may be the same. This is useful to recognise at a farming system level to understand the variety of 'essential functions'. In general, functions can be subdivided towards the provision of private goods and public goods (Meuwissen et al., 2018). Private goods refer to (i) the availability of healthy and affordable food products, (ii) the availability of other bio-based resources for the processing sector, including fuels and fibres, (iii) the economic viability of farm as viable farms contribute to balanced territorial development, and (iv) improved quality of life by providing employment and offering decent working conditions. Public goods refer to (i) maintaining natural resources in good condition, (ii) protecting biodiversity of habitats, genes and species, (iii) ensuring that rural areas are attractive places for residence and tourism, and (iv) ensuring animal health and welfare. We define these functions at the level of farming systems (not farms), implying that the framework is not primarily aimed at preserving individual (family) farms. Although the interaction between the provision of various functions can provide significant synergies for farming systems, they are not always mutually supportive as there can be conflicts between e.g. social and economic dimensions and there are often trade-offs involved. Thus, the level of interdependency can vary according to the farming system and its system boundary. This means that each farming system has a level of sustainability which is relative to its own target functions and depending on system-specific interactions. Essential functions may change over time. Also, there may be functions which could be provided by other systems.

The identity of a farming system depends on key actors, system components, and interactions (section 5.2), but also on the provision of essential functions. Which functions are deemed essential for the farming system depends on stakeholder perspectives. A large change in a specific essential function can imply a collapse or transformation of a system. Therefore, for an integrated impact assessment, ranking the importance of essential functions is important. To be able to rank the importance of an essential function, indicators need to be associated to these essential functions. Often, the identity of a farming system is associated to a specific indicator. For example, in the case study in the Netherlands, in the Veenkoloniën producing starch potato shapes the identity of the farming system.

We propose to have a minimum of one and a maximum of four indicators that are associated to essential functions. It is likely that the function ‘the availability of healthy and affordable food products’ and ‘maintaining natural resources in good condition’ require a larger variability of indicators to reflect the function than some others.

5.4.2 Guiding questions

a. Which **indicators** reflect the essential functions provided by the farming system? For which stakeholders are selected indicators important?
b. What is the **perceived importance** of the eight essential functions? What is the perceived importance of specific indicators? Does the perceived importance differ per stakeholder?

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c. What is the **perceived current performance** of indicators that represent the essential functions? What is the current performance of essential functions? Does the perceived current performance differ per stakeholder?
d. Which indicators shape the **identity** of the farming system? Which are most relevant to evaluate in next steps: historical trends, resilience and current performance.

5.4.3 Preparation phase

Use Worksheet P3 to identify around two indicators per essential function. Identify for which stakeholders these indicators are essential. The guideline is to define an average of two indicators per function, but it is alright to define one or three or four indicators when that is more suitable. For workability, make sure that the total number of indicators does not exceed 24.

Table 3. Worksheet P3. Essential functions, selected indicators, and link to stakeholders.

Essential functions (purpose)	**Indicators**	**Stakeholder**
Private goods		
Deliver healthy and affordable food products		
Deliver other bio-based resources for the processing sector		
Ensure economic viability (viable farms help to strengthen the economy and contribute to balanced territorial development)		
Improve quality of life in farming areas by providing employment and offering decent working conditions.		
	-	
Public goods		
Maintain natural resources in good condition (water, soil, air)		

Protect biodiversity of habitats, genes, and species		
Ensure that rural areas are attractive places for residence and tourism (countryside, social structures)		
Ensure animal health & welfare		

5.4.4 Stakeholder workshop

Present the eight essential functions to the stakeholders and ask them to rank the perceived importance of the eight functions. A total of 100 points can be distributed over eight functions.

Table 4. Worksheet S1. Stakeholder ranking of essential functions.

Name:	
Stakeholder group: farmer/government/industry/NGO	
Essential functions	Score (0-100; total = 100)
Private goods	
Deliver healthy and affordable food products	
Deliver other bio-based resources for the processing sector	
Ensure economic viability (viable farms help to strengthen the economy and contribute to balanced territorial development)	
Improve quality of life in farming areas by providing employment and offering decent working conditions.	
Public goods	
Maintain natural resources in good condition (water, soil, air)	
Protect biodiversity of habitats, genes, and species	
Ensure that rural areas are attractive places for residence and tourism (countryside, social structures)	
Ensure animal health & welfare	

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	Total = 100

After ranking the essential functions, participants are asked to evaluated the list with proposed indicators. In case necessary, indicators can be removed from or added to the list. As time is limited, give not too much space for discussion. After the list is completed, stakeholders are asked to rank the representative indicators per essential function, again totalling 100 points. So, if three indicators are included for one function, a total of 100 points is distributed over these three indicators. Ranking of individual indicators can be done later based on both rankings. In the Excel worksheet S2 (Table 5), the indicators should be filled in automatically after filling in worksheet P3 (Table 3).

Table 5: Worksheet S2. Stakeholder ranking of indicators per essential function.

Name:				
Stakeholder group: farmer/policy/extension/industry/NGO/...				
Essential functions	Indicators			
Private goods	1	2	3	
Deliver healthy and affordable food products	Ind. 1.1	Ind. 1.2	Ind. 1.3	
Score (0-100)				total =100
Deliver other bio-based resources for the processing sector	Ind. 2.1	Etc.	Etc.	
Score (0-100)				total =100
Ensure economic viability (viable farms help to strengthen the economy and contribute to balanced territorial development)	Etc.	Etc.	Etc.	
Score (0-100)				total =100
Improve quality of life in farming areas by providing employment and offering decent working conditions.	Etc.	Etc.	Etc.	
Score (0-100)				total =100
Public goods				
Maintain natural resources in good condition (water, soil, air)	Etc.	Etc.	Etc.	
Score (0-100)				total =100
Protect biodiversity of habitats, genes, and species	Etc.	Etc.	Etc.	

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Score (0-100)				total =100
Ensure that rural areas are attractive places for residence and tourism (countryside, social structures)	Etc.	Etc.	Etc.	
Score (0-100)				total =100
Ensure animal health & welfare	Etc.	Etc.	Etc.	
Score (0-100)				total =100

Use the Excel ranking sheets to analyse means and standard deviations of scores per essential function, and per stakeholder group. While one of the researchers is quickly analysing the ranking (based on a quick scan and/or getting the written ranking into the Excel sheets for analysis; digital data collection is also a possibility), the stakeholders are asked to assess the perceived current performance of the indicators, scoring from 1 to 5, where 1: very low performance, 2: low performance, 3: medium performance, 4: good performance, 5: perfect performance. Worksheet S3 (Table 5) can be used to fill in the scores. Results are processed in the Excel-sheets and discussed in a plenary session.

Table 5. Worksheet S3. Current performance of selected indicators.

Name:		
Stakeholder group: farmer/policy/extension/industry/NGO		
Essential functions (purpose)	Indicators	Score (1 to +5)
Private goods		
Deliver healthy and affordable food products		
Deliver other bio-based resources for the processing sector		
Ensure economic viability (viable farms help to strengthen the economy and contribute to balanced territorial development)		
Improve quality of life in farming areas by providing employment and offering decent working conditions.		

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Public goods		
Maintain natural resources in good condition (water, soil, air)		
Protect biodiversity of habitats, genes, and species		
Ensure that rural areas are attractive places for residence and tourism (countryside, social structures)		
Ensure animal health & welfare		

After the ranking and the scoring, a discussion takes place to identify most important indicators that represent the identity of the system. The bubble graph on indicator performance on sheet 'Analyses S3' can be used to support the discussion as the bubble size indicates the relative importance of the indicators as well. These will be evaluated in the next steps, to assess resilience. It is possible that no consensus can be reached on which indicators to select. In that case, a compromise is good enough. In either case a proper documentation of the discussion is essential.

5.5 Resilience capacities

5.5.1 Introduction

Understanding the resilience of a farming system, requires understanding the dynamics of the representative indicators of the essential functions, and specifically the ones shaping the identity of the system.

While the application of the adaptive cycle, and specifically for the four main processes agricultural production, farm demographics, governance and risk management, is important to understand the resilience of the farming system, we see this as work for researchers, and too complex for a stakeholder workshop (but it could be included in the preparation phase).

In our resilience framework, three resilience capacities are distinguished; robustness, adaptability and transformability. Upfront classification of a system or nested subsystem into stages of robustness, adaptability or transformability is not straightforward. Instead, it seems better to start

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exploring (i) the dynamics of the essential functions (robustness), (ii) the relation between risks (shocks, long-term pressures) and responses (adaptability), and (iii) the occurrence of tipping points (drastic system changes, regime shifts within one generation, changed identity) (transformability) (Meuwissen et al., 2018).

The stakeholder workshop cannot answer all the questions, but can provide a good basis, upon which the researchers can build. We propose to ask the stakeholder to analyse historical dynamics from 2000-2018, but with reference to earlier time periods were relevant.

5.5.2 Guiding questions

a. What are the **historical dynamics** of important representative indicators?
b. What is the relationship between dynamics of representative indicators and **challenges** (long-term challenges and shocks)?
c. What are **strategies** that have been implemented to reduce or benefit from impact of challenges?
d. What are underlying factors (resilience attributes) that are present to reduce or benefit from impact of challenges?
e. **Robustness**. Is the representative indicator robust (high mean level, low variability, low reduction due to risk, quick recover)?
f. **Adaptability**. Were strategies adopted to respond to challenges? Are enough adaptation options available to respond to challenges? Can stakeholders implement these options easily?
g. **Transformability.** What are alternate states of the farming system? What are the transition phases between alternate states in the farming system?

5.5.3 Preparation phase

Researchers do not need to prepare historical dynamics. However, if time allows, it would be useful to collect data on indicators of essential functions, and analyse historical dynamics. Useful sources of data are the publicly available databases of Eurostat (https://ec.europa.eu/eurostat/data/database) and the Farm accountancy Data Network (http://ec.europa.eu/agriculture/rica/database/database_en.cfm). As data may be limited, questions may arise on historical dynamics, and influences of challenges on these. These questions can guide the stakeholder workshop, as stakeholders can be asked specifically about gaps in the data.

5.5.4 Stakeholder workshop

Group stakeholders, and each group focuses on one representative indicator. Make sure that the groups have at least 3 persons. Also, try to have at least one person from government, industry,

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ngo and the farmer community in your groups. Allow stakeholders to change groups, if stakeholders feel uncomfortable to work on a certain indicator and feel more knowledgeable about another. Ask stakeholders to sketch the historical development of the indicators from 2000-2018 in worksheet S3 (Figure 3). In case stakeholders are not sure about what unit the Y-axis should be, you can propose percentages where one chosen year functions as point of reference and has a 'score' of 100%. In the Workshop PowerPoint an example is provided about laying hens in the Netherlands. This example can be used to stimulate stakeholders to think about dynamics rather than only thinking about averages and trends. To further stimulate thinking about the dynamics of an indicator, ask about extreme good and bad years.

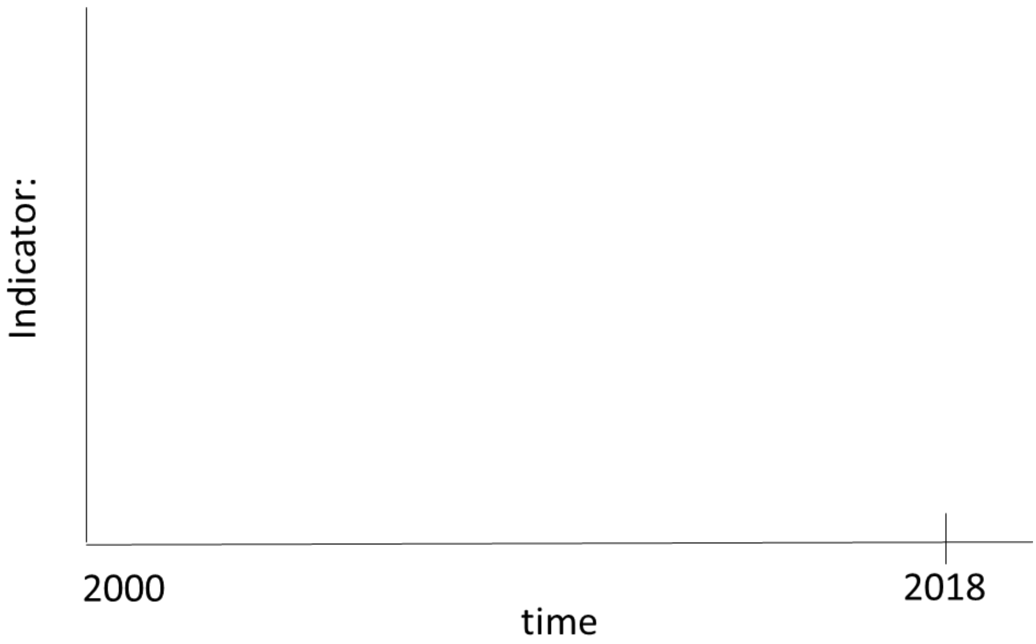

Figure 3. Worksheet S4. Historical dynamics of farming system attribute, including links to challenges and strategies (responses).

Ask stakeholders to show, in the graphs, which challenges have influenced historical dynamics of the indicators. Use the datasets that were mentioned in the preparation phase to verify whether sketched dynamics approach reality. In case the sketches are far from reality, bring in your knowledge (from the datasets) and take notes of your intervention.

Use the list of challenges prepared to stimulate the discussions. In some specific cases, opportunities, rather than challenges have caused dynamics in the farming system performance. If this is the case, it is likely to come forward in this exercise, which is fair enough. However, in line with the resilience framework (Meuwissen et al., 2018) in general the point of departure of FoPIA-Surefarm are the challenges, i.e. resilience to what.

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Ask stakeholders to identify strategies (responses) that have been implemented to reduce or benefit from the impact of a challenge. Also ask whether there were underlying factors that could have reduced the impact or increased opportunities to benefit from the challenge. Getting a list with strategies is the main aim of the whole sketching exercise. In case participants are not able to sketch the dynamics, you could use the discussion itself to come up with a list of strategies, i.e. the sketching should facilitate and not hamper the process of getting to relevant strategies.

Get together with all stakeholders, and discuss historical dynamics of the main representative indicators, based on group presentations. Evaluate robustness/adaptability/transformability of the farming system, based on the main indicators. Also discuss synergies and trade-offs between indicators.

5.6 Resilience attributes

5.6.1 Introduction

Resilience attributes contribute to the resilience of farming systems; they improve the resilience capacities. For instance, they determine the speed of recovery, the variety of responses in the safe operating space, or the pace at which a system can reorganize after a collapse. Cabell and Oelofse (2012) identified 13 general attributes contributing to the resilience of agroecosystems, i.e. (i) socially self-organised networks of e.g. farmers, consumers and the community, (ii) ecological self-regulation, e.g. by farmers maintaining plant cover and incorporating more perennials, (iii) appropriately connected, e.g. crops planted in polycultures and collaboration between chain actors; (iv) functional and response diversity, e.g. by heterogeneity within landscapes and farms; (v) optimal redundancy, i.e. planting multiple varieties of crops, keeping equipment for various crops, and retrieving nutrients from multiple sources; (vi) spatial and temporal diversity, e.g. by a mosaic pattern of managed and unmanaged land and diverse cultivation practices; (vii) exposed to disturbance, dealt with by e.g. pest management and positive selection; (viii) coupled with local natural capital, e.g. by not depleting soil organic matter, and little need to import nutrients or export waste; (ix) reflective and shared learning, e.g. by record keeping and knowledge sharing between farmers; (x) globally autonomous and locally interdependent, e.g. by less reliance on commodity markets and reduced external inputs, more reliance on local markets, and shared resources such as equipment; (xi) honors legacy, e.g. by incorporating traditional cultivation techniques with modern knowledge; (xii) building human capital, e.g. by investing in infrastructure for education, and support for social events in farming communities, and (xiii) reasonably profitable, implying that farmers and farm workers earn a liveable wage, and the agricultural sector does not rely on distortionary subsidies. These 13 attributes are built on >50 references discussing resilience at various scales including farm (Darnhofer, 2010) and socio-ecological systems (Folke et al., 2010).

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The resilience assessment framework of the Resilience Alliance (2010) argues that there is a need to consider both general and specified resilience. Specified resilience relates to the question 'resilience of what, to what and for what purpose'. General resilience applies to the system as a whole. Given that there may be completely novel shocks, with system responses that are as yet unknown, are there parts of the system that exhibit low or declining levels of those attributes that confer general resilience? The Resilience Alliance (2010) argues that the following attributes are related to general resilience: diversity, openness, tightness of feedbacks, system reserves, and modularity. The 13 resilience attributes of agro-ecological systems by Cabell and Oelofse (2012) can be seen as an extension of these. But while these attributes relate to general resilience, they may not contribute to specified resilience. The relation between resilience attributes and main indicators reflecting the essential functions of a farming system, may differ per case study. Relationships should therefore be investigated.

We related the 13 resilience attributes of Cabell & Oelofse (2012) to the farming system processes on which SURE-Farm has its focus: farm demographics, governance, risk management and agricultural production. In some cases we split the attributes in sub-attributes to improve their explicability. In addition, we tuned the definition of the (sub-)attributes more towards characteristics at the farming system level that are relevant in SURE-Farm. Also we developed three extra attributes, to serve the particular interests of SURE-Farm. Finally, we had a list with 22 attributes from which we selected 13 to reduce overlap between attributes and to reduce the workload during the workshop. The original and adapted list of attributes and their definitions are presented in Appendix D.

In our resilience framework (Figure 1) we aim to further specify the level of these attributes and how these attributes contribute to specific resilience capacities, i.e. robustness, adaptability and transformability. Exploring this into detail seems to be complex for a stakeholder workshop, but the relationship between the dynamics of main indicators and general resilience attributes can be explored. This allows a better understanding of the contribution of these resilience attributes to specified resilience.

5.6.2 Guiding questions

1. What is the **relationship** between **strategies** and the resilience (robustness/adaptability/transformability) of the farming system?
2. What is the **relationship** between general **resilience attributes** and the resilience (robustness/adaptability/transformability) of the farming system?
3. Are there additional resilience attributes, specific for the case-study area? And how do they relate to resilience (robustness/adaptability/transformability) of the farming system?

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4. Which resilience attributes are most important for the different resilience capacities of the farming system?

5.6.3 Preparation phase

Data in case studies may be limited, but try to search for data on general resilience attributes and their development over time. Analyse whether there are relationships between the historical dynamics of main indicators of essential functions. This material can be used to prepare specific questions for the stakeholders. Prepare the worksheets.

5.6.4 Stakeholder workshop

During the workshop, both the strategies identified in the previous step will be analysed, and general resilience attributes. For evaluating the strategies, participants remain in the same groups, and evaluate the implementation level and effect of identified strategies with regard to the farming system, i.e. not only for the indicator for which the strategy was implemented. Each individual stakeholder is asked to fill in the worksheets. The evaluation of attributes is also done with regard to the farming system. Also here, each participant is asked to individually fill in the worksheets.

Use Worksheet S5 to write down the strategies as identified in worksheet S4, indicate to which challenge this strategy responded. First, score the degree into which the strategy has been implemented: 1: not implemented, 2: slightly implemented, 3: moderately implemented, 4: well implemented, 5 perfectly implemented. Second, score the relationship between the strategy and the robustness/adaptability/transformability of the farming system (which was identified in Worksheet S4) from -3 to +3. All boxes need to be scored per strategy. Although these were strategies identified as improving resilience, there might be trade-offs between robustness, adaptability and transformability, resulting in negative and positive scores. A 0 implies no relationship, a 1 or -1 a weak positive or negative relationship, a 2 or -2 a intermediate positive or negative relationship, and a 3 or -3 is a strong positive or negative relationship. If time allows, discuss whether this strategy can also be a response to other challenges.

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Table 6. Worksheet S5. Strategies and resilience capacities.

		Level of implementation	**How would a high level of strategy implementation contribute to resilience in your farming system?**			
			Robustness	**Adaptability**	**Transformability**	
Strategy	**Related to which challenge?**	**Score between 1 and 5**	**Score between -3 and +3**	**Score between -3 and +3**	**Score between -3 and +3**	**Also related to other challenges?**

The next step is to evaluate the general resilience attributes, using worksheet S6 (Table 7). Explain the use of resilience attributes to the stakeholders. For comprehensibility, each resilience attribute is accompanied by a statement.

First, participants are asked to score the extent into which the attribute and accompanying statement is the case in the farming system: 1: not at all, 2: small extent, 3: moderate extent, 4: big extent, 5: very big extent. After that, the strength of the relationship for the coloured boxes is scored between -3 and +3. It is expected that most relationships are positive, but negative relationships may also be possible. A 0 implies no relationship, a 1 a weak relationship, a 2 a relationship of intermediate strength, and a 3 is a strong relationship. For negative values, the same terminology applies. Participants can add case-study specific attributes when necessary. Ask participants to write down, explain and score additional attributes that they think of.

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Thirdly, for the three most important resilience attributes (based on the scoring), ask stakeholders for examples in relation to robustness, adaptability and transformability. Preferably, this is added to Worksheet S6, so the information of individuals is directly linked.

Collect the worksheets from all stakeholders, and check their name and type of stakeholder. End4 with a plenary discussion, concluding on main challenges, main strategies and resilience attributes, and synergies and trade-offs between indicators.

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Table 7. Worksheet S6. Relationship between the farming system and general resilience attributes (both based on Cabell & Oelofse (2012) and Meuwissen et al. (2018).

		To what extent does this apply in your farming system?	How would a high level of the resilience attributes contribute to resilience in your farming system?			
			robustness	adaptability	transformability	
Resilience attribute	**Explanation statement**	**Score between 1 (not the case) and 5 (strongly agree)**	**Score between -3 and +3**	**Score between -3 and +3**	**Score between -3 and +3**	**Provide additional comments where necessary**
Reasonably profitable	Farmers and farm workers earn a liveable wage while not depending heavily on subsidies.					
Coupled with local and natural capital (production)	Soil fertility, water resources and existing nature are maintained well.					
Functional diversity	There is a high variety of inputs, outputs, income sources and markets.					
Response diversity	There is a high diversity of risk management strategies, e.g. different pest controls, weather insurance, flexible payment arrangements					
Exposed to disturbance	The amount of year to year economic, environmental, social or institutional disturbance is not too small nor too big in order to timely adapt to a changing environment					
Spatial and temporal heterogeneity (farm types)	There is a high diversity of farm types with regard to economic size, intensity, orientation and degree of specialization					
Optimally redundant (farms)	Farmers can stop without endangering continuation of the farming system and new farmers					

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	can enter the farming system easily					
Supports rural life	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)					
Socially self-organized	Farmers are able to organize themselves into networks and institutions such as co-ops, farmer's markets, community sustainability associations, and advisory networks					
Appropriately connected with actors outside 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					
Coupled with local and natural capital (legislation)	Norms, legislation and regulatory frameworks are well adapted to the local conditions.					
Infrastructure for innovation	Existing infrastructure facilitates knowledge and adoption of cutting-edge technologies (e.g. digital)					
Diverse policies	Policies stimulate all three capacities of resilience, i.e. robustness, adaptability, transformability.					

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5.7 Evaluation phase

In the evaluation phase, Excel worksheets are used to analyse all the information gathered from the stakeholders. The description of the farming system is updated, ranking and scoring of essential functions is analysed, sketches of historical and future dynamics of main indicators are digitalized, and relationships between the resilience of main indicators and resilience attributes are analysed. Based on this, an overview is made of the current resilience and delivery of private and public goods for selected farming systems across the EU. Each SURE-Farm partner produces a report on their case-study within two months after the workshop. Formats for case-study reporting are made available. The case-study reports are processed in D5.2, which is due June 2019. In addition, D5.3 reports on the current resilience. Results from the first FoPIA-Surefarm workshop will come back in this reports, in combination with results from quantitative modelling. Information on the current situation for D5.3 is the farming system description, the historical development of farming system attributes, the link to challenges and main strategies that have influenced the development of farming system attributes.

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Appendix A. Building blocks for FoPIA-Surefarm

Framework for Participatory Impact Assessment (FoPIA)

Steps in FoPIA

FoPIA was originally developed for application in the EU to conduct stakeholder-based impact assessments of alternative land use policies, for example, to assess the policy options for biodiversity conservation in Malta (Morris et al., 2011). This approach has been adapted for the assessment of land use policies in developing countries (Figure A1; König et al., 2013).

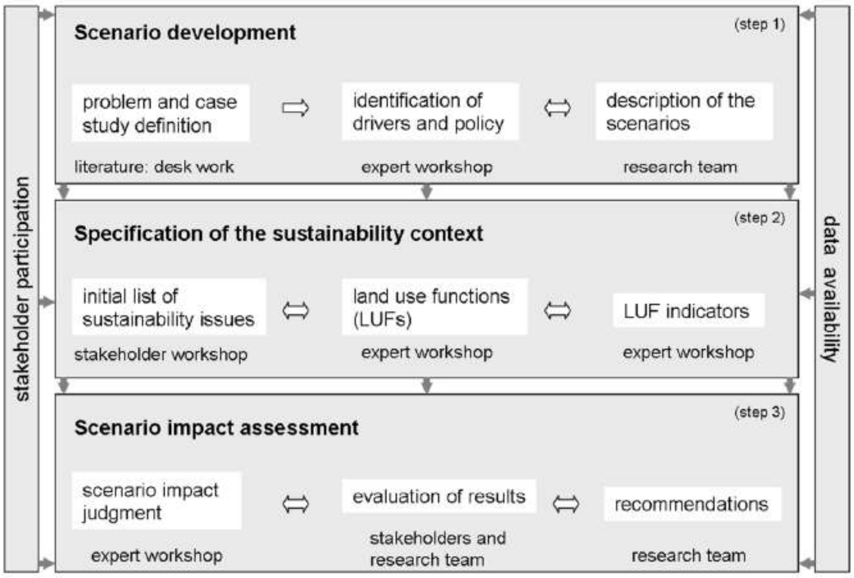

Figure A1. The implementation structure of FOPIA (Source: König et al., 2010).

FoPIA provides a general assessment framework, a template that can be adjusted to different regional contexts. It comprises a preparation phase and a regional stakeholder workshop, that follows a structured sequence of assessment steps as illustrated in Figure A1 and Table A1, namely (i) interactive development of regional land use scenarios, (ii) specification of the regional sustainability context, (iii) and assessment of scenario impacts and analysis of possible trade-offs. The workshop is followed by an evaluation phase in which the workshop results are further analysed and documented (Table A1).

The scenario development (step i in Table A1) starts with a characterization of the main case study attributes. Scenario assumptions are defined together with regional stakeholders, firstly to consider relevant and implicit regional information and secondly, to achieve a common basis of understanding. The specification of the regional sustainability context (step ii in Table A1) has the objective of putting the concept of Sustainable Development (SD) into the regional context by

Table A1. Sequence of FoPIA (Source: König et al., 2013).

Assessment steps		Activities	Who*	Time+
Preparation phase		Gathering and analysis of available literature and material to allow for a first understanding of the regional land use problem supported by informal meetings with experts, stakeholder selection and invitation, preparation of workshop materials	R	Several weeks
Stakeholder workshop (1-2 days)	Opening	General introduction and explanation of the goals and sequence of FoPIA	M	2-3 hours
		Self-introduction of the stakeholders (icebreaker)	S	
	Scenario development (step i)	Presentation of the status quo of the regional land use situation	M	
		Moderated discussion, case study and problem definition	S (M)	
		Definition of land use drivers and policy selection, elaboration of scenario assumptions	S (M)	
	Specification of the sustainability context (step ii)	Presentation of land use functions (LUFs)	M	2-3 hours
		Regional definition of LUFs	S (M)	
		Paper-based weighing of importance of LUF (2 rounds), presentation of result after each round (diagrams, tables), moderated discussion	S (M)	
	Scenario impact assessment (step iii)	Elaboration and selection of LUF assessment indicators	S (M)	3-4 hours
		Paper-based assessment of scenario impacts on each LUF by the stakeholders (2-3 rounds), presentation of group result (diagrams, tables) after each round, discussion of impact result	S (M)	
		Presentation of weighted scenario results, discussion of policy implications and consequences for regional sustainable development	M, S	
		Evaluation of the workshop	S	
Evaluation phase		Processing of results, identification of policy recommendations and report writing	R	Several weeks

*R – Researchers, M – Moderator(s), S – Stakeholders, + broad orientation using land use functions (LUFs) (Pérez-Soba et al., 2008). LUFs structure the assessment problem and allow for an equal consideration of the economic, social and environmental dimensions of sustainability. Stakeholders assign weights of perceived importance to the different LUFs, using a scoring scheme from 0 to 10 (0 = least important; 10 = most important). Weighing results are used to present different perceptions of LUF priorities as to derive a 'picture' of regionally more or less important LUFs. The same weight can be assigned to more than one function. After the assignment of individual weights, average weights are calculated and presented back to the group for discussion. A second scoring round is used to allow for an adjustment of weighing scores. For the impact assessment (step iii in Table A1), each LUF is assigned one corresponding indicator in order to have a precise measurement for the scenario impact assessment (see Table A2). Stakeholders are asked to propose regionally relevant indicators to elaborate an operational set of indicators. For the indicator selection, the following criteria are applied: the indicator should be relevant to the corresponding LUF, the indicator should be understandable to all participants, and the indicator should not be redundant to other indicators.

A scoring scale from - 3 to + 3 is used to assess negative or positive impacts, respectively, with the following scores: 0 = no impact; - 1 and + 1 moderate impact; - 2 and + 2 high impact; and - 3 and + 3 extremely high impact. After completion of the individual scorings, average impact scores for each scenario on each LUF indicator are calculated and presented back to the group. In order to initiate a discussion, the workshop moderator presents the group average score and highlights contrasting positive and negative impact scores. This step is important to make the participants reveal their arguments for the different scorings. After group discussion, one to two rescoring rounds are conducted to allow participants to readjust their scores as needed.

The overall assessment of the scenarios for the three sustainability dimensions is based on an aggregation of the scenario impact scores and LUF weights (König et al., 2013; Figure A2, Table A3). This allows for comparison of different scenarios and a ranking of scenarios, based on which, possible implications for land use and decision support can be discussed.

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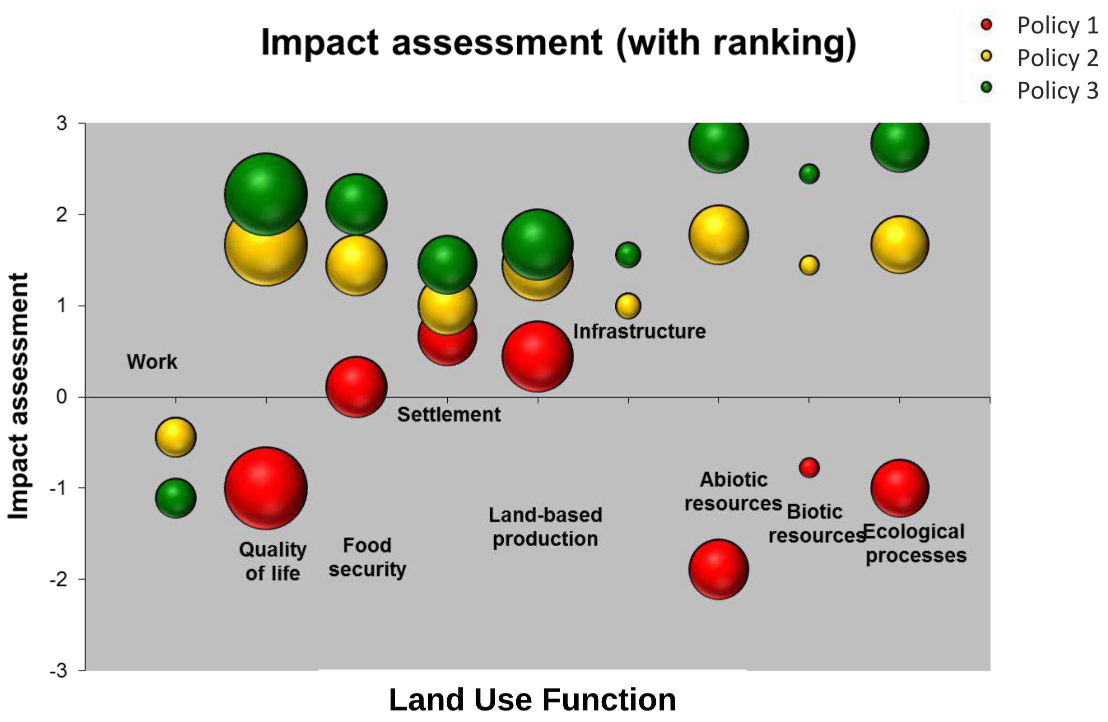

Figure A2. Example output of the original FoPIA (unpublished). The size of each Land Use Function indicates the relative importance. Impact assessment has been performed for 3 policies.

A common indicator framework

As can be observed in Table A2, an indicator framework is used to allow comparison among case studies. The three dimensions of SD (economic, social, environmental) are the main Principles, and are the same across case studies. The Land Use Functions (LUFs) are the Criteria, and per dimension, three LUFs are identified. Nine general LUFs were proposed for the whole project LUPIS, but in one case study the SOC3 food security was considered to be less important than cultural identity, and the LUF was adapted. Per LUF, one indicator was identified per case study. While indicators may be different per case study, the IA can be compared based on the LUFs and the SD dimensions (Table A3).

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Table A2. Land Use Functions and corresponding assessment indicators in five case studies (source: Konig et al. 2013).

Land use function (LUF)		LUF definition	LUF indicator	Y	G	O	B	N
ECO1	Land based production	Provision of land for economic production including agricultural and forest products	economic production	x	x		x	
			on-farm income			x		x
ECO2	Non-land based activities	Provision of space used for industry and service activities	built-up activities	x	x			
			off-farm income					x
			regional investments			x		
			access to financial services				x	
ECO3	Infrastructure	Quantity/quality of roads as means to connect rural regions with outer regions	road density and quality	x	x	x		x
			access to markets				x	
SOC1	Provision of work	Employment opportunities for activities based on natural resources	regional employment	x	x	x		x
			working conditions				x	
SOC2	Quality of life	A 'good' living standard in rural regions related to factors that should improve the quality of life	human health				x	x
			life expectancy	x		x		
			income		x			
SOC3	Food security	Availability of sufficient quantity and quality of food	food availability	x	x			x
			food from farm				x	
	Cultural identity	Values associated with local culture	traditional land use			x		
ENV1	Provision of abiotic resources	The role of land in regulating the supply and quality of soil and water	water availability	x		x	x	x
			soil structure and erodibility		x			
ENV2	Provision of biotic resources	Provision of habitat and factors affecting the capacity of the land to support regional biodiversity	habitat and biodiversity		x		x	x
			vegetation cover			x		
			conservation area	x				
ENV3	Maintenance of ecosystem processes	The role of land in the regulation of natural processes and ecological supporting functions	undisturbed land		x	x		
			soil health				x	x
			clean water	x				

Note: *Y =Yogyakarta, G=Guyuan, O=Oum Zessar, B = Bijapur, N = Narok.

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Table A3. Impact Assessment of policy options in five case studies (source: Konig et al. 2013).

Region	Scenario	Economic LUFs						Social LUFs						Environmental LUFs						Weighted aggregation			
		ECO1		ECO2		ECO3		SOC1		SOC2		SOC3		ENV1		ENV2		ENV3		w_{ECO}	w_{SOC}	w_{ENV}	wi
		w	i	w	i	w	i	w	i	w	I	w*	i	w	i	w	i	w	i				
Yogyakarta	REF (Urban)		-2.00		1.85		1.54		1.69		-1.15		-2.08		-2.15		-2.08		-2.23	13.0	-13.9	-51.3	-52.2
	S1 (Forest)	7.6	-0.08	8.5	0.38	8.1	0.38	7.9	-0.08	7.8	1.77	8.8	0.38	8.0	2.00	7.7	2.15	8.1	1.85	5.8	16.6	47.5	69.9
	S2 (Paddy)		1.69		0.08		0.54		0.85		1.77		2.54		-0.08		0.08		-0.62	17.9	42.8	-5.0	55.7
Guyuan	REF (no policy)		0.44		0.67		1.00		-0.44		-1.00		0.11		-1.89		-0.78		-1.00	13.9	-8.9	-25.7	-20.7
	S1 (SLCP-P1)	8.5	1.44	6.0	1.00	6.1	1.00	6.1	-0.44	7.0	1.67	7.1	1.44	6.5	1.78	7.6	1.44	7.5	1.67	24.4	19.2	35.0	78.6
	S2 (SLCP-P2)		1.67		1.44		1.56		-1.11		2.22		2.11		2.78		2.44		2.78	32.3	23.8	57.5	113.6
Oum Zessar*	REF (SWC-70)		1.30		0.40		0.00		0.30		0.40		1.50		0.70		0.40		-0.10	12.4	14.5	7.3	34.2
	S1 (SWC-85)	8.0	1.60	5.1	0.60	4.4	0.50	7.9	1.50	7.4	0.70	6.0	0.80	7.7	0.40	6.3	1.70	6.3	-0.50	18.1	21.8	10.6	50.5
	S2 (SWC-100)		2.00		0.30		1.40		1.90		0.90		0.50		0.10		2.40		-1.40	23.7	24.7	7.1	55.5
Bijapur	REF (Transition)		0.40		0.10		-0.10		0.20		-0.10		0.00		0.00		0.10		-0.20	3.2	0.5	-0.9	2.8
	S1 (Organic)	8.3	1.30	6.3	1.10	7.1	1.10	7.1	1.50	9.5	0.90	9.3	1.20	8.4	1.70	7.1	1.60	8.8	1.70	25.5	30.3	40.4	96.2
	S2 (Non-organic)		-1.10		-0.80		-0.50		-1.30		-1.50		-1.20		-1.50		-1.40		-1.40	-17.7	-34.5	-34.7	-86.9
Narok	REF (Crop)		2.46		0.15		2.15		2.23		1.00		2.62		-0.69		-2.31		-0.69	33.5	43.6	-28.3	48.8
	S1 (Livestock)	8.0	2.23	5.8	0.46	6.0	1.85	6.8	1.85	7.6	1.77	8.0	2.31	6.9	-0.46	8.0	-1.46	7.3	0.08	31.6	44.3	-14.3	61.6
	S2 (Ecotourism)		0.54		1.54		1.69		0.92		1.15		0.54		1.62		1.92		1.00	23.4	19.3	33.9	76.6

Note: w = average weights for the different LUFs reflecting the regional preferences; i = average impact of the scenarios; wi = weighted impact.

FoPIA as a basis for FoPIA-Surefarm

In developing FoPIA-Surefarm, the strengths and weakness of the approaches developed earlier were considered. As FoPIA-Surefarm needs to follow the new developed resilience framework by Meuwissen et al. (2018), strengths and weaknesses relate to how the approach can be used to follow the steps in the resilience framework, for 11 different case studies.

Strengths of FoPIA include:

- Clear guidelines are provided
- With a common indicator framework, case studies are comparable
- Stakeholders assist in defining scenarios, indicators and performing impact assessment
- Ranking and scoring provide semi-quantitative assessments

Limitations of FoPIA in relation to SURE-Farm framework:

- Focus is on assessment of essential functions (sustainability), not on dynamics of these (resilience capacities) and resilience attributes
- Scenario development and assessment focuses on comparing 2 policy scenarios with a baseline scenario. In SureFarm we have 5 SSPs, and a variety of resilience enhancing strategies related to agricultural production, farm demographics, governance and risk management.
- To be able to do the main work in a one day workshop, the options to choose from need to be defined beforehand, and this may be more complex in SureFarm: farming system, challenges, essential functions, resilience capacities, resilience attributes, resilience enhancing strategies.

Resilience Assessment Framework (RAF)

Five stages

The Resilience Assessment Framework (RAF) is developed by the Resilience Alliance (2010), in a workbook for practitioners. The resilience assessment framework starts by using strategic questions and activities to construct a conceptual model of a social-ecological system that represents a place of interest, along with its associated resources, stakeholders, institutions, and issues. Building on the conceptual model, the assessment guides the identification of potential thresholds that represent a breakpoint between two alternative system states and helps reveal what is contributing to or eroding system resilience. A resilience assessment can thus provide insight into developing strategies for buffering or coping with both known and unexpected change.

There are five main stages of the assessment framework (Figure A3), beginning with describing the system, then understanding system dynamics, probing system interactions, and evaluating governance, and finally acting on the assessment. The actual process is iterative and reflexive at each stage and requires referring back to earlier steps and revising as necessary.

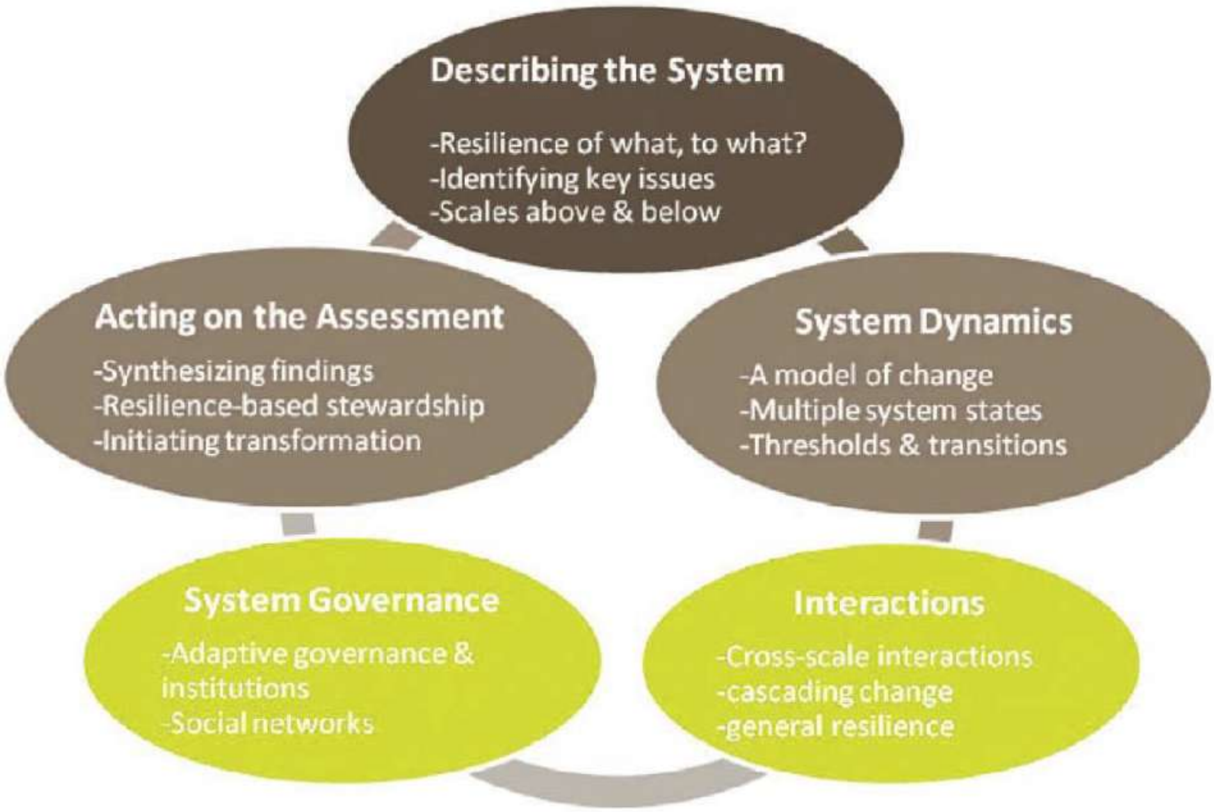

Figure A3. Five stages in the Resilience Assessment Framework (Source: Resilience Alliance, 2010).

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Describing the system: questions

In relation to each of the five stages, sub-stages are included , and structured steps are provided in relation to 1) assessment, 2) discuss, 3) reflect & connect, and 4) synthesize. As an example, the full questions are provided below for the first stage 'describing the system' and the sub-stage 'identifying the main issues' (Resilience Alliance, 2010):

Assessment

1. Consider the main issues that need to be addressed in your focal system. There may be one central issue, or there may be a set of related issues. Take, for example, the case of the Grand Canyon. Here, one issue is the recovery of endangered species (humpback chub and kanab amber snail), and another related issue is restoring and retaining sediments within the system.

2. In considering the main issue(s), identify system attributes that are valued by stakeholders. For example, native biodiversity is a valued attribute of the Grand Canyon system.

Enter the main issue(s) and related valued attributes in the worksheet 1.1 (Figure A4). Add additional rows if necessary.

Discuss

3. Consider to whom the valued attributes are important. Would all stakeholders consider biodiversity, for example, to be a particularly important attribute of the issue(s) you have identified?

4. Given the main issue(s), what is an appropriate time span over which to examine this system? For example, the time span may reflect a planning cycle or be determined by a natural cycle. Consider this to be a first approximation to a relevant time scale, which will be revisited after completing a historical timeline later.

5. Is the main issue already being actively managed? If so, how effective has this management been? Note that institutional and governance challenges will be explored in more depth later.

Reflect & connect

As you progress through subsequent steps in the assessment, be prepared to return to this section to revisit and possibly revise both the main issue(s) as identified and their valued attributes.

Summarize

Succinctly state the main issue(s) to be addressed in the assessment and the time frame of relevance to the issue.

Describing the system: worksheets

Each stage includes worksheets (ws) which can be used to process information. The Figures below show the worksheets used in stage 1 (Figure A4). These steps relate largely to step 1-3 in the SURE-Farm resilience framework: issues (ws 1.1) and disturbances (ws 1.3) relate to the challenges (step 2), values attributed (ws 1.1) and uses (ws 1.2) relate to essential functions (step 3), and stakeholders (ws 1.2) and focal system (ws 1.4) relate to the farming system (step 1). Also in FoPIA, the main issues of concern were the starting point, by starting with the main 'land use problem'.

Important in this approach, is that links are made immediately: issues of concern are related to valued attributes, main uses of natural resources are linked to stakeholders, and disturbances are related to components most affected.

Worksheet 1.1 Summary of main issues of concern for the assessment and of valued attributes of the system.

Issues	*Main issue(s) of concern for the assessment*	*Valued attributes of the system*
Issue 1		
Issue 2		
Issue 3		

Worksheet 1.2 Direct and indirect uses of key natural resources supplied by the system and the stakeholder that rely on them.

Natural resource uses	*Stakeholders*
Direct uses	Inside focal system
Indirect uses	Outside focal system

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Worksheet 1.3 Summary of focal system disturbances and their attributes.

Disturbance (past or present)	Pulse or Press	Frequency of occurrence	Time for recovery between occurrences	Components most affected (e.g., soil, markets)	Magnitude of impact (minor to severe)	Any change in past years or decades? (none, less frequent, more intense, etc.)
Future disturbances						

Worksheet 1.4 Social and ecological dimensions of systems at larger and smaller scales that interact with the focal system.

	Social dimensions that influence the focal system	Ecological dimensions that influence the focal system
Larger-scale systems		
Focal System		
Smaller-scale systems		

Figure A4. Overview of worksheets used in the first stage 'describing the system' (Source: Resilience Alliance, 2010).

System dynamics

The second stage in the RAF is 'system dynamics'. Sub-stages here include 'a conceptual model of change – the adaptive cycle', 'multiple states' and 'thresholds and transitions'. The adaptive cycle of Gunderson and Holling (2002) is used as the conceptual model. The key questions in the assessment are: 1) Apply the adaptive cycle framework to your system; 2) Select one or more key variables that can serve as indicators of how your focal system has changed over time. Discussion questions are: 3) Which change-causing drivers or factors appear to play a major role in the functioning of your system?; 4) What types of natural and social capital should be maintained in your system, regardless of changes that might occur, to enable reorganization and renewal?; 5) Considering tradeoffs between efficiency and flexibility, does your focal system depend on producing a specific set of outputs under a specific set of conditions?

Understanding the resilience of a system involves describing its current state as well as its historic and potential future states. Under the 'multiple states' sub-stage, assessment questions are: 1) Describe the alternate states of your system; 2) Describe the historical state(s) of your system, referring to the timeline developed along with worksheet 1.4; 3) Describe the transistion phases between alternate states in your system; 4) Are there desirable or undesirable traits associated with each alternate state? The discussion focuses on identifying the 3-5 factors that are most important to consider in defining the state of the system. These steps thus refer to getting a clear understanding of the identity of the system, and the essential functions it provides.

The third sub-stage refers to 'thresholds and transitions'. Main questions here are: 1) How might the system in its current state experience transition into each of the alternate states that have been identified previously?; 2) Characterize each threshold of potential concern by indicating the main factors driving the change, its degree of reversibility, and the possible consequences of crossing the threshold. The drivers, or factors responsible for a threshold are often related to slow driving variables in the system (such as phosphorus accumulation in a lake). If possible, try to identify any slow driving variables (in SURE-Farm: attributes) that appear to be system drivers; 3) Estimate the approximate location of the thresholds.

Cross-scale interactions

This stage includes three sub-stages. The first is 'the panarchy'. Here, the question is to describe in which phase of the adaptive cycle the larger-scale systems (in SURE-Farm: province, country) and the smaller-scale systems (in SURE-Farm: farms) appear to be in, and identify the influence of these systems on the focal system (in SURE-Farm: the farming system) (Figure A5).

The second sub-stage is 'interacting thresholds and cascading change'. The assessment includes: 1) Complete worksheet 3.2 (Figure A6) by listing thresholds of potential concern associated with the key slow variables identified under 'thresholds and transitions'; 2) Assign a level of certainty from 1 to 3 to each of the thresholds of potential concern; 3) Indicate on the worksheet any cross-scale interactions, based on worksheet 3.1.

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Worksheet 3.1 Cross-scale interactions.

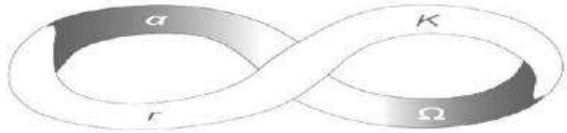
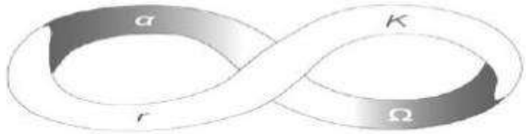
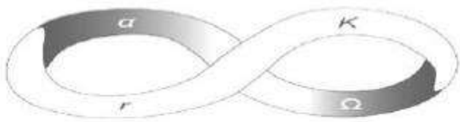
Larger-scale systems	
Focal system	
Smaller-scale systems	

Figure A5. Worksheet to identify cross-scale interactions (Source: Resilience Alliance, 2010).

Worksheet 3.2 Thresholds of slow variables and potential interactions.

Social	Smaller-scale system(s) ←	Focal system	→ Larger-scale system(s)
Ecological			

Figure A6. Worksheet to identify thresholds of slow variables and potential interactions (Source: Resilience Alliance, 2010).

The third sub-stage is 'general and specified resilience'. A resilience approach calls for assessing both specified and general resilience. Specified resilience refers to the resilience 'of what, to what'. General resilience does not consider any particular kind of disturbance or any particular aspect of the system that might by affected. The distinction between these two aspects of resilience is important because if the attention and resources of management are channeled into managing resilience to one particular type of disturbance and it associated thresholds, management actions may inadvertently be reducing system-wide resilience.

The assessment includes: Consider the following attributes that confer general resilience: diversity, openness, tightness of feedbacks, system reserves and modularity. Answer the following questions: what are the main issues? Where may a low level or trends in the attribute be of concern? In which part of the system is the attribute low, which may render the system vulnerable to a loss of function? Are there trends that reflect a change in the attribute? During the discussion phase trade-offs between specified and general resilience are investigated.

Governance systems

This stage includes two sub-stages. The first is 'adaptive governance and institutions'. Main questions here are: 1) What key institutions have a bearing on decision-making on your system? Do these enhance or constrain flexibility to address the issues as they arise? 2) At what level are key decisions being made that affect the focal system and the main issues of concern?; 3) Is rule compliance and enforcement effective? A worksheet is also provided here.

The second sub-stage includes 'social networks among stakeholders'. In the assessment 1) the social network in the system is mapped; 2) the social network is analysed, based on the number of relations, the degree of centrality, and the existence of cohesive groups; 3) key people or groups are identified.

Acting on the assessment

The last stage starts with 'synthesizing the asssessment findings'. Two conceptual diagrams are provided to build a model of the socio-ecological system that is the focus of the assessment (Figure A7, A8). Guiding questions are provided for constructing the conceptual model.

The second sub-stage is 'resilience based stewardship'. Based on the earlier stages, specfiic management interventions and strategic plans are developed. The last sub-stage is 'time for transformation?' A transformation is said to have taken place when there is a change in the key components that define the system. In this stage, strategies are linked to actions and barriers of change.

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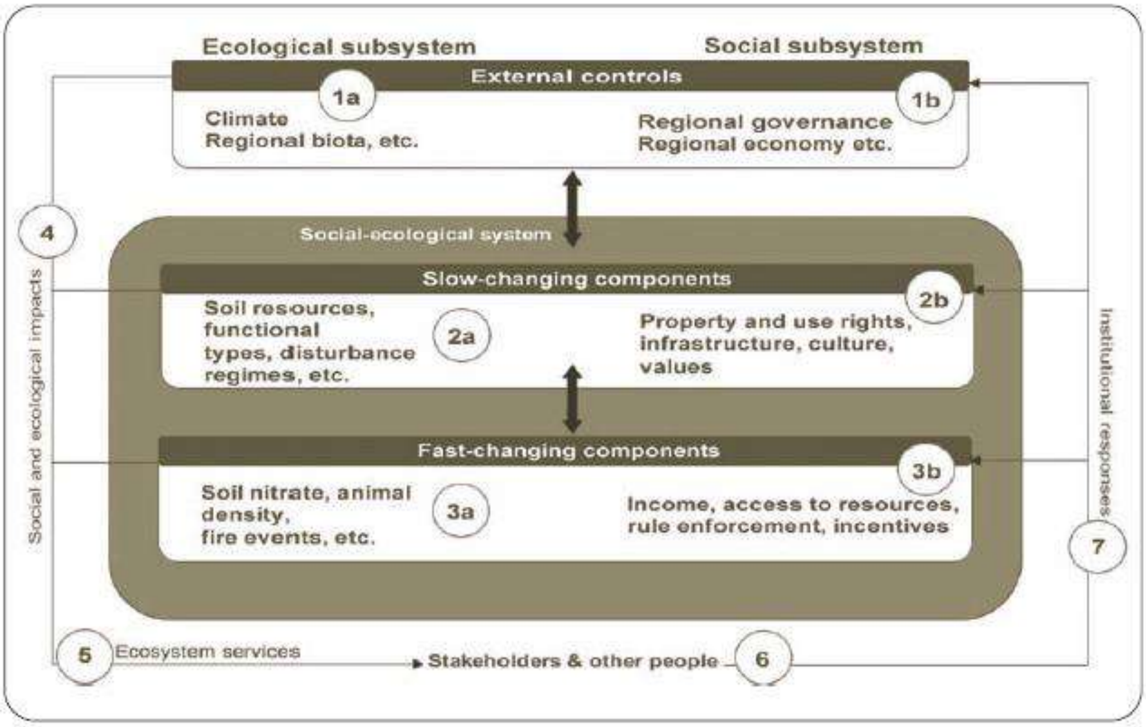

Figure A7. General conceptual model of a social-ecological system (Source: Resilience Alliance, 2010).

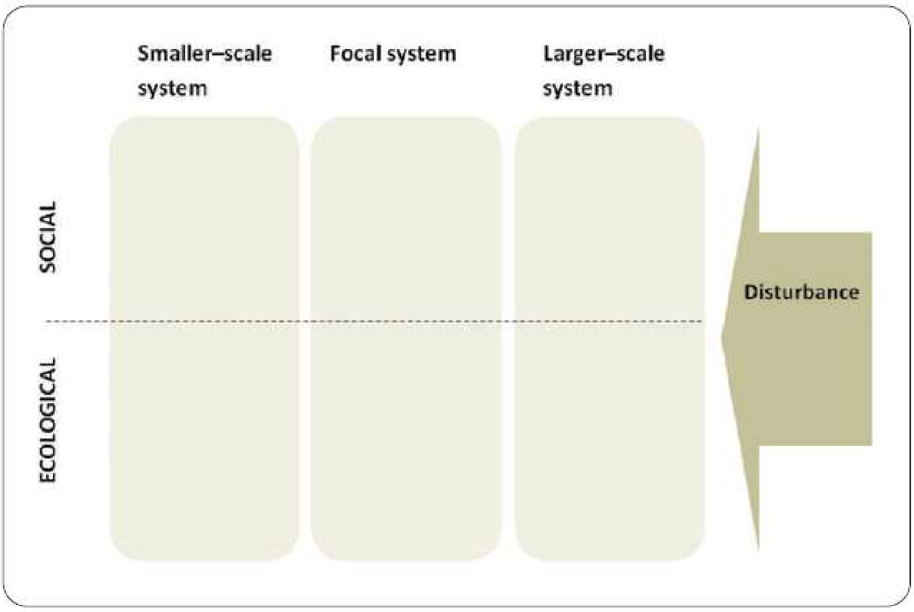

Figure A8. Template guide for a thresholds and interactions diagram (Source: Resilience Alliance, 2010).

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RAF as a basis for FoPIA-Surefarm

Also for the RAF, it was evaluated how components could be used for FoPIA-Surefarm.

Strengths of RAF are:

- The definition of the system, challenges and essential functions receive a lot of attention
- Links are made between elements/stakeholders in the system, challenges and essential functions
- A historical analysis is included
- The adaptive cycle is used
- Questions allow to define the 'identity' of the system, and identify alternative states
- Thresholds between alternative states are linked to slow driving variables (resilience attributes)
- A link is made between resilience capacities and resilience attributes, considering specified resilience
- A distinction is made between specified and general resilience: attributes like diversity, openness, tightness of feedbacks, system reserves and modularity are thought to contribute to general resilience, but there may be trade-offs with specified resilience.
- Cross-scale interactions are considered. In SURE-Farm, the farming system is the focal system, but many assessments will be made at the farm level, and some at the higher level, so links are relevant to consider. Also adaptive cycles in agricultural production, farm demographics and governance should be linked

Limitations of RAF are:

- Almost all assessments include open questions without an overview of f.e. challenges or essential functions, which may make it difficult to compare case studies
- Assessments are mainly qualitative
- Focus is on resilience, while little attention is given to sustainability
- No scenario assessments are included
- The govervance system section is relatively short. In SURE-Farm, we expect the Resilience Assessment Wheel in WP4 to take this up
- The assessment takes a lot of time, and needs to be structured in multiple workshops and interviews

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The 'system dynamics' approach of the University of Bergen

Participatory input to system dynamic modelling

The University of Bergen has been using the system dynamics approach to assess the resilience of systems (Herrera, 2017). A participatory model-based approach to resilience (Walker et al., 2002) has been used to structure the assessment: 1) Problem structuring process (resilience of what and for whom?), 2. Vision and scenarios (resilience to what?), 3. Model development, 4. Policy alternatives (leverage points, scenarios, trade-offs and impacts).

In the problem structuring process, stakeholders participated in developing the causal loop diagram (Figure A9).

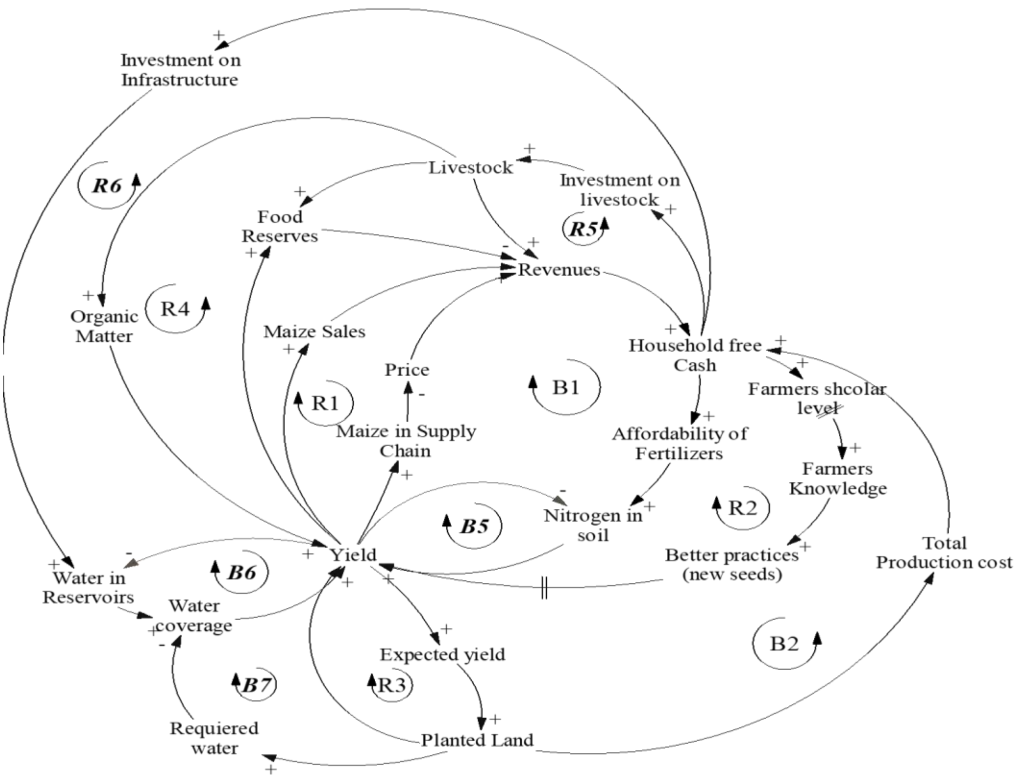

Figure A9 Example causal loop diagram, linking drivers (challenges) and indicators (essential functions). R and B refer to different feedback loops.

The causal loop diagram was used to identify the main indicators for developing a vision and scenarios. For these indicators their historical development, baseline scenarios and targets for the future were sketched (Figure A10).

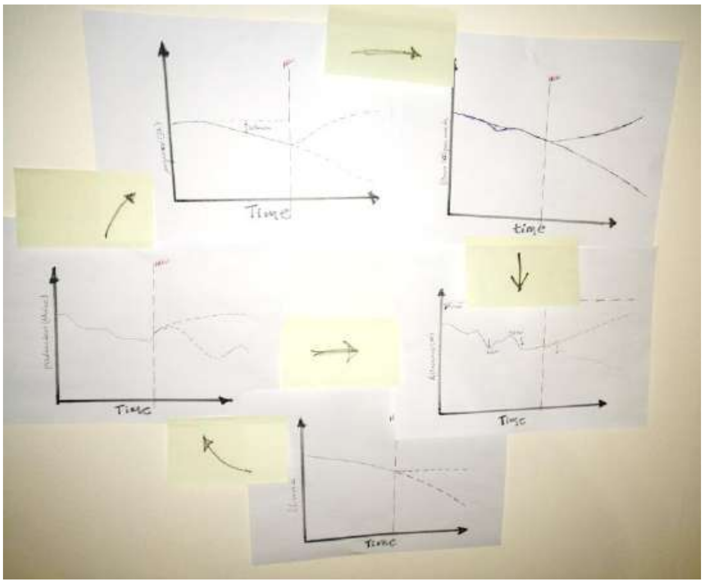

Figure A10. Sketches of stakeholders on past and future development of five main indicators.

The causal chain diagram and the sketched developments of main indicators were input for a simulation model. The model was used to simulate alternative policy alternatives and implications. The baseline scenario and multiple policy alternatives were assessed based on five resilience capacities/attributes: hardness, recovery rapidity, robustness, elasticity, index of resilience.

Systems dynamic approach as a basis for FoPIA-Surefarm

Strengths of the participatory system dynamics approach are:

- The causal loop diagram allows to identify all interactions between drivers and indicators.
- Causal loop diagrams allow to assess consistency in causal relationships.
- Participatory input is provided in the development of the main indicators, including the dynamics. Similar input was asked for in RAF, but the information is included in tables instead of graphs.

Limitations of the participatory system dynamics approach are:

- While FoPIA performs a semi-quantitative assessment of the impact of a strategy on all indicators using scores between -3 and +3, participatory input here focuses only the sign of the impact.
- While insights from stakeholders on development of main indicators may be insightful, sketches may be very general, and need input (i.e., data) from researchers.

Appendix B. Checklist workshop requirements

Organizers

- One workshop leader
- Someone who makes minutes
- Someone who can process results in Excel during the workshops
- Optionally, 1-3 extra persons who can assist during the group exercises

Facility

It is important that a good facility is found to host the workshop. In terms of food and drinks, it is advised to have coffee and tea and something to eat available the whole day. A good lunch should be provided as well.

Materials

- Beamer
- Flipover
- Markers
- Pens
- Photo camera
- ...

Printed documents

- 30 x printed table scoring importance Essential functions (Cross ref Excel)
- 30 x printed table scoring importance Indicators (Cross ref Excel)
- 30 x printed table scoring performance Indicators (Cross ref Excel)
- 18 x printed empty graph for drawing dynamics of indicators
- 30 x printed table scoring strategies (Cross ref Excell)
- 30 x printed table scoring resilience attributes
- (30 x printed overview identified challenges)
- 30 x printed A4 with explanation of resilience attributes
- 30 x printed PowerPoint? (Cross ref Excel)
- ...

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Appendix C. Selecting participants

Guidelines

To ensure comparability between case-studies and to avoid bias as much as possible, it is key to have a good selection procedure of participants in the workshop.

- Make sure that participating farmers come from different places/villages in your case-study area.
- Make sure that from each farm type (D3.1, filled in in Excel-sheet 'P1 Farming System') farmers are present in the workshop.
- Make sure there is an appropriate balance among the participants with regard to gender (and age).
- Globally, stakeholders can be categorized into farmers, industry, government and ngo. The proportion of each group should be around 40, 20, 20 and 20% respectively.
- Participants from industry should come from as much different companies as possible.

Tips to get participants on board

- Participate in meetings in the case-study area that are organized by other organizations.
  - Get to know the organizers.
  - Get contact details of participants.
- When interviewing farmers for other deliverables in SURE-Farm you can approach them for this workshop.

Appendix D. Explanation resilience attributes

Cabell and Oelofse (2012) explain their resilience attributes (indicators in their vocabulary) in a table providing 1) references, 2) definitions, 3) the implications for the system and 4) characteristics to look for to be able to recognize the resilience attributes (Table A4).

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Indicator (sources)	Definition	Implications	What to look for
Socially self-organized (Levin 1999, Holling 2001, Milestad and Darnhofer 2003, Atwell et al. 2010, McKey et al. 2010)	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 and consumers are able to organize into grassroots networks and institutions such as co-ops, farmer's markets, community sustainability associations, community gardens, and advisory networks
Ecologically self-regulated (Sundkvist et al. 2005, Ewell 1999, Jackson 2002, Swift et al. 2004, Jacke and Toensmeier 2005, Glover et al. 2010, McKey et al. 2010)	Ecological components self-regulate via stabilizing feedback mechanisms that send information back to the controlling elements	A greater degree of ecological self-regulation can reduce the amount of external inputs required to maintain a system, such as nutrients, water, and energy	Farms maintain plant cover and incorporate more perennials, provide habitat for predators and parasitoids, use ecosystem engineers, and align production with local ecological parameters
Appropriately connected (Axelrod and Cohen 1999, Holling 2001, Gunderson and Holling 2002, Picasso et al. 2011)	Connectedness describes the quantity and quality of relationships between system elements	High and weak connectedness imparts diversity and flexibility to the system; low and strong impart dependency and rigidity	Collaborating with multiple suppliers, outlets, and fellow farmers; crops planted in polycultures that encourage symbiosis and mutualism
Functional and response diversity (Altieri 1999, Ewell 1999, Berkes et al. 2003, Luck et al. 2003, Swift et al. 2004, Folke 2006, Jackson et al. 2007, Di Falco and Chavas 2008, Moonen and Barbieri 2008, Chapin et al. 2009, Darnhofer et al. 2010*b*, McIntyre 2009)	Functional diversity is the variety of ecosystem services that components provide to the system; 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	Heterogeneity of features within the landscape and on the farm; diversity of inputs, outputs, income sources, markets, pest controls, etc.
Optimally redundant (Low et al. 2003, Sundkvist et al. 2005, Darnhofer et al. 2010*b*, Walker et al. 2010)	Critical components and relationships within the system are duplicated in case of failure	Also called response diversity; 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	Planting multiple varieties of crops rather than one, keeping equipment for various crops, getting nutrients from multiple sources, capturing water from multiple sources
Spatial and temporal heterogeneity (Alcorn and Toledo 1998, Devictor and Jiguet 2007, Di Falco and Chavas 2008)	Patchiness across the landscape and changes through time	Like diversity, spatial heterogeneity provides seeds of renewal following disturbance; through time, it allows patches to recover and restore nutrients	Patchiness on the farm and across the landscape, mosaic pattern of managed and unmanaged land, diverse cultivation practices, crop rotations
Exposed to disturbance (Gunderson and Holling 2002, Berkes et al. 2003, Folke 2006)	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"	Pest management that allows a certain controlled amount of invasion followed by selection of plants that fared well and exhibit signs of resistance
Coupled with local natural capital (Ewell 1999, Milestad and Darnhofer 2003, Robertson and Swinton 2005, Naylor 2009, Darnhofer et al. 2010*a*,*b*, van Apeldoorn et al. 2011)	The system functions as much as possible within the means of the bioregionally 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	Builds (does not deplete) soil organic matter, recharges water, little need to import nutrients or export waste

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Indicator (sources)	Definition	Implications	What to look for
Reflective and shared learning (Berkes et al. 2003, Darnhofer et al. 2010*b*, Milestad et al. 2010, Shava et al. 2010)	Individuals and institutions learn from past experiences and present experimentation to anticipate change and create desirable futures	The more people and institutions can learn from the past and from each other, and share that knowledge, the more capable the system is of adaptation and transformation, in other words, more resilient	Extension and advisory services for farmers; collaboration between universities, research centers, and farmers; cooperation and knowledge sharing between farmers; record keeping; baseline knowledge about the state of the agroecosystem
Globally autonomous and locally interdependent (Milestad and Darnhofer 2003, Walker et al. 2010, van Apeldoorn et al. 2011)	The system has relative autonomy from exogenous (global) control and influences and exhibits a high level of cooperation between individuals and institutions at the more local level	A system cannot be entirely autonomous but it can strive to be less vulnerable to forces that are outside its control; local interdependence can facilitate this by encouraging collaboration and cooperation rather than competition.	Less reliance on commodity markets and reduced external inputs; more sales to local markets, reliance on local resources; existence of farmer co-ops, close relationships between producer and consumer, and shared resources such as equipment
Honors legacy (Gunderson and Holling 2002, Cumming et al. 2005, Shava et al. 2010, van Apeldoorn et al. 2011)	The current configuration and future trajectories of systems are influenced and informed by past conditions and experiences	Also known as path dependency, this relates to the biological and cultural memory embodied in a system and its components	Maintenance of heirloom seeds and engagement of elders, incorporation of traditional cultivation techniques with modern knowledge
Builds human capital (Buchmann 2009, Shava et al. 2010, McManus et al. 2012)	The system takes advantage of and builds "resources that can be mobilized through social relationships and membership in social networks" (Nahapiet and Ghoshal 1998:243)	Human capital includes: constructed (economic activity, technology, infrastructure), cultural (individual skills and abilities), social (social organizations, norms, formal and informal networks)	Investment in infrastructure and institutions for the education of children and adults, support for social events in farming communities, programs for preservation of local knowledge
Reasonably profitable	The segments of society involved in agriculture are able to make a livelihood from the work they do without relying too heavily 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; agriculture sector does not rely on distortionary subsidies

Table A4: Overview of attributes as proposed by Cabell & Oelofse (2012), including their definitions, implications and characteristics.

(i) socially self-organised networks of e.g. farmers and the processing industry who organized themselves such that they can timely react to challenges in an appropriate way.

(ii) ecological self-regulation, e.g. by farmers maintaining plant cover and incorporating more perennials,

(iii) appropriately connected, e.g. crops planted in polycultures and collaboration between chain actors;

(iv) functional and response diversity, e.g. by heterogeneity within landscapes and farms;

(v) optimal redundancy, i.e. planting multiple varieties of crops, keeping equipment for various crops, and retrieving nutrients from multiple sources;

(vi) spatial and temporal diversity, e.g. by a mosaic pattern of managed and unmanaged land and diverse cultivation practices;
(vii) exposed to disturbance, dealt with by e.g. pest management and positive selection;
(viii) coupled with local natural capital, e.g. by not depleting soil organic matter, and little need to import nutrients or export waste;
(ix) reflective and shared learning, e.g. by record keeping and knowledge sharing between farmers;
(x) globally autonomous and locally interdependent, e.g. by less reliance on commodity markets and reduced external inputs, more reliance on local markets, and shared resources such as equipment;
(xi) honors legacy, e.g. by incorporating traditional cultivation techniques with modern knowledge;
(xii) building human capital, e.g. by investing in infrastructure for education, and support for social events in farming communities,
(xiii) reasonably profitable, implying that farmers and farm workers earn a liveable wage, and the agricultural sector does not rely on distortionary subsidies.

In FoPIA-Surefarm the list with original attributes as proposed by Cabell & Oelofse (2012) is extended by splitting up original attributes (italic in Table A5) and adding new attributes and explanations (bold in Table A5) based on the research focus and the resilience research framework of SURE-Farm (Meuwissen et al. 2018 ; Table A5). For the sake of workability during the workshop, only 13 attributes are selected to be evaluated in the workshops (in green).

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Resilience attribute	**Definition**	**Implications**	**Characteristics**	**Link with resilience principle(s)**	**Link with SURE-Farm process(es)**
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 liveable wage; agriculture sector does not rely on distortionary subsidies	**System reserves (financial capital)**	**Agricultural production, risk management**
Coupled with local and natural capital **(production)**	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	Builds or maintains soil fertility, recharges water resources, little need to import nutrients or export waste	**System reserves (natural capital)**	**Agricultural production**
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*	*Diversity of inputs, outputs, income sources, markets, etc.*	**Diversity**	**Risk management**
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*	***Diversity of risk management strategies**, e.g. different pest controls, **weather insurance, flexible payment arrangements.***	**Diversity**	**Risk management**
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"	Pest management that allows a certain controlled amount of invasion followed by selection of plants that fared well and exhibit signs of resistance	**Openness**	**Risk management**
Spatial and temporal heterogeneity **(farm types)**	Patchiness across the landscape and changes through time	Like diversity, spatial heterogeneity provides seeds of renewal following disturbance	**Diverse farm types with regard to economic size, intensity, orientation and degree of specialisation.**	**Modularity, diversity**	**Farm demographics, risk management**
*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 stop without endangering continuation of the farming system and new farmers can enter the farming system easily***	**Modularity**	**Farm demographics; risk management** ***Table A5 continues on the next page***

Resilience attribute	Definition	Implications	Characteristics	Link with resilience principle(s)	Link with SURE-Farm process(es)
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.**	**A balanced population with young, intermediate and older people; Enough facilities in the nearby area to maintain an adequate standard of life.**	**System reserves (human capital)**	**Farm demographics**
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, farmer's markets, community sustainability associations, and advisory networks	**Tightness of feedbacks, system reserves (social capital)**	**Governance**
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 level**	**Tightness of feedbacks**	**Governance**
Coupled with local and natural capital **(legislation)**	**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 framework adapted to the local conditions**	**System reserves (social capital)**	**Governance, agricultural production**
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.**	**Infrastructure that allows new ways of agricultural production and improved information flows e.g. allowing track and trace of agricultural products throughout the value chain.**	**Openness, system reserves**	**Governance, agricultural production**
Diverse policies	**Policies stimulate all three capacities of resilience, i.e. robustness, adaptability, transformability**	**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 that create a stable and safe environment in which experimentation and structural change for more sustainable agriculture is supported.**	**Diversity**	**Governance** ***Table A5 continues on the next page***

Resilience attribute	Definition	Implications	Characteristics	Link with resilience principle(s)	Link with SURE-Farm process(es)
Ecologically self-regulated	Ecological components selfregulate via stabilizing feedback mechanisms that send information back to the controlling elements	A greater degree of ecological self-regulation can reduce the amount of external inputs required to maintain a system, such as nutrients, water, and energy	Farms maintain plant cover and incorporate more perennials, provide habitat for predators and parasitoids, use ecosystem engineers, and align production with local ecological parameters	**Tightness of feedbacks**	**Agricultural production**
*Optimally redundant **(crops)***	*Critical components and relationships within the system are duplicated in case of failure*	*Also called response diversity; 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*	*Planting multiple varieties per crop rather than one, keeping equipment for various crops*	**Modularity**	**Risk management**
*Optimally redundant **(nutrients&water)***	*Critical components and relationships within the system are duplicated in case of failure*	*Also called response diversity; 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*	*Getting nutrients and water from multiple sources.*	**Modularity**	**Risk management**
Spatial and temporal heterogeneity **(land use)**	Patchiness across the landscape and changes through time	Like diversity, spatial heterogeneity provides seeds of renewal following disturbance; through time, it allows patches to recover and restore nutrients	Diverse land use on the farm and across the landscape, mosaic pattern of managed and unmanaged land, diverse cultivation practices, crop rotations	**Modularity, diversity**	**Risk management**
*Optimally redundant **(labour)***	*Critical components and relationships within the system are duplicated in case of failure*	*Also called response diversity; 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*	***Labour comes from multiple sources***	**Modularity**	**Risk management; Farm demographics**
Globally autonomous and locally interdependent	The farming system has relative autonomy from exogenous control and influences and inhibits a high level of cooperation between individuals and institutions at the more local level	A system cannot be entirely autonomous but it can strive to be less vulnerable to forces that are outside its control; local interdependence can facilitate this by encouraging collaboration and cooperation rather than competition.	Less reliance on commodity markets and reduced external inputs; more sales to local markets, reliance on local resources; existence of farmer co-ops, close relationships between producer and consumer, and shared resources such as equipment	**Openness, tightness of feedbacks**	**Governance, risk management** ***Table A5 continues on the next page***

Resilience attribute	Definition	Implications	Characteristics	Link with resilience principle(s)	Link with SURE-Farm process(es)
Reflective and shared learning	Individuals and institutions learn from past experiences and present experimentation to anticipate change and create desirable futures	The more people and institutions can learn from the past and from each other, and share that knowledge, the more capable the system is of adaptation and transformation, in other words, more resilient.	Extension and advisory services for farmers; collaboration between universities, research centres, and farmers; cooperation and knowledge sharing between farmers; record keeping; baseline knowledge about the state of the agroecosystem	**Opennes**	**Governance**
Honours legacy	The current configuration and future trajectories of systems are influenced and informed by past conditions and experiences	Also known as path dependency, this relates to the biological and cultural memory embodied in a system and its components	Maintenance of old varieties and engagement of elders, incorporation of traditional cultivation techniques with modern knowledge	**Systems reserves (social capital)**	**Governance**
Builds human capital	The farming system takes advantage of and builds resources that can be mobilized through social relationships and membership in social networks	Human capital includes: constructed (economic activity, technology, infrastructure), cultural (individual skills and abilities), social (social organizations, norms, formal and informal networks)	Investment in infrastructure and institutions for the education of children and adults, support for social events in farming communities, programs for preservation of local knowledge	**Systems reserves (human capital)**	**Governance**

Table A5 : Attribute list based on Cabell & Oelofse (2012) and Meuwissen et al. (2018). Italic font indicates that these attributes are split up into two attributes with reference to the original attribute in Cabell & Oelofse (2012). Bold font indicates that the information is based on Meuwissen et al. (2018). Green font indicates that these attributes are selected to be evaluated during the FoPIA-Surefarm workshop.

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