Project acronym: SURE-Farm
Project no.: 727520

Start date of project: June 2017
Duration: 4 years

Guidelines for FoPIA-SURE-Farm 2: future resilience

Work Performed by P1, Wageningen University

Wim Paas, Pytrik Reidsma

(Wim Paas; wim.paas@wur.nl)

Due date	31/May/2020 (part of D5.5)
Version/Date	Final 27/May/2020
Work Package	WP5
Task	T5.3
Task lead	INRAE
Dissemination level	Public

D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

Contents

Please cite this report as:

Paas, W., Reidsma, P., 2020, ‘Guidelines for FoPIA-SURE-Farm 2: future resilience’. In: Accatino, et al. D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods. Sustainable and resilient EU farming systems (SURE-Farm) project report.

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

1 Introduction

These guidelines extend the FoPIA-SURE-Farm approach by providing results of participatory assessments on future resilience of EU farming systems (FoPIA-SURE-Farm 2). In a previous deliverable of SURE-Farm, current sustainability and resilience was assessed (D5.2; Paas *et al.*, 2019), using the Framework of Participatory Impact Assessment for Sustainable and Resilient EU farming systems (FoPIA-SURE-Farm 1; Reidsma *et al.*, 2019). FoPIA-SURE-Farm 1 included the five steps of the SURE-Farm resilience framework (Meuwissen et al., 2019): 1) defining the system, 2) identifying main challenges, 3) assessing current farming system functions, 4) assessing resilience capacities (robustness, adaptability and transformability), and 5) assessing resilience attributes (system characteristics that supposedly convey resilience to a system). While continuing being embedded in the theoretical resilience framework of SURE-Farm (Meuwissen et al., 2019), FoPIA-SURE-Farm 2 aims to include resilience concepts as critical thresholds or tipping points, cascading scales (e.g. Kinzig *et al.*, 2006), and regime shifts (e.g. Biggs et al., 2018), which were not explicitly taken into account in FoPIA-SURE-Farm 1.

System resilience relates to system dynamics and hence changes over time. As a consequence, not only the past and current, but also the future needs to be considered. Scenario research shows that there are different pathways of development towards the future (e.g. D1.2; Mathijs *et al.*, 2018). Along these future pathways, systems' functioning can change, and critical thresholds could be trespassed, possibly initiating cascading scales (Kinzig et al., 2006). This could lead to a different system with a changed identity, dependent on the scenario. Consequently, for future resilience, different futures need to be explored.

In general, extrapolations of statistical models to explore the future only show a limited part of all possible futures, based on patterns from the past. Systems dynamics modelling (e.g. Herrera, 2017; Chapter 4) can take into account multiple pathways towards the future, but is dependent on input from other methods for parameterization and structuring of the model(s). Moreover, currently available models are not excelling in modelling transformative change, e.g. simulating trajectories to alternative desired systems. Participatory methods can integrate multiple future pathways (Delmotte et al., 2013; Walker et al., 2002) and to a limited extent can also include resilience concepts such as critical thresholds (Resilience Alliance, 2010; Walker et al., 2002).

Stakeholders may provide empirical knowledge about their system (Delmotte et al., 2013) that can fill in knowledge gaps (Vaidya and Mayer, 2014). Stakeholder input will be influenced by stakeholder's perceptions, which partly can also explain or drive system dynamics as stakeholders are important components of socio-ecological systems (Walker et al., 2002). However, it should be kept in mind that stakeholder inputs are based on different perceptions than for instance researchers' perceptions, indicating that both perceptions should be used in complementary ways (e.g. Sieber et al., 2018). Hence, participatory methods can provide a first exploration of farming system resilience in possible futures. Participatory methods also provide an opportunity to assess whether current strategies for more sustainability and resilience make sense in the light of expected future developments.

In Section 2 of these guidelines, the theoretical background and main research question are presented. Section 3 explains in detail the FoPIA-SURE-Farm 2 methodology for assessing future resilience and how it should be applied in the case studies. Section 4 provides information on how to report workshop results. We expect the workshops regarding future resilience to be held in autumn/winter of 2019/2020. Results from the workshops will be synthesized in D5.5 on future resilience and D5.6 on future scenarios and resilience-enhancing strategies.

2 FoPIA-SURE-Farm 2 approach

2.1 Resilience framework

The resilience framework used for FoPIA-SURE-Farm 2 is based on Meuwissen et al. (2019; Figure 1). The different steps in Figure 1 are amongst others detailed in Meuwissen et al. (2019) and Reidsma *et al.* (2019). For assessing current sustainability and resilience, main research questions in FoPIA-SURE-Farm 1 followed the five steps of the resilience framework (Figure 1). For assessing future resilience, the main research questions address multiple steps at once. However, sub-questions of each main research question relate directly to only one of the steps of the resilience framework.

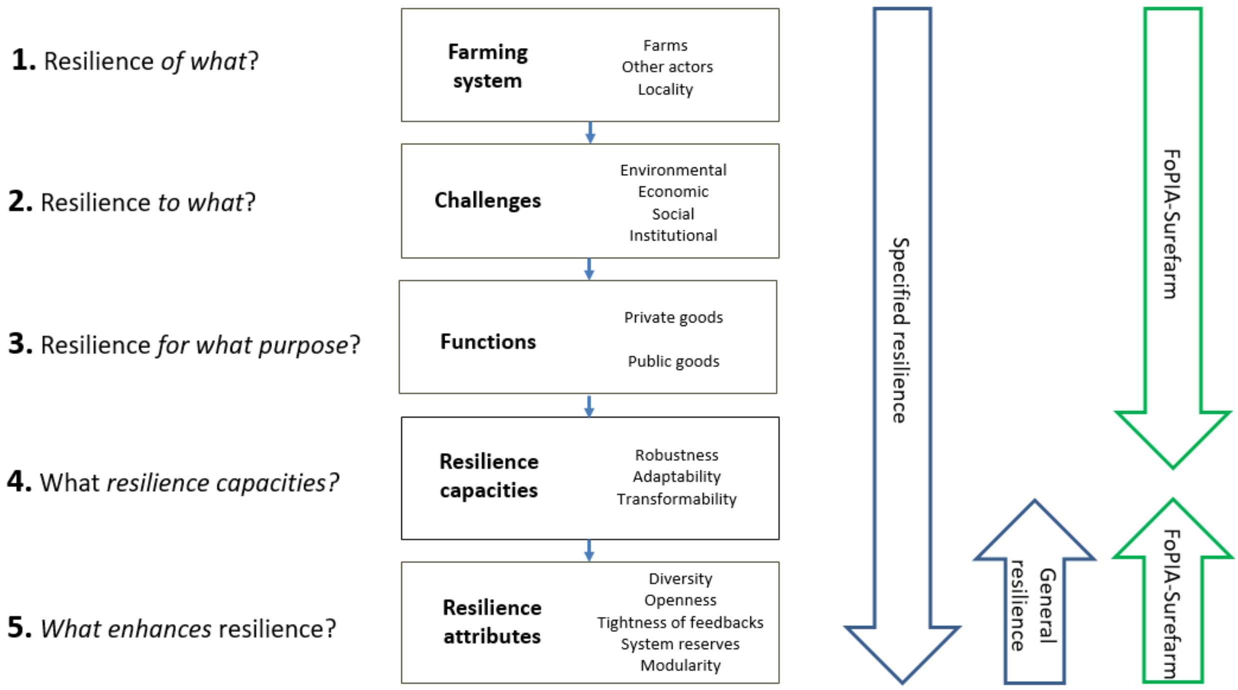

Figure 1. Framework to analyze the resilience of farming systems, including resilience capacities and attributes. Source: adapted from Meuwissen et al. (2019).

FoPIA-SURE-Farm 2 is inspired by the work of Kinzig *et al.* (2006) and Biggs et al. (2018). Both sources have in common that they aim to present evidence for (potential) system transformation in a narrative way, with support of a visualization of interactions between important system parameters.

Biggs et al. (2018) mainly elaborate on transformations of the ecological part of social-ecological systems. Biggs et al. (2018) use a causal loop diagram (CLD) to support narratives of system transformations. In a CLD, system parameters are presented by boxes that are connected with each other by arrows that represent interactions. A '+' or '-' indicates whether an interaction is seen as positive or negative, i.e. whether an increase in one parameter results in an increase or decrease of another parameter. In a CLD, multiple interactions can form closed loops that provide either reinforcing (positive) or balancing (negative) feedback. The increase of a certain challenge may increase emphasis on certain feedback loops, explaining a change in system performance and identity.

Kinzig et al. (2006) specifically assess critical thresholds and cascading scales for alternative future states of agricultural regions. Kinzig et al. (2006) distinguish the ecological, as well as the economic and social/cultural domain across the patch, farm and region scale. Thresholds of systems parameters can interact across domains and levels of integration (Kinzig *et al.*, 2006; Figure 2). This might result in cascading effects and ultimately in alternative system states. The framework of Kinzig et al. (2006) can be seen as an abstract of a usually information richer CLD. The advantage of the framework of Kinzig et al. (2006) is that main thresholds and changes can be well qualified and visualized, where in a CLD it is not directly clear where and in which direction system changes occur. In FoPIA-SURE-Farm 2, the possibility of cascading scales will be evaluated. Critical thresholds will be mainly evaluated for system challenges, but where necessary also for system indicators and resilience attributes.

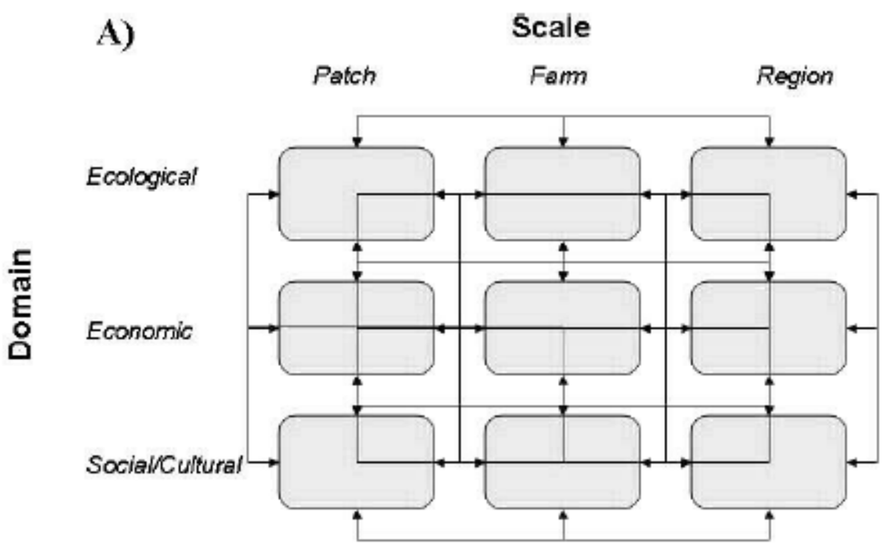

Figure 2. A visualization of possible threshold interactions between domains and scales. Source: Kinzig et al. (2006).

2.2 Structure and expected outcomes

FoPIA-SURE-Farm 2 includes a preparation phase, the workshop and an evaluation phase. The preparation phase and evaluation phase are conducted by the research team. In the preparation phase, research teams will make use of SURE-Farm deliverables and (grey) literature. We consider scenarios and adaptive cycles too complicated and too time-consuming to communicate during a workshop. Hence, we designed main research questions that we think of as being easy to understand and directly relevant for participants in the workshops. So, while the full approach covers the complexity of resilience (including causal loop diagrams, cascading scales, future scenarios), this complexity is largely covered by the research teams. The stakeholder workshops are set up in such a way that they contribute to understanding complexity, but the stakeholders will not be tired out by this complexity.

It is generally difficult to assess transformation and transformability with quantitative models (D5.1; Herrera *et al.*, 2018). FoPIA-SURE-Farm 2 allows to improve understanding on transformation and transformability. It should however be noted that towards the stakeholders a neutral approach is taken regarding their current farming system. The workshop should assist them to better understand the challenges affecting their current system, and strategies to improve the current system, or if desired, to transform to an alternative system.

2.3 Research questions

As the point of departure, the case study research teams will conduct an assessment of the current performance levels and trends in the farming systems. This assessment will be based on FoPIA-SURE-Farm 1 (Paas et al., 2019), other SURE-Farm deliverables and (grey) literature. Under RQ2, the boundary conditions will be assessed to keep the current system as desired in the future (maintaining status quo). This will include taking into account current trends and required improvements in function performance. Under RQ2, critical thresholds of important system indicators, resilience attributes and challenges will be assessed by workshop participants. System's closeness to thresholds will consequently be evaluated by the research team based on participant's comments and (grey) literature, e.g. based on ongoing trends identified under RQ1. Third, farming system performance will be assessed when critical thresholds of main challenges would be exceeded (RQ3; system decline). Under RQ3, possibilities of cascading effects could be discussed. After discussing the conditions for maintaining the status quo and system decline, RQ4 will address possible desired transformations of the farming system towards the future. Under RQ4, it will be discussed what alternatives are possible when challenges would become more severe, and when certain functions would need more improvement than possible with the current system configuration.

RQ5 aims to gain information on whether the right investments were currently made and the possibilities of no regret options, regardless the direction of future pathways.

Main Research Questions (RQ):

1. What are the current performance levels and trends of main indicators, resilience attributes and challenges of the farming system?
2. What is required to keep the current farming system in the future? (i.e. what boundary conditions need to be in place and what critical thresholds should be avoided to maintain the status quo?)
3. What will happen if the essential requirements are not met? (system decline)
4. What are possible desired transformations of the farming system? (alternative systems)
5. Given the likelihood of future states, are current strategies dedicated to the right issues?
6. What are underlying mechanisms causing farming system dynamics?
7. Are maintaining the status quo and proposed alternative systems compatible with Eur-Agri-SSPs?

Based on the information acquired in RQ1-RQ5, research teams aimed to expose the underlying mechanisms that cause farming system dynamics (RQ6). This approach was inspired by the work of Kinzig *et al.* (2006) and Biggs et al. (2018). Both sources have in common that they aim to present evidence for (potential) system transformation in a narrative way, with support of a visualization of interactions between important system parameters. Under RQ7, proposed alternative systems were evaluated for compatibility with Shared Socio-economic Pathways (SSPs; O'Neill *et al.*, 2014, 2017) for European agricultural systems (Eur-Agri-SSPs; Mitter et al., 2019; under review).

In Section 3, main research questions and sub-questions will be explained in more detail, including linkages to the resilience framework (Figure 1). Note that Figure 1 will not be presented during the workshop, but is used as framework for the researchers.

3 Guidelines for stakeholder workshop on future resilience

3.1 Introduction to stakeholder workshop

The stakeholder workshop is designed to take half a day (Table 1). The workshops mainly consists of plenary and small group discussions. Participants from the agricultural community, processing industry, government and NGO's are invited. In the next section, the research questions are explained and elaborated. Were possible, a link with the resilience framework (Figure 1) is provided by indicating the step of the framework that is addressed (e.g. "Step 2" when it is related to identifying challenges). The total time is 3 hours and 15 minutes, excluding breaks. A tentative program for the workshop could be:

12.00-12.40: lunch

12.40-14.15: RQ2 & RQ3 Status quo and system decline

14.15-14.30: break

14.30-16.00: RQ4 & RQ5 Alternative systems and strategies

16.00: drinks and closing discussion

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

*Table 1. Schedule for FoPIA-SURE-Farm 2, including the preparation phase, the workshop and the evaluation phase. *RQ refers to research question, R to researchers, S to stakeholders, I to individuals, G to small groups and P to plenary. Table continues on the next page*

Phase	Step/RQ*	Activities	How: who*	Duration	Timing
Preparation	RQ1	Make an overview of results from FoPIA-SURE-Farm 1 regarding functions, challenges, and resilience attributes	R		
	RQ1,2	Identify main characteristics of current system	R		
	RQ 3	Make an inventory of alternative systems that participants may propose during the workshop	R		
	RQ4	List identified strategies	R		
	RQ6	Create a causal loop diagram to draw interactions between challenges, indicators and attributes	R		
	RQ3,6	Include elements of possible future states in the causal loop diagram	R		
	RQ4,6	Include strategies in the causal loop diagram	R		
Workshop	Lunch	Provide a lunch to the participants		50	12.00
	Welcome and introduction round	Welcome participants and let them introduce themselves to the groups (name, organization, reason for attending the workshop)	P: R,S	15	12.45
	Introduction	Use PowerPoint template to give an introduction to the workshop, explain also the concepts of robustness, adaptability and transformability	P: R	15	13.00
	Feedback previous workshop	Show main results from the previous workshop	P: R	10	13.15
	RQ2	Ask all participants to write on post-its between what levels indicators should stay and which need improvement, and between what levels challenges should stay.	I: S	10	13.25
	RQ2	In a plenary session, evaluate between what levels indicators should stay and which low performing indicators should improve	P: S	10	13.35
	RQ2	Evaluate between what levels challenges should stay	P: S	15	13.45
	RQ3	In small groups, evaluate per challenge how main indicators and resilience attributes of the system will perform in 2030 when thresholds are exceeded.	G: S	15	14.00

Phase	Step/RQ*	Activities	How: who*	Duration	Timing
	RQ3	Moderators present outcomes of small group discussions in 1-minute pitches.	P: R	10	14.15
	Break			15	14.25
	RQ4	Ask all participants to write on post-its one alternative	I: S	10	14.40

		state they desire if challenges cross thresholds and/or functions need improvement			
	RQ4	In a plenary session make an inventory on which alternative systems could be realized towards 2030.	P: S	10	14.50
	RQ4	In small groups, stakeholders discuss one alternative system with regard to indicators, attributes, boundary conditions and strategies.	G: S	30	15.00
	RQ4	Moderators present outcomes of small group discussions.	P: R	20	15.30
	RQ5	Present the prepared list with strategies based on D5.2 and D5.3 and the list with strategies based on RQ3.	P: R	10	15.50
	RQ5	Check whether there is a shared vision for the farming system or not and discuss what strategies are needed to realize alternative systems.	P: R,S	20; during drinks	16.00
	RQ5	*Optional: invite participants to individually score the desirability and likelihood of the different alternative states.*	*I: S*	*During drinks*	
Evaluation	RQ1,2	Document the characteristics of current state, future state of current system, and associated thresholds	R		
	RQ2	Evaluate how close the system is to critical thresholds	R		
	RQ3	Evaluate performance when critical thresholds of challenges are exceeded	R		
	RQ4	Document and finalize alternative systems	R		
	RQ4	Evaluate resilience of future systems	R		
	RQ4	Evaluate whether future systems are adaptations/transformations	R		
	RQ5	Determine whether strategies are dedicated to the right issues	R		
	RQ6	Update causal loop diagram and use it to explain possible transformations	R		
	RQ6	Synthesize interactions across scales and domains	R		
	RQ7	Link future systems to scenarios	R		
	Reporting	**Write a complete draft report within one month after the workshop**	R		

3.2 Status-quo

3.2.1 Introduction

At the end of the previous workshop, in which current sustainability and resilience was assessed, an overview of the current situation was perceived. Although the current situation was not the desired situation in all case-studies, it still is a good starting point for assessing future resilience. If some indicators do not perform at a desired level, they may need improvement in order to keep the current farming system. Studying the conditions that are needed to keep the current situation as desired in the future, provides a first possibility to identify critical thresholds. For instance, if drought is a challenge for a farming system, participants could be asked to assess how often the system can process events of drought without changing much in terms of system performance and characteristics. Critical thresholds mostly relate to slow variables in the farming system (Resilience Alliance, 2010).

3.2.2 Guiding questions

- RQ2. What is required to keep the system as desired in the future?
    1. Between what levels should indicators and resilience attributes stay to keep the same system, as desired? (Step 3 and 5)
    2. Are there low performing indicators and resilience attributes that should improve? (Step 3 and 5)
    3. Between what levels should challenges stay? (Step 2)

3.2.3 Preparation phase

Use the country report from D5.2 to make an overview of 1) the perceived importance and performance of functions and related indicators, 2) the main challenges, and 3) the level of the resilience attributes and their contribution to the resilience capacities. Use preparation sheet 1. Some figures and tables may be copy-pasted from D5.2. Gather ideas for units to express thresholds of indicators and challenges in Support sheet 1.

Kinzig et al. (2006) defined the current state of the farming system as the start of their analyses (Figure 3). Read Kinzig et al. (2006), and define the 'current state of the farming system' based on 1) the sector and/or dominant land use (e.g. arable), 2) the main indicators and their performance levels (using the 1-5 scoring from very low to very high), including important trends 3) most important attributes and their performance level (using the 1-5 score from very low to very high), including important trends and 4) if needed, other relevant characteristics. Evaluate expected developments (trends) in levels of indicators and resilience attributes by classifying trends in strong negative (↓), moderate negative (↘), no trend (→), moderate positive (↗) and strong positive trends (↑). Focus on indicators and resilience attributes that are important for the identity of the farming system, and which, when changed, imply a transformation of the farming system. Use preparation sheet 2.

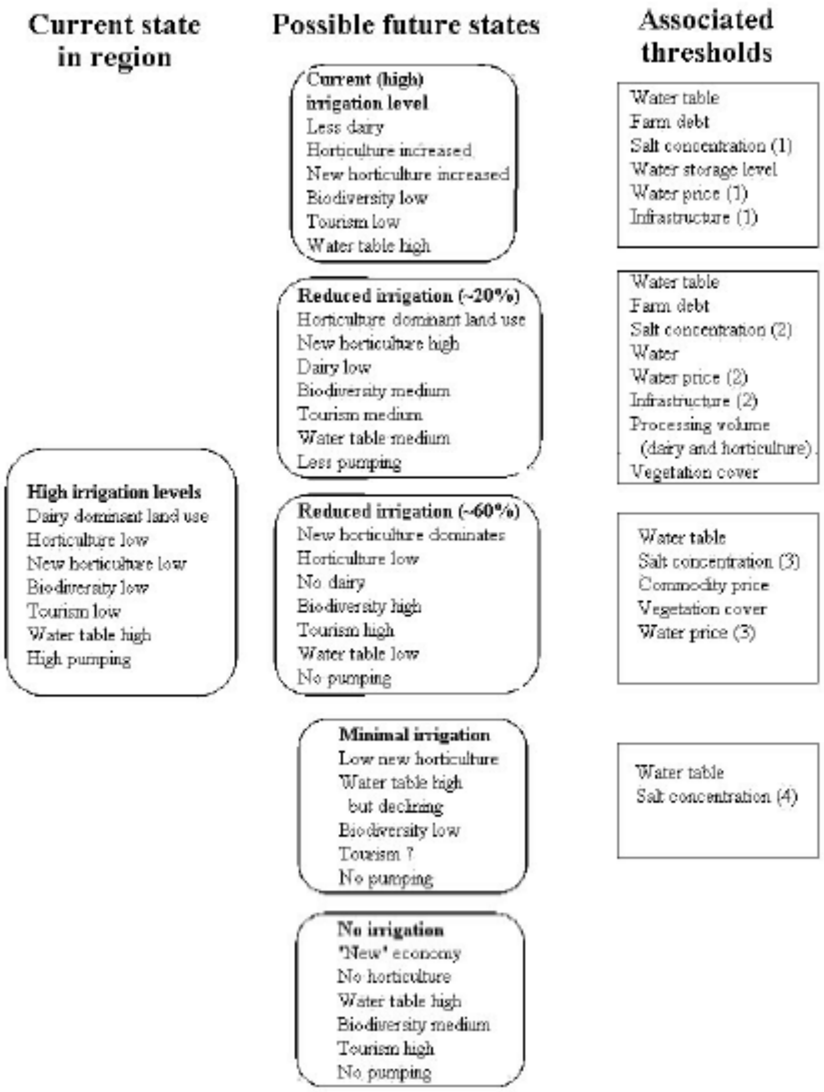

Figure 3. Definition of the current state and future states and associated thresholds for an agricultural region in Australia. Source: Kinzig et al. (2006).

3.2.4 Stakeholder workshop

Start with a presentation with the aims of the workshop (a template will be provided along with the guidelines), and a synthesis from the previous workshop. Explain also the concepts of robustness, adaptability and transformability. Invite participants to sign the “informed consent form” in the language as used in the workshop (a template in English will be provided).

Present the synthesis of the ‘current state of the farming system’ based on preparation sheet 2. Try not to get into a discussion, but ask all participants to first use post-its to note down their input. Ask them to indicate between which levels the most important indicators and resilience attributes should remain to allow continuation of the current system. These levels define the thresholds of the current state to remain as a possible future state (associated thresholds in Figure 3). Try to go beyond the scoring system of 1-5, i.e. in case a threshold level of 2 (poor) is given for a certain indicator, try to reveal what this level stands for. Use Support sheet 1 to provide ideas to participants in case they have problems finding the right units to express thresholds. Participants can focus on specific indicators or attributes if they want; this may also give an indication of the most relevant ones.

In addition, stakeholders use another set of post-its (different color), to indicate what this implies for the level of challenges. How much can challenges change before the levels of indicators and resilience attributes of the current faming system change beyond the identified thresholds? The maximum or minimum levels of challenges are the associated thresholds (Figure 3).

After 10 minutes, collect all post-its and group them on a board. In plenary, first discuss the levels of indicators and resilience attributes, and then the level of challenges. This should lead to a common understanding of the current system, performance levels and associated thresholds. If time is available, record the outcomes of discussions on worksheet 1 or do this in the evaluation phase. Ultimately, for the reporting, data from worksheet 1 will be summarized in Excel-sheet “Table 3 Report”.

Participants may already come up with strategies to avoid exceedance of critical thresholds. These strategies will be interpreted as being necessary to maintain the status quo towards 2030.

3.2.5 Evaluation phase

Document the feedback on main system indicators, resilience attributes and challenges. Evaluate how close the system is to (undesired) transformation, given its presence to the identified thresholds.

Based on comments of participants and (grey) literatures, the closeness to critical thresholds need to be evaluated based on the current performance levels, and magnitude of variation and/or trends of indicators, resilience attributes and challenges concerned. Closeness to critical thresholds is defined according to four categories:

Not close	It is unlikely that the distance to critical thresholds will be trespassed in the coming ten years, based on knowledge on possible variation and/or trends.

Somewhat close	It is somewhat likely that the distance to critical thresholds will be trespassed in the coming ten years, based on knowledge on possible variation and/or trends.
Close	It is likely that the distance to critical thresholds will be trespassed in the coming ten years, based on knowledge on possible variation and/or trends.
At threshold or beyond	Current levels are at or beyond the critical threshold

3.3 System decline

3.3.1 Introduction

Under the previous research question (RQ2), threshold levels for challenges were identified. In case conditions go beyond these threshold levels, the farming system is supposedly going to perform different. Dependent on which conditions change, farming system performance may change more or less. Under RQ3, the effect of going beyond critical thresholds on farming system performance will be assessed.

3.3.2 Guiding questions

- RQ3. What will happen if the essential requirements are not met?
    1. At what level will the indicators and resilience attributes perform? (Step 3 and 5)
    2. Are there interactions among and between challenges, main indicators and resilience attributes? (Step 2, 3 and 5)

3.3.3 Preparation phase

Synthesize results from the previous FoPIA-SURE-Farm 1 workshop regarding challenges and effects on main indicators and resilience attributes. The sketches of historical dynamics were done for main indicators, and main challenges associated to these were identified. In addition, other SURE-Farm deliverables can be used to develop cause-effect relationships among challenges, indicators and resilience attributes.

Create a causal loop diagram (CLD) to draw interactions that you expect between challenges and indicators and attributes. For consistency and comparability across case-studies, we will provide a basic CLD structure for arable, livestock and mixed systems that can be used as a basis to which case study specific elements can be added. Explain all connections in the CLD in Preparation Sheet 3. Indicate where the main feedback loops of your farming system are. For drawing the CLD you can use the freely available software Vensim PLE (https://vensim.com/freedownload/). Register yourself via the link and an email will be sent to you for downloading the software. Have a look at Appendix A for building a simple CLD.

For the case study on starch potato production in Veenkoloniën, the Netherlands (NL-starch potato) an example of a CLD is provided (Figure 4). In NL-starch potato, the decoupling of subsidies (Challenge; C) stimulated the local processor, a cooperative, to innovate to increase prices for farmers (Indicator; I). Fortunately, at that time there was a market demand for innovative starch potato products that further stimulated, and still stimulates, the innovation in the value chain, for instance extraction of protein for human consumption. Innovations for protein extraction can lead to new products that create new demands, e.g. protein for making vegan cheese with good melting properties. Thus, demand and innovation can reinforce each other (reinforcing feedback loop; R1 in Figure 4). For innovating, the local processing industry currently benefits from having larger supplies of starch potatoes (I). Inversely, a too small supply would limit the financial room for funding research and development for innovation. Current demand for starch potato products results in better farm gate prices (I), thus stimulating farmers to cultivate more area with potatoes (I), which safeguards supplies (reinforcing feedback loop; R2 in Figure 4). However, increasing the area with starch potatoes within the region, narrows the rotation plan and reduces diversity (Attribute; A), which generally increases the presence of harmful nematodes in the soil (C). More-over, potato is a relative intensive crop compared to cereals in terms of nutrients and crop protection products and at harvesting the top layer of the soil is disturbed. Consequently, a larger share of potatoes in the crop rotation reduces the soil quality (I). Increased nematode presence and reduced soil quality results in lower yields which reduce total supply of starch potatoes in the area. This is an example of a balancing feedback loop (B in Figure 4). Increased self-organization through land sharing between dairy and arable farmers (A) can help to widen crop rotations.

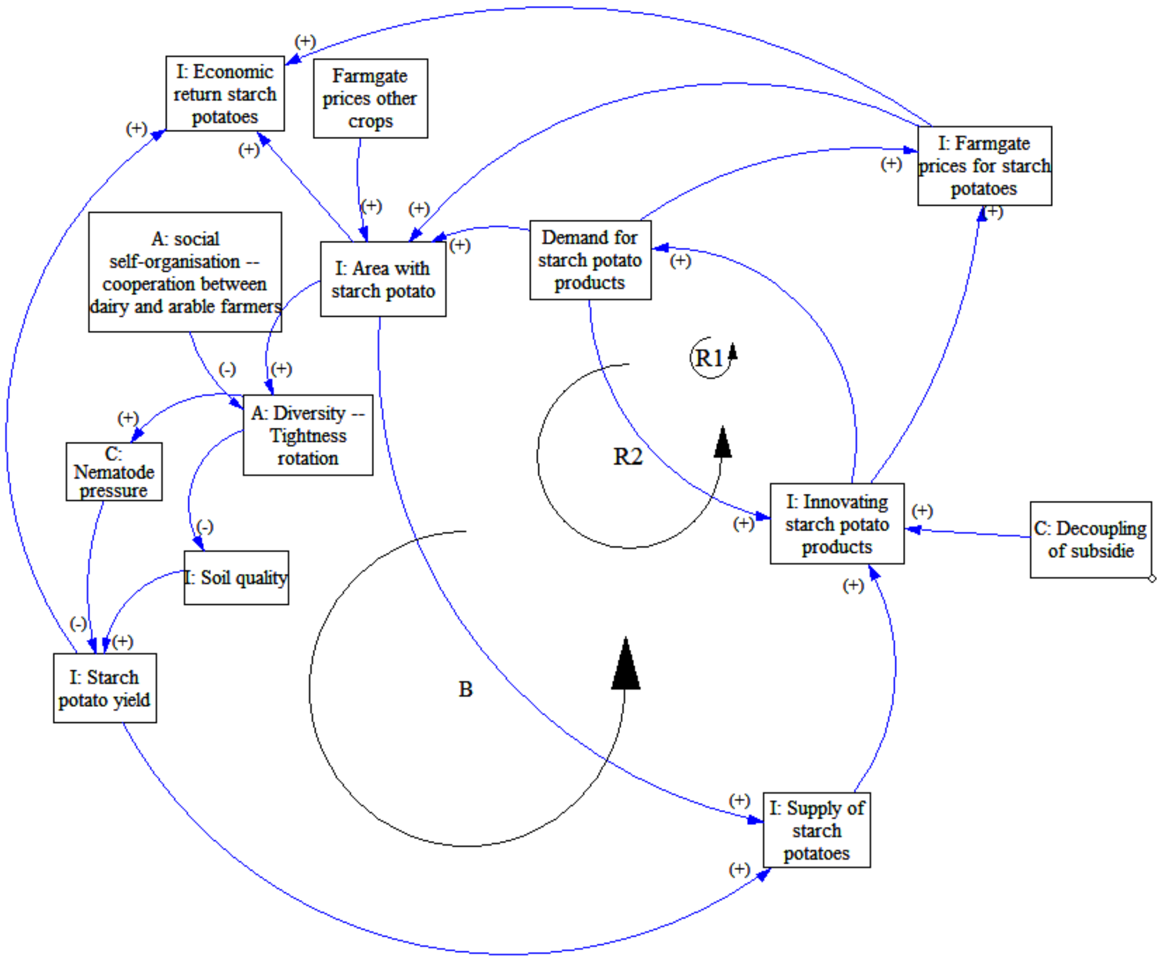

Figure 4. Example of a causal loop diagram covering main indicators, challenges and resilience attributes of the case study on starch potato production in Veenkoloniën, The Netherlands. B and R stand respectively for a balancing and reinforcing feedback loop. I, A and C stand respectively for specific system indicators, attributes and challenges.

3.3.4 Stakeholder workshop

Main challenges should be identified after RQ2 (but also based on the preparation phase; RQ1). Discuss per challenge what the effect of a change beyond the thresholds will be on main indicators and attributes. For this, split in small groups, and discuss one challenge per small group. Use a big sheet of paper. Worksheet 2 can be used as a basis. First, the expected direction of change of the challenge should be clarified. Secondly, the relation between challenge and indicator/attribute is discussed. The moderator synthesizes this with a score of --, -, +-, + and ++ alongside arrows from challenges to indicators/attributes (Figure 5). A + relation implies that if the level of the challenge increases, the indicator or attribute also increases (i.e., e decrease in the level of the challenge also leads to a decrease in the indicator/attribute). Verify whether there are possible interactions among and between indicators and attributes.

Synthesize these interactions with a score as well. Thirdly, the expected impact on the indicator/attribute is indicated. This impact will be scored by referring to the expected performance level from 1-5, similar to FoPIA-SURE-Farm 1. The same level implies no impact. Note that stakeholders do not fill in forms, but the moderator together with other researchers is responsible to synthesize discussions among stakeholders (Worksheet 2). The third step should logically follow the second step, so the moderator can provide suggestions, to be confirmed by the stakeholders. Record the discussions of small groups using an audio-device. In a plenary session, each moderator feeds back the results of the small group in a 1-minute pitch.

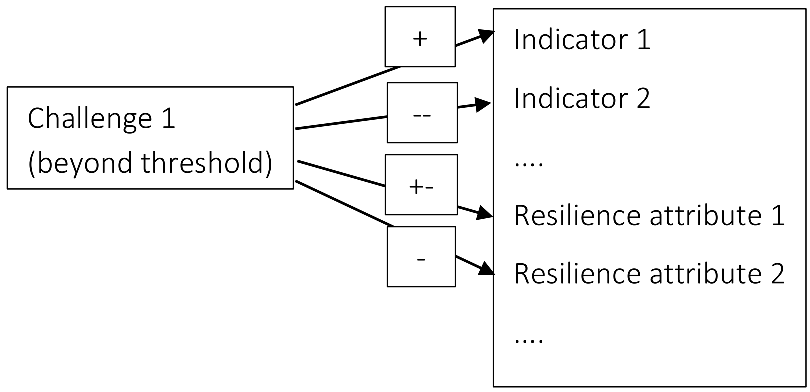

Figure 5. Example of synthesized perceived effects of a challenge beyond identified thresholds on indicators and resilience attributes.

3.3.5 Evaluation phase

For each challenge, indicator and resilience attribute, performance is discussed. In fact, these performances under different conditions represent the performance of alternative systems. In Excel-sheet “Table 3 Report”, summarize expected developments (trends) in levels of indicators and resilience attributes by classifying them in strong negative (↓), moderate negative (↘), no trend (→), moderate positive (↗) and strong positive developments (↑). Based on the outcomes of the workshop, evaluate how (un)desirable the alternative systems are. Update the causal loop diagram (CLD; RQ6) that you started in the preparation phase (Preparation sheet 3), including all challenges, indicators and attributes that are discussed in the workshop (Work sheet 2). Where necessary, add indicators to improve the logic of your CLD, provided these indicators are backed up by other SURE-Farm deliverables and/or (grey) literature. Identify closed loops in your CLD, determine whether they are reinforcing or balancing, and use this to explain how regime shifts towards alternative systems can take place in your case study (see for instance Biggs et al., 2018; Brzezina et al., 2016).

Synthesize the main challenging processes and their consequences in the framework of Kinzig et al. (2006) (Figure 2), to see whether you can identify interactions across scales and domains (Evaluation sheet 1; RQ6). For an example, see Figure 6. Each arrow in Figure 6 indicates an interaction of thresholds of main processes in the studied farming system. Underlying the interactions of thresholds are the developments of indicators, functions, resilience attributes and (external) challenges. For instance, in Figure 6, passing the threshold of transformation of grassland into woodland (indicator) makes that farmers shift their production type (system function), which on its turn implies passing a threshold that could induce the loss of a product label.

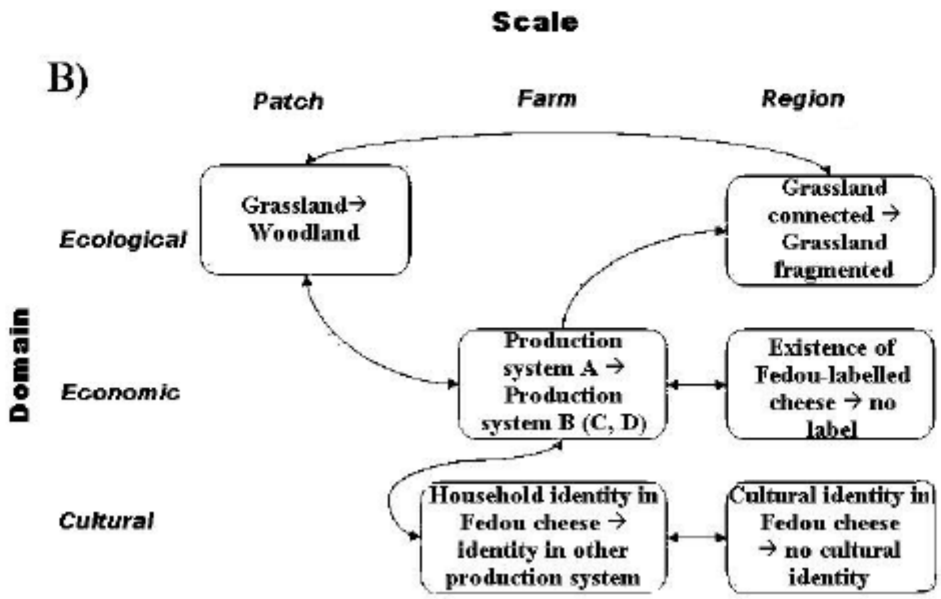

Figure 6. Visualization of interacting thresholds between domains and scales for a sheep cheese producing region in France. Source: Kinzig et al. (2006).

3.4 Alternative systems

3.4.1 Introduction

Before a system declines, stakeholders in the farming system will probably have employed strategies to avoid a total collapse: individual farmers may quit, but in one way or another, remaining actors will find ways to continue. Actors may adapt and/or transform their farming system. Stakeholders probably will see multiple options for their farming system, e.g. different forms of multi-functionality, new crops, new institutions, and new collaborations. Desirable alternative systems are dependent on likely future scenarios (i.e., under certain scenarios no ideal states are possible). Desirable alternative systems aim to improve functions and attributes that do not perform at a desired level in order to be sustainable and resilient (e.g., biodiversity is low in many farming systems; even when not all stakeholders agree, this function may need to improve).

3.4.2 Guiding questions

- RQ4. What are possible desired alternatives for the farming system?
    - If challenges as discussed under RQ1-3 cross critical thresholds, which more desirable farming systems are possible? (Step 2)
    - If functions as discussed under RQ1-3 need to improve, which more desirable farming systems are possible? (Step 3)
    - Will function (and indicator) importance change? (Step 3)
    - At what level will functions and indicators perform? (Step 3)
    - What boundary conditions need to change? (Step 2)
    - What strategies need to be followed?
    - What actors are important for the implementation?
    - In what Eur-Agri-SSPs could these alternative systems thrive? (RQ7)
    - Are the proposed alternative systems considered adaptations or transformations with regard to the current system? (Step 4)

3.4.3 Preparation phase

Based on research done so far, news items, literature and the available Shared Socio-Economic Pathways (SSPs) adapted for SURE-Farm (D1.2; Mathijs et al., 2018) and the further specified Eur-Agri-SSPs (Mitter et al., 2019; under review), researchers can think of possible future states. FoPIA-SURE-Farm 1 forms a good basis as well. If stakeholders considered certain functions and indicators important, but their performance was low, desired alternative systems should improve these functions and indicators. Similarly, resilience attributes that contribute to resilience capacities according to stakeholders, are perceived relevant, and therefore may require improvement. In addition, policy documents may ask for alternative systems, like organic agriculture, agroecology, circular agriculture or more specialized and intensive systems. Gather ideas for future states in Support sheet 2.

Developments regarding the challenges may also lead to alternative systems. For example, when extreme events become more severe, some crops may not yield enough anymore without irrigation. In case the Brexit takes place, trade between the UK and EU may change and influence the prices of crop products or environmental regulations. If the environment is polluted because of expanding production, more environmental friendly management practices may be needed.

Include elements of possible future states in your CLD (Preparation sheet 3), including possible new attributes and strategies. In the example about NL-starch potato for instance, drought may become a much more important factor than it is now, influencing water requirements, yield, nematode pressure and economic returns of starch potato (Figure 7; left hand side). One alternative (adapted) state, could be a system with increased irrigation, as a direct response to the challenge of increased drought.

A more transformative alternative state, which adapts to several challenges, could be the move towards circular agriculture. In the Netherlands, the ministry of agriculture presented a vision in which a development towards circular agriculture is proposed. Circular agriculture can be interpreted in different ways, but includes that crop production for food is preferred above crop production for other purposes, nutrient cycles are closed as much as possible, more collaboration takes place between crop and livestock farmers, and regional trade is stimulated. This could for example include the cultivation of soybean for human consumption, to replace meat consumption, or for feed, to reduce imports from South America. Soybean responds different to drought than starch potato.

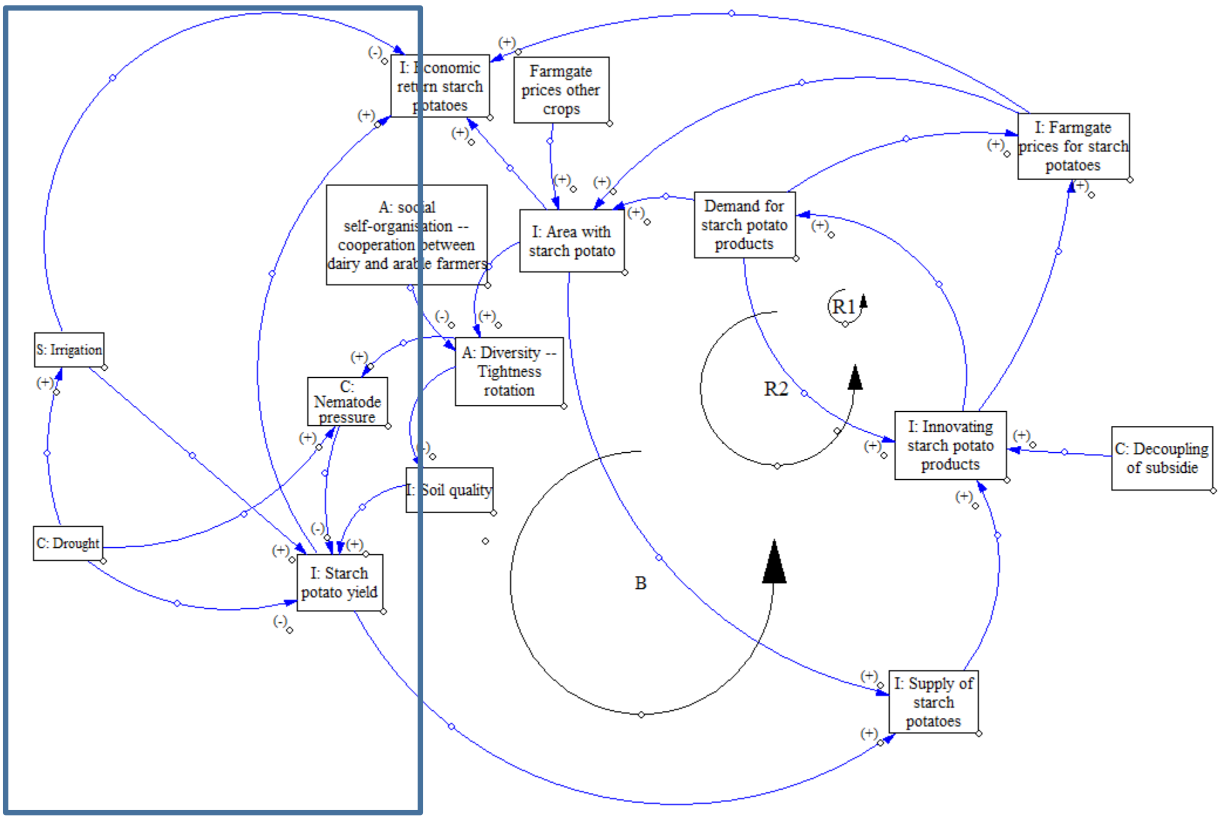

Figure 7. Example of an updated CLD for NL-starch potato. The blue frame includes the updates "C: drought" and "S: irrigation" and their interactions with other system indicators. B and R stand respectively for a balancing and reinforcing feedback loop. I, A, C and S stand respectively for specific system indicators, attributes and challenges.

3.4.4 Stakeholder workshop

It is important to take a break after RQ2 and RQ3 which have focused on the current system and possible system decline. In this part, stakeholders should make a switch to desired alternative states, and more creativity is required.

Start this part with two main questions: 1) If challenges as discussed under RQ2 and RQ3 cross critical thresholds, which more desirable farming systems are possible? 2) If functions as discussed under RQ2 and RQ3 need to improve, which more desirable farming systems are possible? The challenges and functions can be specified based on earlier discussions. Ask all participants to write on post-its one alternative system they desire if challenges cross thresholds and/or functions need improvement. This makes sure stakeholders can give their own input, and are not directly influenced by others. If input is low, use Support sheet 2 of the Excel-file to stimulate thinking among participants.

In a plenary session, collect the post-its and identify several alternative future systems. These may be combinations of suggestions of different stakeholders. Some may be adaptations and some transformations of the current system. After giving them a name, sub-groups are formed to further discuss which indicators and attributes will change for one alternative future system. In addition, changes in land use, sectors, objectives and other relevant aspects may be discussed. Sub-groups also discuss the boundary conditions, i.e. how challenges and other drivers should change in order to be able to reach these alternative future systems. Presence of interaction between thresholds of boundary conditions and indicators/attributes will be evaluated. Finally, sub-groups propose concrete strategies to realize the alternative system and how they are linked to main indicators and attributes. Additionally, ask which actors need to be involved to implement the strategies. All previous steps can be summarized in Worksheet 3. These discussions will likely not provide a complete overview, but provide relevant input for further evaluation.

Sub-groups should have at least one moderator and three stakeholder members. During the discussions, the moderator should use worksheet 3 to synthesize and stimulate the discussion among stakeholders (leading to results similar as in Figure 3). The CLD can also be used. The moderator can use the basic elements from the CLD that is prepared in the preparation phase. Also, the moderator can use the updates based on RQ3. In case CLDs are used, make sure that the different sub-groups start with identical basic CLDs. When strategies are already mentioned, the moderator lists these strategies that will be further discussed under RQ5. Record the discussions in the sub-groups using an audio-device. In a plenary session, each moderator will present results, using worksheet 3, and where possible with the support of a CLD.

3.4.5 Evaluation phase

Use Excel-sheet “Table 3 Report” to document the different alternative systems, and reflect on how they can have an effect on other system indicators/attributes that were not discussed during the workshop. In Excel-sheet “Table 3 Report”, summarize expected developments (trends) in levels of indicators and resilience attributes by classifying them in strong negative (↓), moderate negative (↘), no trend (→), moderate positive (↗) and strong positive developments (↑). Use Excel-sheet “Table 4 Report” to document the strategies for the different alternative systems, including the system in which the status quo is maintained.

Include the new information from the different sub-groups in your CLD (preparation sheet 3; RQ6) that you started in the evaluation phase under RQ3. Where necessary, add indicators to improve the logic of your CLD, provided these indicators are backed up by other SURE-Farm deliverables and/or (grey) literature. Identify closed loops in your CLD, determine whether they are reinforcing or balancing and see how mentioned strategies fit in and can be validated (in some cases proposed strategies may not be appropriate). Finally, you can use the strategies and feedback loops to explain how regime shifts towards alternative systems can take place in your case study (see for instance Biggs et al., 2018).

Update the main challenges and their consequences in the framework of Kinzig et al. (2006) (Figure 2), to see whether you can identify interacting thresholds across scales and domains (evaluation sheet 1; RQ6). When necessary, construct multiple frameworks to synthesize interactions across scales and domains for multiple future states.

Evaluate what the expected change of main resilience attributes implies for robustness, adaptability and transformability in the future. For this, use the results from FoPIA-SURE-Farm 1 on resilience attribute’s potential contribution to resilience capacities. For instance the attribute “reasonably profitable” is perceived to positively contribute to robustness and adaptability in most case studies. Consequently, an increase in presence of this attribute could imply an increase in mainly robustness and adaptability.

Compare the level of food production, economic performance, maintenance of natural resources and other important functions in the different alternative systems with the storylines of adapted SSPs of Mitter *et al.* (2019; see Excel-sheet "Table 5 Report"; RQ7). Indicate in the appropriate cells in Excel-sheet “Table 5 Report” how important an increase in the SSP-indicators as proposed by Mitter et al. (under review) is for the alternative system, where 0 is not important, 1 is somewhat important and 2 is very important. Expected developments of SSP-indicators are copied from Mitter et al. (under review), where ↘,→ and ↗ are translated as -1, 0 and 1, indicating negative, no and positive changes, respectively. Multiplication of importance of positive developments for future systems with expected developments of SSP-indicators is used as an approximation for compatibility. Compatibility scores are first averaged per section (Population, Economy, Policies & institutions, Technology and Environment & natural resources). Final compatibility scores per future system per SSP is an average of the overall section scores, where values -1 to -0.66 imply strong incompatibility, -0.66 to -0.33 moderate incompatibility, -0.33 – 0 weak incompatibility, 0-0.33 weak compatibility, 0.33-0.66 moderate compatibility, and 0.66-1 strong compatibility.

Table 2. Example on compatibility of future systems with different Eur-Agri-SSPs (Mitter et al., 2019)*. Where values -1 to -0.66: strong incompatibility, -0.66 to -0.33: moderate incompatibility, -0.33 – 0: weak incompatibility, 0-0.33 weak compatibility, 0.33-0.66: moderate compatibility, and 0.66-1: strong compatibility.*

			Scenarios		
Future systems	**SSP1**	**SSP2**	**SSP3**	**SSP4**	**SSP5**
Maintaining status quo	0.65	0.21	-0.76	0.18	0.31
Alternative system 1	0.76	0.17	-0.76	0.02	0.05
Alternative system 2	0.61	0.19	-0.77	0.32	0.36
Alternative system 3	0.86	0.27	-0.88	0.01	0.04
Alternative system 4	0.72	0.26	-0.79	0.13	0.19

Evaluate whether the proposed alternative systems are adaptations to or transformations from the current system. Transformations are characterized by a switch in system functions and/or a large change in performance of at least one of the main indicators or attributes (see RQ3.2).

3.5 Strategies for resilience

3.5.1 Introduction

In 2030, not all designed system configurations (status quo, system decline, alternative desired systems) can be realized. They are however all possible future states in 2030. Research Question 4 discusses how likely and desirable different future states are, and evaluates whether current strategies are dedicated to the right issues.

3.5.2 Guiding questions

RQ5. Given the likelihood of future states, are current strategies dedicated to the right issues?

- Is there a shared vision for the future farming system?
- Are the current strategies the same as for the alternative future systems?
- Are there strategies that work for only on alternative future state?
- Are there no-regret strategies that work well for all future states?

- Are there strategies that allow for experimentation? (Safe to fail)
- On what indicators do the strategies have their biggest impact?
- What strategies have the biggest impact on resilience?
- Which actors need to be involved to implement the strategies?
- What is the likelihood that the discussed future states will be realized?
- What is the overall desirability of the discussed future states? (Step 3)

3.5.3 Preparation phase

Use the results from FoPIA-SURE-Farm 1 as synthesized in D5.2 to identify current strategies to cope with challenges associated to the main indicators (Preparation sheet 4). In addition, D5.3 may provide a broader list of current strategies. These strategies can be grouped based on the type of strategy, and the resilience capacities they contribute to. Where possible, process identified strategies in your CLD (Preparation sheet 3).

3.5.4 Stakeholder workshop

Explain what is meant with "strategy" in the context of the workshop. In the context of the workshop we see strategies as a *"plan of action, or part of it, implemented by actors within and outside the farming system to maintain or reach a desired farming system in 2030"*. Explain that in this last phase of the workshop, you would like to see whether actors inside and outside the farming system invest in the right strategies. To start with this, ask whether there is a shared vision about the future farming system. If there is a shared vision, it is possible to tailor your discussion towards this vision. If there is not such a vision, it is possible to keep all alternatives in mind.

Present the list with strategies derived from FoPIA-SURE-Farm 1. Ask for confirmation and add strategies when necessary. In addition, present the list with strategies for realizing alternative systems (Worksheet 5; based on worksheet 3). The latter need to be quickly processed based on the previous step.

During the drinks, in a plenary session, discuss what the likelihood and desirability of different future states are. Discuss whether there are strategies that work for only one or for all future states, including maintaining the status quo. Discuss on what system indicators these strategies have their biggest impact. Also discuss which strategies will contribute most to resilience of the farming system. It is very important to also discuss which stakeholders need to be involved to implement the proposed strategies. This information is key for developing the roadmaps to more resilient farming systems (WP6 of SURE-Farm).

Optionally, during the drinks at the end of the workshop, provide participants with a form to score the desirability and likelihood of alternative states being realized (Worksheet 4). Assess desirability on a score from 1 to 5, where 1: very undesirable, 2: undesirable, 3: equally desirable or undesirable ,4: desirable, 5: very desirable. Assess likelihood on a score from 1 to 5, where 1: not likely, 2: somewhat likely, fifty/fifty, likely, very likely (include blank space to assess other possible future states that were not discussed in the workshop). When time still allows: process the scores and present the results to the participants.

3.5.5 Evaluation phase

Compare strategies implemented currently and in the past with the strategies that need to be implemented to realize alternative states.

Identify the leverage points for transformation in your system, i.e. the farming system components or processes where changes can most effectively be realized. For instance, if starting of producer organizations is expected to have a big impact, evaluate where and how the change actually is realized, e.g. what indicators are directly affected. Indicate in the CLD where the leverage points for transformation are.

Compare likelihood of alternative states with how well these fit with Eur-Agri-SSP storylines and conclude with caution which Eur-Agri-SSP is probably expected by stakeholders. To tell which system configuration will be present in 2030 is not possible. However, it is possible to project and speak in terms of likelihood, for instance, stating that maintaining the status quo in the future is not likely, somewhat likely, very likely, etc. The likelihood is also related to the location of the current system in the adaptive cycle. If the system is in a growth phase, it is more likely that the current system prevails, then when the system is in the reorientation phase. However, whether a system can prevail, also depends on the Eur-Agri-SSP storyline.

4 Reporting

In the evaluation phase, acquired information under the different research questions needs to be combined in a report. **A complete draft report should be ready within one month after the workshop was conducted.** We envision reporting to be in a narrative style, supported by the CLD and other figures and tables, i.e. it should read as a story rather than a technical report. For this reason it is important to record discussions with stakeholders well.

Below, general guidelines for reporting are presented. More precise guidelines are supplied in Appendix B to increase consistency and comparability across case studies.

4.1.1 Current and alternative future states

Start with presenting and explaining the current state of the system and its associated thresholds (FoPIA-SURE-Farm 1). Explain how indicators and attributes will perform in 2030 when the current system configuration is maintained, provided boundary conditions are met (RQ1,2). Also explain how indicators and attributes will perform in 2030 when boundary conditions are not met (RQ3). Finally, present alternative future states (RQ4). We propose to follow the table in Excel-sheet “Table 3 Report” present the current and all future systems in one table. All variables and thresholds need to be explained in the text: explain why these variables were selected by logically including them in the farming system narrative. For thresholds, explain all related factors that influence the levels. Also reflect lightly on completeness of the list of variables and thresholds. For instance, by asking whether adding more variables and thresholds would make your narrative more realistic or just more fuzzy. When applicable, visualize interaction of thresholds (Figure 2 and Figure 6; RQ6). Where possible, compare workshop outcomes with available data, (grey) literature and outputs from SURE-Farm activities to support your findings.

Present the CLD you developed for your farming system (RQ6). Describe the important interactions and feedback loops in the text and present all interactions in a table (preparation sheet 3). While explaining the CLD, follow the structure of the workshop, i.e. first describe current main interactions and then include elements and interactions related to maintaining the status quo, system decline and alternative systems in 2030.

4.1.2 System improvements

Evaluate what strategies have come forward in the preparation phase and the workshop. Cross-check with the CLD how these strategies could make a change in the system. Also evaluate whether these strategies mainly relate to specific resilience or general resilience (see e.g. Walker and Salt, 2012).

Re-evaluate likelihood of alternative systems in the five Eur-Agri-SSPs as proposed by Mitter et al. (2019) (RQ7). Assess in which scenarios the required changes for alternative future states can take place. Evaluate for which Eur-Agri-SSPs, participants seem to be ready and for which ones not.

4.1.3 Resilience capacities

Evaluate whether your farming systems shows signs of robustness, adaptability and/or transformability towards the future (Step 4 in the resilience framework; Figure 1). A starting point is to evaluate the change of presence of resilience attributes (see section 3.4.5). Robustness can further be evaluated by looking at how close the system is to the thresholds that are associated with the current system. Related to this, also the presence or absence of cascading scales can be used to evaluate robustness. Thresholds can be compared with developments in different Eur-Agri-SSPs to cross-check whether it is likely that thresholds will be passed.

Adaptability can be assessed by looking at how much and how many indicators/attributes can change before the system has changed. Transformability can be assessed by evaluating whether there are alternative desired systems that are radically different, and how likely it is that these are reached. When there are alternative systems that are more adaptations to than transformations from the current systems, these can be used to support statements on adaptability, rather than transformability. It is the responsibility of the research team to reason whether an alternative system is considered an adaptation or a transformation (see section 3.4.5).

4.1.4 Synthesis of results across case studies

For comparability across case studies, arrows indicating the expected developments of indicators and resilience attributes in future systems will be quantified, i.e. ↓,↘,→,↗ and ↑, standing for respectively strong negative, moderate negative, no, moderate positive and strong positive developments, were respectively quantified as -2,-1,0,1 and 2. After quantification, scores across indicators/resilience attributes and/or case studies can be averaged.

For comparability across case studies, alternative systems will be categorized according to the primary direction that they seem to take. The categories are alternative systems primarily driven towards: intensification, specialization, diversification, organic/nature friendly production, product valorization, technologizing, collaboration. Alternative systems that are not primarily driven towards above mentioned categories, are allocated to the category “Other”. Categories are not mutually exclusive, e.g. an alternative system primarily driven towards specialization may also have a drive towards technologizing and collaboration.

D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

5 References

Biggs, R., Peterson, G.D., Rocha, J.C., 2018. The Regime Shifts Database: a framework for analyzing regime shifts in social-ecological systems. Ecol. Soc. 23. https://doi.org/10.5751/ES-10264-230309

Brzezina, N., Kopainsky, B., Mathijs, E., 2016. Can organic farming reduce vulnerabilities and enhance the resilience of the European food system? A critical assessment using system dynamics structural thinking tools. Sustain. https://doi.org/10.3390/su8100971

Gunderson, L.H., Holling, C.S., 2002. Panarchy: Understanding transformations in human and natural systems. Island Press, Washington D.C. USA.

Herrera, H., 2017. From Metaphor to Practice: Operationalizing the Analysis of Resilience Using System Dynamics Modelling. Syst. Res. Behav. Sci. 34, 444–462. https://doi.org/10.1002/sres.2468

Herrera, H., Kopainsky, B., Appel, F., Balmann, A., Accatino, F., Tichit, M., Antonioli, F., Severini, S., Paas, W., Reidsma, P., 2018. D5.1 Impact assessment tool to assess the resilience of farming systems and their delivery of private and public goods. Sustainable and resilient EU farming systems (SureFarm) project report.

Kinzig, A.P., Ryan, P., Etienne, M., Allison, H., Elmqvist, T., Walker, B.H., 2006. Resilience and regime shifts: Assessing cascading effects. Ecol. Soc. 11. https://doi.org/10.5751/ES-01678-110120

Mathijs, E., Deckers, J., Kopainsky, B., Nitzko, S., Spiller, A., 2018. D1.2 Scenarios for EU farming. Sustainable and resilient EU farming systems (SureFarm) project report.

Meuwissen, M., Feindt, P., Spiegel, A., Termeer, C., Mathijs, E., de Mey, Y., Finger, R., Balmann, A., Wauters, E., Urquhart, J., Vigani, M., Zawalinska, K., Herrera, H., Nicholas-Davies, P., Hansson, H., Paas, W., Slijper, T., Coopmans, I., Vroege, W., Ciechomska, A., Accatino, F., Kopainsky, B., Poortvliet, M., Candel, J., Maye, D., Severini, S., Senni, S., Soriano, B., Lagerkvist, C.J., Peneva, M., Gavrilescu, C., Reidsma, P., 2019. A framework to assess the resilience of farming systems. Agric. Syst.

Mitter, H., Techen A., Sinabell, F., Helming, K., Kok, K., Priess, J.A., Schmid, E., Bodirsky, B.L., Holman, B.L., Lehtonen, H., Leip, A. 2019. A protocol to develop shared socio-economic pathways for European agriculture. Journal of Environmental Management, 252, 109701.

Mitter, H., Techen, A., Sinabell, F., Helming, K., Kok., K., Priess, J., Bodirsky, B., Holman, I., Lehtonen, H., Leip, A., Le Mouël, C., Lotze-Campen, H., Mathijs, E., Mehdi, B., Michetti, M., Mittenzwei, K., Mora, O., Øistad, K., Øygarden, L., Reidsma, P., Schaldach, R., Schmid, E., Webber, H., Schönhart, M., 2019. Developing a protocol for establishing new storylines that extend the Shared Socio-economic Pathways and inform integrated assessments of

European agricultural systems. Under review

O'Neill, B.C., Kriegler, E., Ebi, K.L., Kemp-Benedict, E., Riahi, K., Rothman, D.S., van Ruijven, B.J., van Vuuren, D.P., Birkmann, J., Kok, K., Levy, M., Solecki, W., 2017. The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Glob. Environ. Chang. 42, 169–180. https://doi.org/10.1016/j.gloenvcha.2015.01.004

O'Neill, B.C., Kriegler, E., Riahi, K., Ebi, K.L., Hallegatte, S., Carter, T.R., Mathur, R., van Vuuren, D.P., 2014. A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Clim. Change 122, 387–400. https://doi.org/10.1007/s10584-013-0905-2

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., 2019. D5.2 Participatory impact assessment of sustainability and resilience of EU farming systems. Sustainable and resilient EU farming systems (SureFarm) project report. https://doi.org/10.13140/RG.2.2.25104.25601

Reidsma, P., Paas, W., Spiegel, A., Meuwissen, M., 2019. Guidelines for the Framework of Participatory Impact Assessment of SUstainable and REsilient EU 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. (Eds.), D5.2 Participatory Impact Assessment of Sustainability and Resilience of EU Farming Systems. Sustainable and resilient EU farming systems (SURE-Farm) project report.

Resilience Alliance, 2010. Assessing resilience in social-ecological systems: Workbook for practitioners. Version 2.0.

Walker, B., Salt, D., 2012. Resilience practice: Building capacity to absorb disturbance and maintain function, Resilience Practice: Building Capacity to Absorb Disturbance and Maintain Function. https://doi.org/10.5822/978-1-61091-231-0

Appendix A. How to develop causal loop diagrams in Vensim

Open Vensim PLE.

Click on the button “Level” and click then somewhere in the blank space to include an indicator/attribute/challenge in your CLD (Figure A1). These are the levels of your CLD. You can adapt levels in your CLD as long as you have the “Level” button switched on.

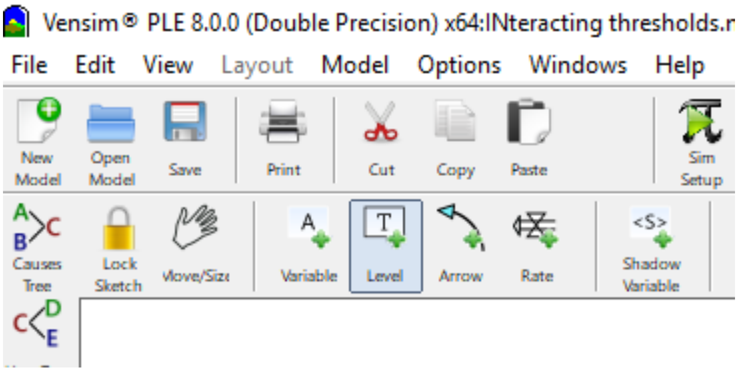

Figure A1. Selection of the "level" button to include indicators/attributes/challenges in the CLD.

To select, move or increase the size of your levels, make use of the “Move/Size” button (Figure A2).

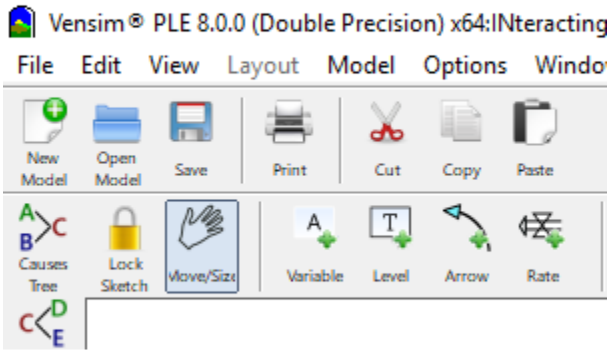

Figure A2. Selection of the "Move/Size" button to move or increase the size of levels or change the shape of arrows in the CLD.

After including several levels, start making the connections by clicking on the button “Arrows” (Figure A3). Then click on a first box and then on a second box to connect two boxes. You can adapt the shape of the arrows in your CLD as long as you have the “Arrow” (Figure A3) or “Move/size” (Figure A2) button switched on.

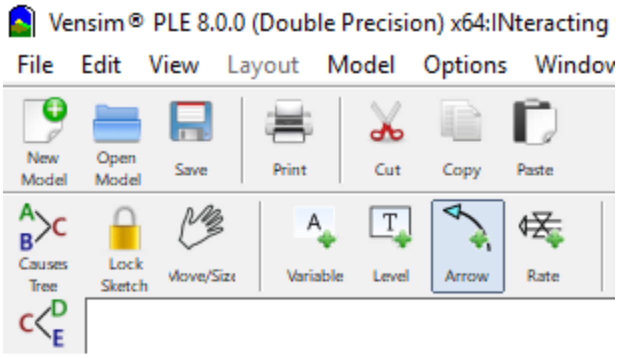

Figure 3. Selection of the "Arrows" button to connect levels in the CLD.

To detect closed loops in your CLD, select a level in the CLD and click on the "Loops" button (Figure A4). If no loop is detected you will get a message similar to the one in Figure A4. In case a closed loop is detected, a message such as in Figure A5 will appear.

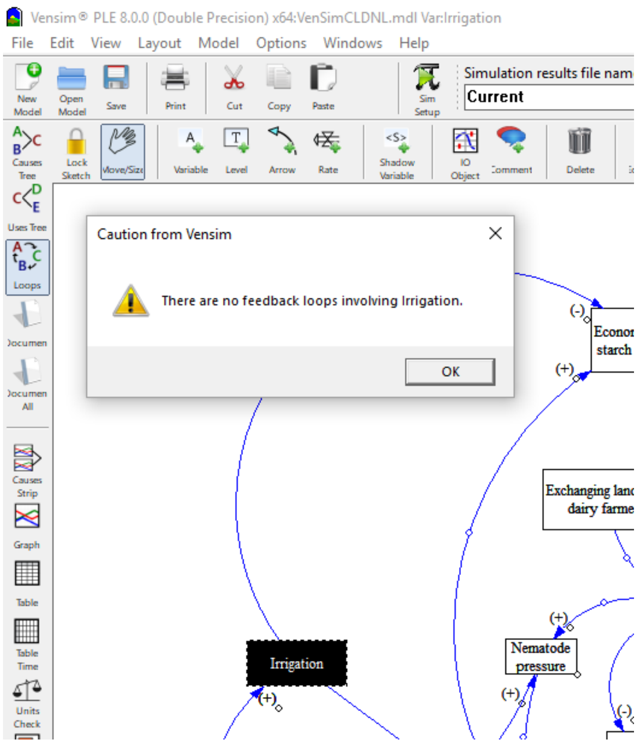

Figure A4. Check whether a level in the CLD is involved in a closed loop. In this example, no closed loop is detected.

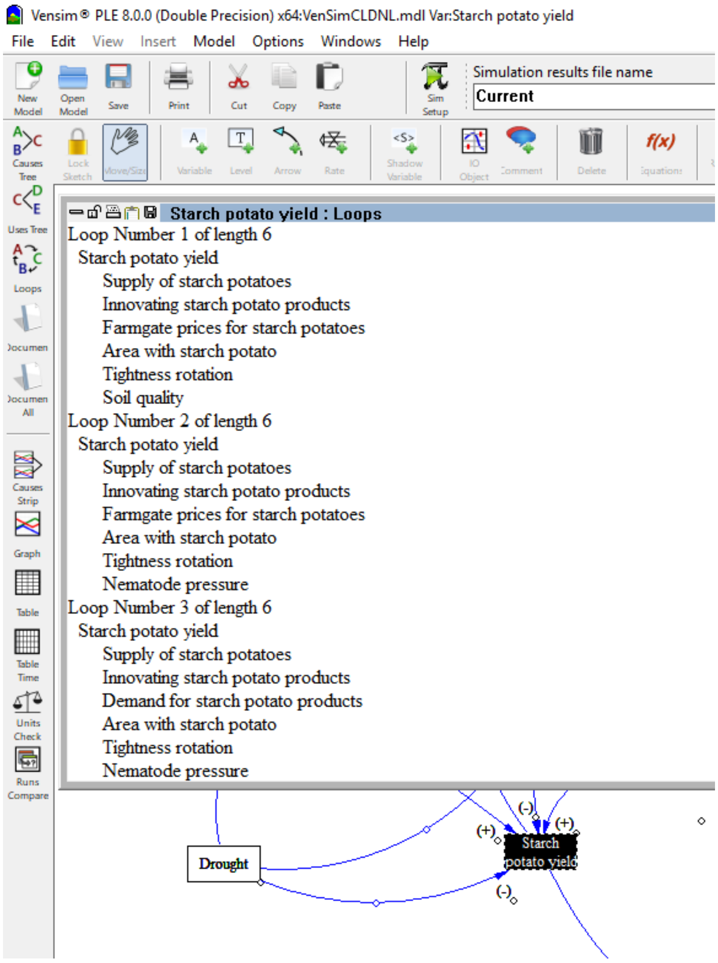

Figure A5.Check whether a level in the CLD is involved in a closed loop. In this example, multiple closed loops are detected.

To indicate balancing and reinforcing feedback loops in your CLD, click the button "Comment" (Figure A6) and then somewhere on your CLD where you would like to have the sign of the feedback loop. After clicking somewhere on your CLD, a window will pop-up, just as in Figure A6. Please, select whether your loop goes clockwise or counter clockwise. In the space for comments, include with an R or B whether the loop is balancing or reinforcing.

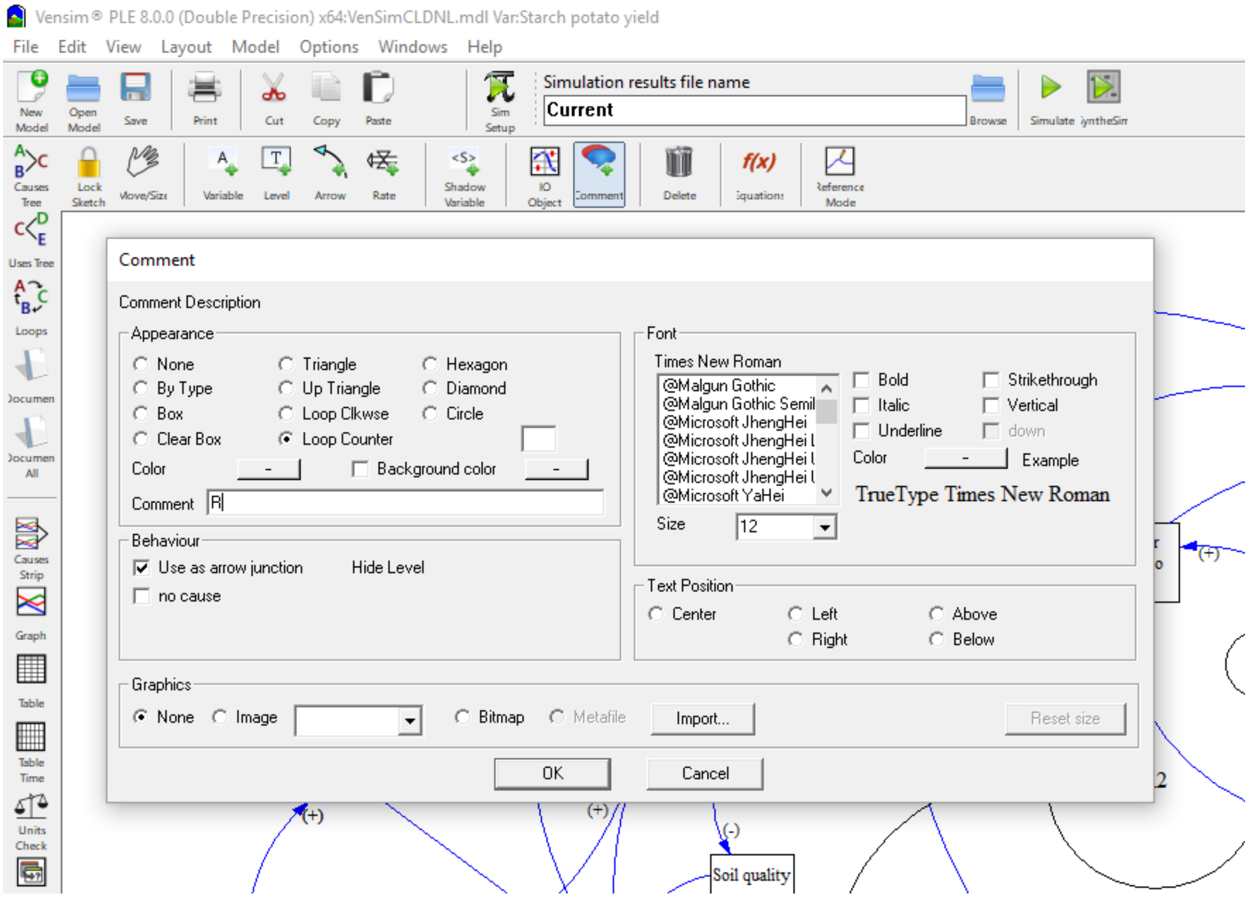

Figure A6. Adding feedback loop sign to the CLD. In this example a counter clockwise, reinforcing feedback loop is included.

At the bottom of the screen in the Vensim interface, you can select different colors for levels and arrows (Figure A7).

Figure 7. Buttons at the bottom of the Vensim interface for selecting colors for levels and arrows.

D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

Appendix B. Reporting template

Project acronym: SURE-Farm

Project no.: 727520

Start date of project: June 2017

Duration: 4 years

FoPIA-Surefarm 2 Case Study Report Your Country

Work Performed by PX, Name of your institution

Names researchers involved

(Name contact person; mail address contact person)

Due date	31/May/2019 (part of D5.5)
Version/Date	...
Work Package	WP5
Task	T5.3
Task lead	INRAE
Dissemination level	At this stage confidential, only for members of the consortium

D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

Contents

D5.5 Impacts of future scenarios on the resilience of farming systems across the EU assessed with quantitative and qualitative methods

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

1 Introduction

1.1 Main indicators, resilience attributes and challenges

Provide a small introduction to the case study area. Mention the most important functions, indicators (Table 1), resilience attributes (Table 2) and challenges.

For Table 1 See Excel-sheet "Preparation sheet 2", Table P2a

Table 2. Main indicators and their performance and development. Source: *Mention the case study report of FoPIA-SURE-Farm 1*

Main indicators	Current level (score 1:5)	Current level (explanation)	Current development
Indicator 1			
Indicator 2			
Indicator 3			
Indicator 4			

For Table 2 see Excel-sheet "Preparation sheet 2", Table P2b

Table 3. Main resilience attributes and their presence in the farming system. Source: *Mention the case study report of FoPIA_SURE-Farm 1*

Main resilience attributes	Current level (score 1:5)	Current level (explanation)	Current development
Resilience attribute 1			
Resilience attribute 2			
Resilience attribute 3			
Resilience attribute 4			

Main challenges for the farming systems are:

- Name challenge 1 + short explanation
- Etc.

1.2 Participation in the workshop

Mention the date of the workshop and the number of participants in the workshop and to which stakeholder group they belonged.

Indicate whether participants agreed upon the main challenges and the main indicators for functioning and resilience of the system. Also indicate whether they agreed with the perceived performance scoring, resulting from FoPIA-SURE-Farm 1.

2 Results

2.1 Maintaining the status-quo

2.1.1 Introduction

In order to keep the current system as it is, participants provided minimum or maximum levels of indicators, resilience attributes and challenges.

2.1.2 Indicators

When necessary, mention deviations in the process for dealing with the indicators (compared to the process as proposed in the guidelines).

Name indicator 1:

Discuss what was noted down by stakeholders on post-its. Do this for all indicators.

Name indicator 2:

Name indicator 3:

Name indicator 4:

2.1.3 Resilience attributes

When necessary, mention deviations in the process for dealing with the resilience attributes (compared to the process as proposed in the guidelines).

Name resilience attribute 1:

Discuss what was noted down by stakeholders on post-its. Do this for all resilience attributes.

Name resilience attribute 2:

Name resilience attribute 3:

Name resilience attribute 4:

2.1.4 Challenges

When necessary, mention deviations in the process for dealing with the challenges (compared to the process as proposed in the guidelines).

Name challenge 1:
Discuss what was noted down by stakeholders on post-its. Do this for all challenges.

Name challenge 2:

Name challenge 3:

Name challenge 4:

2.2 System decline

2.2.1 Introduction

In small groups, participants discussed one challenge and its impact on main indicators and resilience attributes, in case thresholds were exceeded.

2.2.2 Performance of indicators and resilience attributes

Based on the small group discussions, qualitatively describe per challenge how performance of indicators and resilience attributes will change when critical thresholds of challenges are exceeded.

If mentioned in the small group discussions, also describe interaction between different challenges.

If mentioned in the small group discussions, present concrete strategies to avoid a system decline.

Challenge 1

Challenge 2

Challenge 3

Challenge 4

2.3 Alternative systems

2.3.1 Introduction

Start with a summary of the results:

-names of the alternative systems

-overall change in alternative systems compared to the current system. (Refer to Table 1)

-main/shared boundary conditions across alternative systems

-Possibly: deviations from the process of acquiring the results, compared to the process as described in the guidelines.

Table 3. Current perceived performance of main functions and presence of resilience attributes (FoPIA-SURE-Farm 1) and their expected change in future systems.→ implies no change, ↗ implies moderate positive change, ↑ implies strong positive change, ↘ implies moderate negative change, ↓ implies strong negative change, V implies that a boundary condition is relevant for a future system. Arrows and tick marks in bold font are results obtained in the workshop. Arrows and tick marks in normal font are deductions from what has been said in the workshop.

					Future systems		
Indicator	**Current level**	**Status quo**	**System decline**	**Alternative crops**	**Precision agriculture**	**Nature inclusive**	**Collaboration & water**
Indicator 1							
Indicator 2							
Indicator 3							
Indicator 4							
Resilience attribute 1							
Resilience attribute 2							
Resilience attribute 3							
Resilience attribute 4							
Extra resilience attribute							
Extra resilience attribute							
Boundary conditions	**Domain**						
Boundary condition a	Agronomic						
Etc.	Etc.						
Boundary condition	Economic						
Etc.	Etc.						
Boundary condition h	Environmental						
Etc.	Etc.						
Boundary condition p	Institutional Etc.						
Etc.							

Boundary condition x	Social
Etc.	Etc.

Explain per alternative system:

- *The (functioning of the) alternative system, inclusive expected changes in performance of indicators*
- *Expected change in performance of resilience attributes*
- *Concrete strategies needed for realizing the alternative system*
- *Boundary conditions that need to be in place for the alternative system*

Where useful, refer to Table 1.

Alternative system 1

Alternative system 2

Alternative system 3

Alternative system 4

2.4 Strategies towards the future

Try to address the following questions:

- Is there a shared vision for the future of the farming system?
- Are the current strategies the same as for the alternative future states?
- Are there strategies that work for only on alternative future state?
- Are there no-regret strategies that work well for all future states?
- Are there strategies that allow for experimentation? (Safe to fail)

- On what indicators do the strategies have their biggest impact?
- What strategies have the biggest impact on resilience?
- Which actors need to be involved to implement the strategies?
- What is the likelihood that the discussed future states will be realized?
- What is the overall desirability of the discussed future states? (Step 3)

Fill the table below. For instructions see the caption or Excel-sheet "Table 4 Report".

Group strategies by domain in the following order:

-agronomic

-economic

-environmental

-institutional

-social

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

Table 4. Current strategies and future strategies for different future systems. Current strategies are based on FoPIA-SURE-Farm 1. Bold font indicates that these strategies were mentioned during the workshop for a specific system. Normal font indicates that, based on the discussions during the workshop, it seems likely that strategies will be applied in certain systems.

		Current system	**Future systems**				
Strategy	**Domain**		**Status quo**	**Alternative system 1**	**Alternative system 2**	**Etc.**	**Etc.**

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant

3 Interpretation

3.1 Tipping points

Evaluate whether your system is close to a tipping point. Based on:

-Notes from participants on post-its about critical thresholds

-Current performance (FoPIA 1, literature) and current presence of challenges.

-Presence of boundary conditions that can help to realize alternative systems in time.

3.2 Thresholds exceeded

Discuss the implications when thresholds of indicators, resilience attributes and challenges are exceeded.

In the last paragraph, synthesize the main challenging processes and their consequences in the framework of Kinzig et al. (2006), to see whether you can identify interactions across scales and domains (Evaluation sheet 1). When necessary, construct multiple frameworks to synthesize interactions across scales and domains for multiple future states.

Also reflect lightly on completeness of the list of variables and thresholds. For instance, by asking whether adding more variables and thresholds would make your narrative more realistic or just more fuzzy.

An example from the Dutch case study is provided below. A better lay out is recommended.

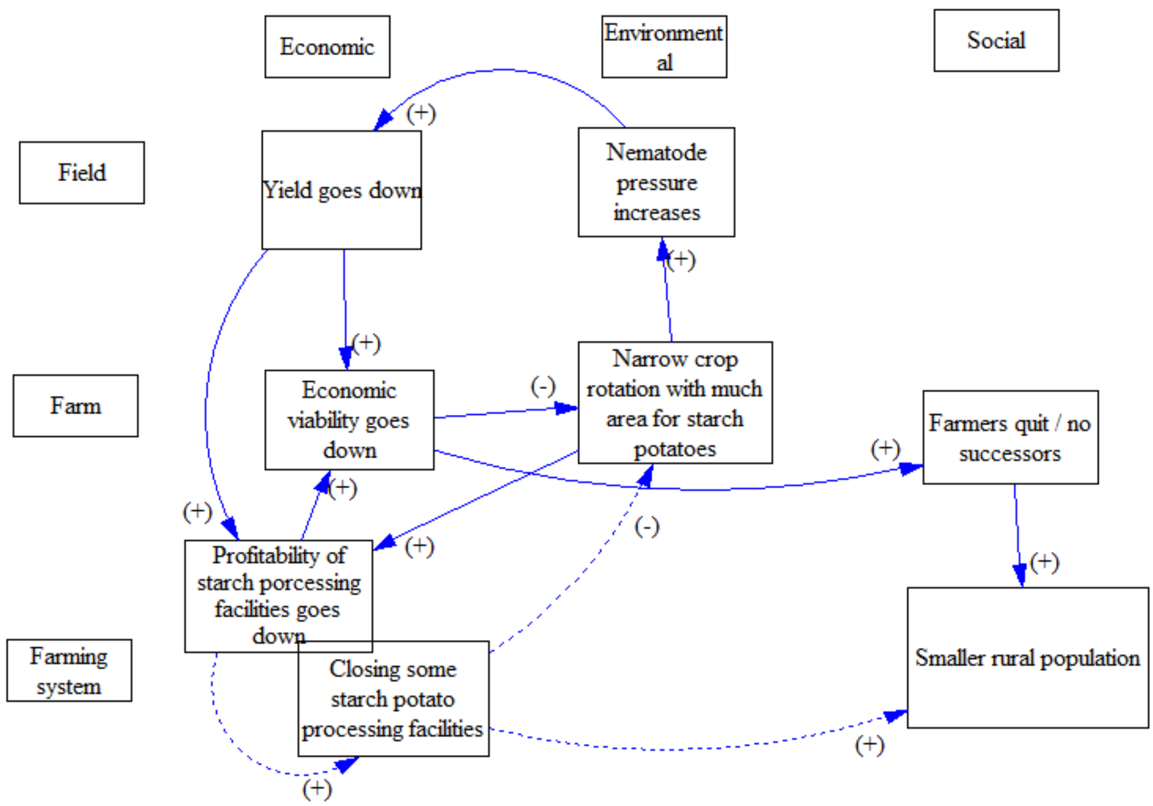

Figure 8. Interacting thresholds in the farming system. Dashed lines indicate relationships that were not discussed during the workshop.

3.3 Alternative systems

Shortly discuss how main indicators change in the alternative systems.

Use worksheet 3 to document the different alternative systems, and reflect on how they can have an effect on other system indicators/attributes that were not discussed during the workshop.

Evaluate whether the proposed alternative systems are adaptations to or transformations from the current system. Transformations are characterized by a switch in system functions and/or a large change in performance of at least one of the main indicators or attributes (see RQ2.2).

3.4 Causal loop diagram

Update the causal loop diagram (CLD) that you started in the preparation phase (Preparation sheet 3), including all challenges, indicators and attributes that are discussed in the workshop (Work sheet 2). Where necessary, add indicators to improve the logic of your CLD, provided these indicators are backed up by other SURE-Farm deliverables and/or (grey) literature.

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

Present identified closed loops in your CLD here in the text, mention whether they are reinforcing or balancing.

In a final paragraph, explain with aid of the identified feedback loops, how regime shifts towards alternative systems can or cannot take place in your case study (see for instance Biggs et al. (2018); Brzezina et al. (2016)). (Reflect for instance on whether loops can go into a negative as well as positive direction for the system; where stochasticity could play a role; whether strategies in place are part of a feedback loop or only interfering from outside without receiving feedback themselves, etc.)

An example from the Dutch case study is provided below.

Supplementary Materials A. Guidelines for FoPIA-SURE-Farm 2: future resilience

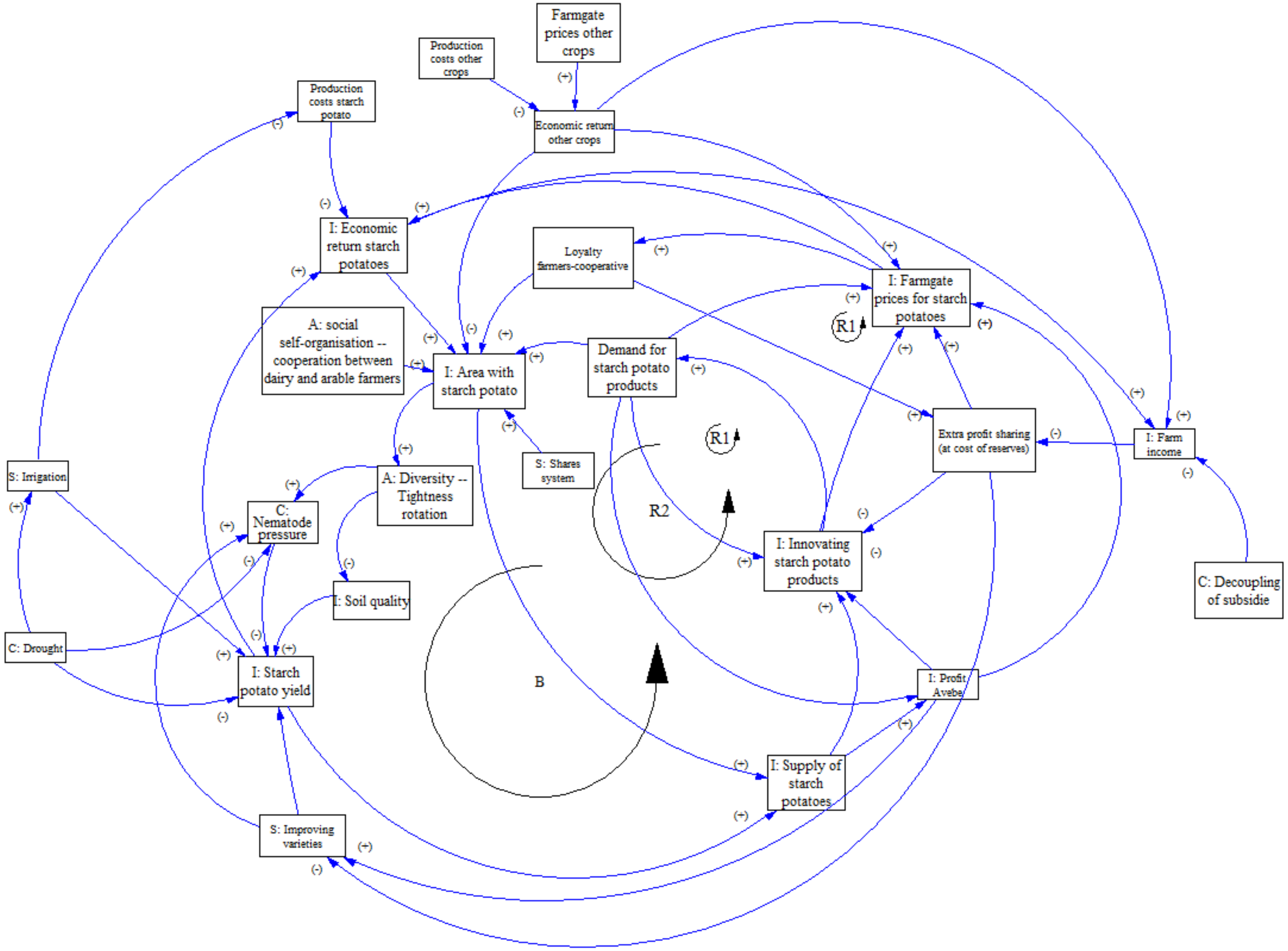

Figure 9. Causal loop diagram of the farming system in name of your case study. A + implies a positive cause-effect relationship and a - implies a negative cause-effect relationship. B stands for a balancing feedback loop and R stands for a reinforcing feedback loop. I indicates an important system indicator related to the system's functions. C indicates a system challenge. A indicates an indicator related to a resilience attribute. S indicates a strategy applied to maintain current functionality of the system.

This Project has received funds from the European Union's Horizon 2020 research and innovation programme under Grant

3.5 Linking alternative systems to scenarios

Start with mentioning the requirements of the maintaining the status quo in the future and the requirements for the alternative systems. (e.g. requirements related to adopting strategies, realizing certain outputs, boundary conditions).

Compare the level of food production, economic performance, maintenance of natural resources, and other important functions in the different alternative systems with the storylines of adapted SSPs of under review). Do the same for challenges and boundary conditions. Evaluate in which Eur-Agri-SSPs the alternative systems could thrive (Excel-sheet "Table 2 Report). A matrix can be used to provide an overview (Table 2; Excel-sheet "Table 2 Report"). Explain per scenario why certain alternative systems do or don't perform well. When necessary/useful, also feel free to explain per alternative system why it is (not) compatible with a certain scenario (although this might to seem double, it could reveal extra information).

Reflect on the possibility of combining different alternative systems and what the effect would be on compatibility with scenarios.

Optionally, compare likelihood of alternative states with how well these fit with Eur-Agri-SSP storylines and conclude with caution which Eur-Agri-SSP is probably expected by stakeholders. To tell which system configuration will be present in 2030 is not possible. However, it is possible to project and speak in terms of likelihood, for instance, stating that maintaining the status quo in the future is not likely, somewhat likely, very likely, etc. The likelihood is also related to the location of the current system in the adaptive cycle. If the system is in a growth phase, it is more likely that the current system prevails, then when the system is in the reorientation phase. However, whether a system can prevail, also depends on the Eur-Agri-SSP storyline.

For Table 5 see Excel-sheet "Table 2 Report". Colors are updated automatically.

Table 5. Compatibility of alternative systems with different Euri-Agri-SSPs. Where values -1 to -0.66: strong incompatibility, -0.66 to -0.33: moderate incompatibility, -0.33 – 0: weak incompatibility, 0-0.33 weak compatibility, 0.33-0.66: moderate compatibility, and 0.66-1: strong compatibility.

	Scenarios				
Systems	**SSP1**	**SSP2**	**SSP3**	**SSP4**	**SSP5**
Maintaining status quo					
Alternative system 1					
Alternative system 2					
Alternative system 3					
Alternative system 4					

3.6 Strategies

Compare strategies implemented currently and in the past with the strategies that need to be implemented to realize alternative states.

Identify the leverage points for transformation in your system, i.e. the farming system components or processes where changes can most effectively be realized. For instance, if starting of producer organizations is expected to have a big impact, evaluate where and how the change actually is realized, e.g. what indicators are directly affected. Indicate in the CLD where the leverage points for transformation are.

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

3.7 Conclusion

Conclude whether your farming systems shows signs of robustness, adaptability and/or transformability towards the future (Step 4 in the resilience framework). A starting point is to recap the change of presence of resilience attributes (see section 3.4.5). Robustness can further be evaluated by looking at how close the system is to the thresholds that are associated with the current system. Related to this, also the presence or absence of cascading scales can be used to evaluate robustness. Thresholds can be compared with developments in different Eur-Agri-SSPs to cross-check whether it is likely that thresholds will be passed.

Transformability can be assessed by evaluating whether there are alternative desired systems that are radically different, and how likely it is that these are reached. When there are alternative systems that are more adaptations to than transformations from the current systems, these can be used to support statements on adaptability, rather than transformability. It is the responsibility of the research team to reason whether an alternative system is considered an adaptation or a transformation.

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