Assessing Resilience and Sustainability in German large-scale corporate arable farms

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Assessing Resilience and Sustainability in German large-scale corporate arable farms

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Abstract

European agriculture is facing multiple economic, environmental, institutional and social challenges which are threatening the stability of production. This also applies for the case study (CS) in the Altmark region, which is located in the North of the federal state "Sachsen-Anhalt" in the East of Germany. The farming system of this case study is characterized by large-scale corporate arable farms. The occurring shocks and long-term pressures are, for instance, emigration due to little social infrastructure, low yields due to dry summers and non-availability of qualified work force.

This thesis is part of the Towards SUstainable and REsilient EU FARMing systems" (SURE-Farm) project. In the first part of the thesis the Framework for Participatory Impact Assessment adapted for SURE-farm (FoPIA-Surefarm) was used as an integrated assessment (IA) tool to assess current sustainability and resilience of farming systems in the Altmark. In the second part of the thesis a scenario development for the Altmark region was conducted to identified trends of the demographic dynamics and their impact for the case study's' resilience.

FoPIA-Surefarm was conducted in a workshop with twelve participants from different stakeholder groups of the farming system. The participants defined the importance and performance of functions and indicators of the farming system. Secondly, strategies of the last 18 years to improve the resilience were identified. Those strategies and the so-called resilience attributes were assessed for their contribution to the resilience capacities: robustness, adaptability and transformability.

The most important function of the farming system is the "provision of food" and "economic viability". The function "economic viability" scored lower in performance compared to "food production". Overall "natural resources" is the third most important function and scores the best performance. The indicator *wages* is perceived low performing by the participants and determined as main challenge. Strategies in the past to increase the farming system resilience were grouped into "cost saving measures", "adding value to the production" and "government regulations". The strategies contributed mostly to the robustness and adaptability of the farming system. The resilience attributes contribute to the robustness of the system but also indicate the spatial heterogeneity and the extensive farming management of the farming system, which makes it adaptable. However, the financial and human capital is limited because the farming system is not sustainable in terms of profitability and consequently cannot pay decent wages. The highest scored resilience attribute is "socially-self organized" and contains a chance for the resilience, through networks between the farming system actors in the Altmark. Conclusions from the stakeholder workshop are that the farming system is mainly adaptable and also robust in particular processes but experiences a lock-in due to low profitability. Consequently, transformability of the farming system is considered to be low.

The scenario development to identify trends of the demographic dynamics highlights that the business as usual scenario will lead to low availability of labor in agriculture due to rural exodus, which challenges the resilience of the farming system. This is because of slow economic growth and a low infrastructure development. The scenario development indicates that medium economic growth is needed to increase the resilience. Direct marketing is one future strategy to increase profitability. However, only the future scenarios which invest into infrastructure development, are resilient pathways in the long-term. Infrastructure development depends on the predominated support scheme of the government. This means that the resilience of the farming system also relies on the national and European government.

1. Introduction

1.1 Background

European agriculture is facing multiple **economic, environmental, institutional and social** challenges at regional, national and global level which are threatening the stability of production.

Environmental challenges are, for instance, more extreme weather events such as heat waves and extreme precipitation, which cause an increased volatility in agricultural production (IPCC, 2014). One example is the summer 2018, in which droughts occurred in regions of Europe and caused harvest losses.
Social challenges are, among others, finding farm succession (Fennell, 1981; Mishra et al., 2004; Wheeler et al., 2012) to keep farming business alive and to have working force available in rural areas (EU, 2012). The demographic change is one cause, which comprises e.g. the trend of aging population (EU, 2012). Another challenge is that this trend and the trend of emigration of people to the cities, leads also to decline in attractiveness of rural areas and the social infrastructure, like hospitals, schools, public transportation (Stoate et al., 2001).
Economic challenges are, for example, the uncertainty of farmers' profit through more volatile producer and input prices (Rosin et al., 2013; Gertel and Sippel, 2016). Also, an economic challenge is the market orientation of the farmer since in the last years a changing consumer preference can be observed. Certain consumer groups are more aware of production conditions and the impact on environmental and social conditions, which leads to a development of a market for organic and fair-trade products (Spiller and Nitzko, 2015).
Institutional challenges are the dependency of farmers on landowners and financial institutions for their profitability (Gertel and Sippel, 2016) and the continuous change in the legal framework, which brings a lack of stability for the farmers and a high administrative burden.

All these challenges lead to uncertainty of long-term viability of food and other agricultural production. It is necessary to increase the resilience and sustainability of the farming systems. A system's resilience is, enabling the production by maintaining its functionality in the face of perturbations, thus being able to withstand disturbances and to adapt and transform in response to change (Tendall et al., 2015).

This thesis is organized in two parts. In the first part it has the purpose of assessing the resilience of a case study in a region called Altmark in Germany, with large-scale cooperative farms. In the second part regional scenarios are developed to assess the demographic situation in the case study region by scaling down the Shared Socioeconomic Pathways. The thesis is conducted as part of the European "Towards SUstainable and REsilient EU FARMing systems" (SURE-Farm) project. Therefore, the SURE-Farm project is introduced in section 1.2, the resilience concept of the project in section 1.3, the concept of the shared socioeconomic pathways is explained in section 1.4 and the German case study in section 1.5. Section 1.6 includes the research questions.

1.2 The SURE-Farm Project

The "Towards SUstainable and REsilient EU FARMing systems" (SURE-Farm) project is investigating the resilience and sustainability of European agriculture, since it is facing multiple economic, environmental, institutional and social challenges at different levels. SURE-Farm is joined by 16 European partners. It comprises eleven different case studies all over Europe to analyze, assess and improve the resilience and sustainability of farming systems in Europe (SURE-Farm website, 2017). The project is funded by the

Horizon 2020 work program and SURE-Farm contributes to the work program on Sustainable Food Security – resilient and resource efficient value chain.

SURE-Farm is analyzing the resilience and sustainability of the farming system rather than of single farms. Farming systems are interconnected via the different actors (Ge et al., 2016). A farming system is defined as a system hierarchy level above the farm (Giller, 2013) where those actors interact in a formal and informal manner. Actors participating in the value chain are farmers, consumers, retailers and supermarkets among other forms of sales, policy makers, NGOs, and companies for agricultural inputs. Assessing the performance on a farming system level demands an assessment which takes this into account.

One part of the SURE-Farm project is the work package (WP) 5. The aim of WP 5 is to determine the integrated impact of resilience-enhancing strategies on the selected farming systems in all case studies, regarding their performance. For this aim the integrated assessment (IA) tool is used. It is operating through existing static and dynamic, quantitative and qualitative Models (Herrera et al., 2018). The IA-tool includes models, as for example, the Agricultural Policy Simulator (AgriPoliS), and the Framework for Participatory Impact Assessment adapted for SURE-Farm (FoPIA-Surefarm), among other models.

1.3 Resilience concept of the SURE-Farm project

1.3.1 Resilience thinking

Resilience thinking is an approach to investigate the dynamics and development of complex social-ecological systems (Folke et al, 2010). There are different definitions of resilience, therefore, a careful consideration of the specific meaning in different contexts is needed (Newton 2016). The concept of resilience has been used in different disciplines for instance, in economy, psychology as well as ecology (Altieri et al., 2015). In 1973 the resilience term was introduced in relation to natural ecosystems by Holling (1973), referring to the capacity of these systems to bounce back to their original state after a perturbation. In the resilience framework of the SURE-Farm project resilience of a farming system is defined as "*its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of robustness, adaptability and transformability"* (Meuwissen et al., 2018). The resilience framework analyses the dynamics of the functions, which delivery is defined as the performance of a farming system. Those functions are defined as eight functions which provide private and public goods. (Meuwissen et al., 2018). A list of the functions is reported in section 2.1.1.

In the SURE-Farm project there are certain **attributes** defined, which have an impact on the resilience of the system, in case they are found to be present in the system (Meuwissen et al., 2018). Cabell and Oelofse (2012) determine 13 attributes, which contribute to the resilience of social-ecological systems. Those attributes describe characteristics of a system which positively impacts the resilience. Resilience attributes are defined to contribute to the resilience of farming systems in such a way that they improve the functions of the farming system. For example, "socially self-organized networks of e.g. farmers, consumers and the community" is one attribute. The whole list of attributes is presented in Table A9.

1.3.2 Adaptive cycle with main processes

The concept of resilience used in the SURE-Farm project builds on the adaptive cycles, as they are characterized by Holling et al. (2002). There are different stages which a system is passing in the dynamics of the adaptive cycle. Those stages are growth, equilibrium, collapse and reorientation (Figure 1). A system

is exploiting resources in the first stage (growth), becomes more stable and less flexible in conservation stage (equilibrium), and collapses in the third stage (collapse). In the last stage the system can take opportunities and innovation (reorganization) (Holling & Gunderson, 2002; Walker et al., 2004). Systems can have different speed, direction, sequence and different duration in the four stages of the passing the cycles.

Several different processes are important in shaping the dynamics of farming systems. For example, political decisions, changes in markets and technical innovation can change the developments in agriculture. Therefore, next to the process **of agricultural practices** also the processes of **farm demographics, governance and risk management** are assessed in the SURE-Farm concept (Figure 1). Agricultural practices include all agricultural and processing activities undertaken by farms and the whole farming system, leading to the provision of private and public goods. Private goods comprise, for instance, food and fiber production while public goods are, for instance, regulating services for climate change mitigation (Reidsma et al., 2010) or the preservation of cultural services such as landscapes. Farm demographics concern the provision of labor to farming systems, capturing both farm populations and hired labor force. Governance embraces elements of the Common Agricultural Policy (CAP) and its national transpositions and public and private regulations, affecting agricultural production chains. Finally, risk management is defined as on-farm risk management, as well as risk sharing within a farming system. Thus, it comprises both public and private risk management strategies (Meuwissen et al., 2018).

All four processes can be linked to the selected 13 resilience attributes. It is defined that the attributes have an impact on the resilience of one or several of the processes, in case they are applied in the system. The classification, which attributes is linked to which process was done according to the SURE-Farm project and is presented in the Appendix (Table A9).

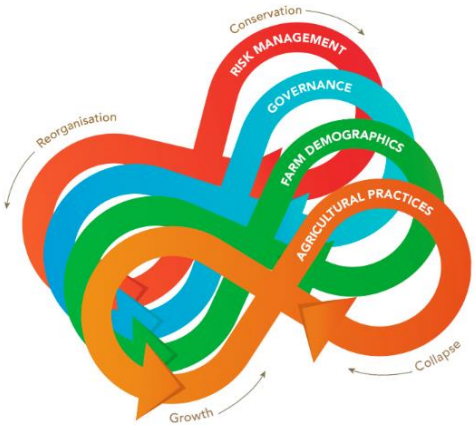

Figure 1. Adaptive cycles concept from Holling (2002) with the 4 defined processes defining a farming system in the SURE-Farm project. Source: Meuwissen et al. (2018).

The occurrence of a change in a stage of one process can speed up or slow down the dynamics of the other process cycles. Existing frameworks do not sufficiently represent the interconnectedness between those processes and the multiple stakeholders in the farming system. Understanding of resilience can be enhanced through the understanding of the theory of adaptive cycles (Carpenter et al., 2001) even though it is only theoretical and, in some cases, not all stages of the farming system might be visible.

1.3.3 Resilience principles

At the same time the mentioned resilience attributes are assessed in the context of five generic principles, which describe resilience. Those resilience principles are proposed by the Resilience Alliance. Those five principles are 1) diversity, 2) openness, 3) tightness of feedback, 4) system reserves and 5) modularity (Resilience Alliance, 2010). The principle of diversity can be applied for functional diversity (Kerner and Thomas, 2014) or response diversity. Response diversity refers to the ability of a system to have a diverse response mechanism to disturbances (Reidsma and Ewert, 2008). The principle of openness refers to how connected certain elements of a system are (Carpenter, 2012). Tightness of feedback refers to how one part of a system changes in response of the dynamics of another part of the system (Walker and Salt, 2006). The principle of system reserves defines the redundancy of certain reserves in the system (economic, natural, social and human capital) (Kerner and Thomas, 2014). System reserves indicate a certain puffer capacity of the system to withstand socks. Lastly modularity refers to the subdivision of a system in parts which, which are still connected to each other (Carpenter, 2012).

The in section 1.3.1 mentioned resilience attributes (Cabell and Oelofse 2012) are also linked to the 5 principles in the SURE-Farm project, according the impact an attribute has on the characteristics of the system (see Table 9A).

1.3.4 Resilience capacities – robustness, adaptability and transformability

According to Folke (2010), resilience can be divided in three different capacities, which are robustness, adaptability and transformability.

Robustness can be illustrated through the dynamics of the essential functions of the farming system. It is the capacity to maintain desired levels of outputs despite the occurrence of perturbations (Urruty et al., 2016). Robustness can be measured, for instance, through the recovery rate, which is presented through the time needed to bounce back to the essential functions (Scheffer et al., 2012).
Adaptability can be illustrated through the relationship between risks and responses. Adaptability is the capacity to adjust responses to changing external drivers and internal processes of the system and therefore maintain the essential functions of the system (Folke et al., 2010) This can be measured by the space which is available for responses of the system to adapt to risks.
Transformability is the occurrence of a new farming system. It is the "capacity to create a fundamentally new system when the existing system is untenable" (Walker et al., 2010) and can be measured through the space for options of the transformed system to function.

In the past, resilience was seen mostly only as robustness, which means, that the option of overcoming challenges through a system transformation could be overlooked (Meuwissen et al. 2018). Also known is that robust systems have less capacity to be transformative, since they are less flexible (Hoekstra et al., 2018). In this thesis the dependencies on the different resilience capacities will be taken into account.

1.4 Concept of Shared Socioeconomic Pathways

To improve understanding of the complex interactions of e.g. the ecosystems, climate system and human activities, research communities develop and use scenarios (Moss et al, 2010). Scenarios for long-term analyses at global scale were used by the climate change research community already for more than 20 years (Leggett et al., 1992, Nakicenovic et al., 2000, Raskin et al., 2005, van Vuuren et al., 2012). When

applied in climate change research, scenarios evaluate the uncertainty of e.g. temperature increase in scenarios of different challenges of mitigation (measures to reduce net emissions) and adaptation (actions that facilitate response to new climate conditions) (Moss et al, 2010). Later, the research community developed a next generation of scenarios, the Shared Socioeconomic Pathways (SSPs) (Moss et al. 2010; Kriegler et al., 2012). These scenarios are storylines that qualitatively describe pathways of plausible socioeconomic conditions of e.g. economic growth in the next century (Kriegler et al., 201, O'Neill et al., 2014). The SSPs are designed to describe pathways in which societal trends result in making mitigation of, or adaptation to, climate change harder or easier, without explicitly considering climate policies or climate change itself. (O'Neill et al., 2017)

The SSPs are specific combinations of socioeconomic challenges to mitigate and adapt and are defined in the following paragraph. 1) The "**sustainable scenario"** describes a future global socioeconomic development focused on sustainable gains and equality with low challenges for mitigation and adaptation (SSP1). 2) The "**middle of the road scenario"** describes a "business-as-usual" socioeconomic development and therefore challenges to mitigation and adaptation are medium (SSP2). 3) The "**unsustainable scenario"** describes a fragmented world, in which a breakdown of international cooperation and globalizations leads to high challenges of mitigation and adaptation (SSP3). 4) The "**inequality scenario"** describes a world characterized by increasing inequality in society regarding the economic growth etc. and therefore has high challenges to adaptation. This scenario development relies on resources which are not exploiting nature and therefore has low challenges to mitigate (SSP4). 5) "**Fossil fuel driven scenario"** describes a world with rapid technological progress, development of human capital, and economic growth strongly relying on fossil fuels. Therefore it is characterized by high challenges to mitigation and low challenges to adaptation (SSP5).

These scenarios are used to inform large scale integrated assessments which describe, explain and explore cause-effect relations to deliver useful information for policy and decision-maker (Van Ittersum et al 2008; Rotmans and Asselt, 2001). Integrated Assessment has been defined as "an interdisciplinary and participatory process combining, interpreting and communicating knowledge from diverse scientific disciplines to allow a better understanding of complex phenomena" (Rotmans and van Asselt, 1996).

1.4.1 Shared Socioeconomic Pathways for European and regional agriculture

The SSPs are used by different scientists to assess e.g. the trends of the agricultural sector at European scale. The global SSPs do only include some elements to describe the agricultural sector. Meaning that e.g. socio-economic and technological elements to describe scenarios of the agricultural sector are not covered in the global SSP's. Also, the global scenarios do not cover political conditions which are important for the regional characteristic (Mitter et al., 2018). Therefore, the development of European scenarios which cover the agricultural sector (Eur-Agri-SSPs) was done by Mitter et al. (2018).

To create regional scenarios, the Eur-Agri-SSPs can be scaled down even more. For the development of additional scenarios, new storylines, which describe the dynamics of the elements (e.g. technological uptake) have to be created. Therefore, an understanding of the reginal challenges and factors of the demographic change is necessary for the execution of the scenario development. This understanding can be reached through stakeholder involvement, which takes their perspective into account. Mitter et al. (2018), developed quality criteria of the storylines, which are necessary to meet in the processes of scenario development.

To guarantee the quality of the storylines six generally expected product criteria are used to evaluate storylines and comprise: **plausibility, consistency, salience, legitimacy, richness and creativity** (Alcamo and Henrichs, 2008; Cash et al., 2003; Rounsevell and Metzger, 2010). The main challenge is to link global SSPs with regional perspectives and maintain the **vertical consistency** at the same time. Vertical consistency is defined as the link of the storylines between scales. This refers to the fact that larger scale storylines provide boundary conditions for smaller scale storylines. **Richness** implies a sufficient number of used storyline elements, to guarantee comprehensiveness (Alcamo, 2008). **Salience** concerns the relevance of the storylines for the target group. **Plausibility** describes the likelihood of the drawn storylines to occur in the future (Alcamo and Henrichs, 2008). **Legitimacy** describes a sufficient and transparent participation of stakeholder to guarantee the fair reflection of perspectives in the storylines (Cash et al., 2003; Rounsevell and Metzger, 2010). **Creativity** describes differences between storyline elements, to guarantee that potentially even not expected storylines are included (Alcamo and Henrichs, 2008).

1.5 German large-scale corporate arable farming systems

The region of the German case study is called "Altmark". It is located in the North of the German federal state "Sachsen-Anhalt," which is in the East of Germany, and consists of the two districts "Stendal" and "Altmarkkreis Salzwedel" (see Figure 2). The structure of the agricultural production system reflects the large-scale agricultural structures of East German agriculture but also comprises small farm structure. Thus, farm size is heterogonous. Compared to other districts in the federal state the Altmark has with 27% a high share of grassland, the soils are rather poor and the yields of the arable farmers rather low (Appel and Balmann, 2018).

Figure 2: Case study area in Germany

Altmark also comprises almost half of the cow population of Sachsen-Anhalt. Most of the utilized agricultural area is used by mixed farms, while the highest number of farms are the arable farms. In terms of utilized agricultural area, cooperate farms have the highest share, but in terms of the number of farms family farms comprise half the share. This is reflected in the fact that most of the cooperative farms are very large farms. The particularities of many large corporate farms in the East Germany, has a socialist history. The current structure of the farming system of the Altmark is influenced by the German Democratic Republic from 1949 till 1990. In the beginning of that era, farms were transformed into state farms and collectives and therefore the size of the individual farm increased. After the reunion of West and East Germany many of the farmers decided not to reclaim their land to work as independent farmer but became members of cooperatives. Other farmers claimed their land back and started again farming businesses. Also, a small number of farmers migrated from West Germany and from the Netherlands to East Germany after the reunion, to overtake the farm management of those cooperatives. This is a reason for the heterogeneity of the farm sizes.

There are several challenges which this farming system is facing. Environmental challenges are the periods of drought in early summer which are affecting the yields and the rather wet winter which makes the access

to the fields difficult due to waterlogged soils. Another environmental challenge is the water access for some farms. This is due to implemented infrastructure of the water canal system during the German Democratic Republic. The right to use this infrastructure is not equally distributed. Especially farmers who are dependent on artificial watering systems for their crops are impacted. Impacts also vary because the precipitation is not equally distributed over the area.

The demographic situation is dynamic which is especially relevant for the Altmark region. The limitation of skilled labor with suitable education is a big social-economic challenge. This is due the aging population of farmers and emigration occurring in the region (Zawalińska et al., 2018). It is also challenging to find successors for the farming businesses. Emigration takes place also due to little social infrastructure e.g. of hospitals, and daycare facility for children. Also, the internet infrastructure is not sufficient. The demographic situation is one of the main challenges of the Altmark region.

1.6 Research Objective

As previously stated, the objective of the SURE-Farm project is to assess, analyze and improve the resilience and sustainability of European farming systems (https://surefarmproject.eu/, 2018). The main purpose of this thesis is to assess and analyze the current resilience of farming system of the German case study in Altmark. In addition, regional scenarios for farm demographics are developed as bases for future resilience assessment.
Therefore, the first research question is defined as following: *What is the current resilience of farming systems in Altmark, East Germany?*
This question is answered by the following: *What is the importance and performance of essential functions and indicators? What are strategies to improve resilience and how do they contribute to the resilience capacities? How present are resilience attributes and how do they contribute to the resilience capacities?*

The assessment is done in a participatory approach, for which the FoPIA-Surefarm workshop is used as a tool. For this purpose, specific questions were elaborated. All sub questions are divided among the areas of interest and listed in the methodology section 2.1.

The second research question is focused on scenario development. For the Altmark region farm demographics is one of the main challenges that influence the resilience (1.5). Future scenarios are needed to understand how the demographic situation develops in storylines. Storylines are used to find a description of trends in certain scenarios, through an internally consistent logic of the main causal relationships. Those scenarios can also deliver information of trends to integrated assessment tools, which describe, explain and explore cause-effect relations to deliver useful information for decision-maker. Scenarios are available at European level (Eur-Agri-SSPs described in section1.4) and those can be used to develop regional, sectorial scenarios. This has to be done through stakeholder involvement, since their perspective of changes of the demographic situation is necessary to be able to adapt it to regional, sectorial scale. Those adapted scenarios allow to explore the resilience of the system in the future.

Information from FoPIA-Surefarm, and other SURE-Farm activities will be used as sources (see methodology). Therefore, the further research aim is: *What do the obtained results imply for the description of trends for the demographic situation in the developed scenarios (the adapted five SSP'S).* To use the scenario development for the SURE-Farm project, the research question is: *What do the developed scenarios (explored future conditions) imply for the resilience in the Altmark region?*

2. Methodology

2.1 Framework of Participatory Impact Assessment of Sustainable and Resilient EU FARMing systems (FoPIA-Surefarm)

FoPIA-Surefarm is a tool which is built on a participatory approach. It builds on three frameworks that are used for its development: 1) the Framework for Participatory Impact Assessment (Morris et al., 2011), 2) the Resilience Assessment Framework (Resilience Alliance, 2010) and 3) the Participatory Approach used for system dynamics modelling by the University of Bergen (Herrera, 2017). FoPIA-Surefarm was developed within the EU project SENSOR and is also used for other projects. In FoPIA-Surefarm, a semi-quantitative approach was used to summarize judgments of participants on performance of sustainability indicators (Reidsma et al., 2018). For FoPIA-Surefarm a workshop, which assessed the past and current resilience and sustainability of the production system, was conducted. This workshop is used as results for this thesis.

In five steps the resilience and sustainability of the farming system was assessed in the FoPIA-Surefarm by using the resilience framework (see Figure 3).

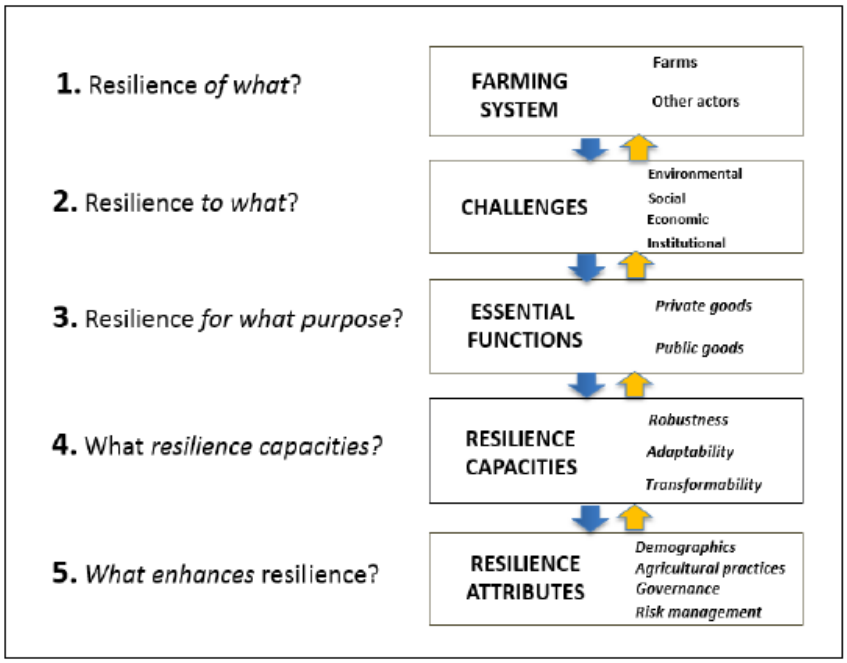

Figure 3 Resilience framework from the SURE-Farm Deliverable 5.2.1 (Reidsma et al., 2018).

In the FoPIA-Surefarm approach, the first three steps are to clearly define the system (resilience *of what*), to identify the challenges faced by the system (resilience *to what*) and to assess the system functions (resilience *for what purpose*). After these steps, the resilience is analysed by distinguishing between the three capacities which are robustness, adaptability and transformability (see section 1.3.3). In the last step the resilience attributes are analysed. Resilience attributes improve the resilience capacities (see 1.3, List of 13 attributes is in the Appendix, Table A9). In this step is was assessed how the attributes are related to the four introduced main processes of the production system (1.3.2). Also, it was assessed how the attributes can be linked to the introduced resilience principles (1.3.3). By linking the attributes with the main

processes and the resilience principles the characteristic of the farming system resilience can be better identified. It was identified which of the processes is better linked to resilience attributes and therefor relevant in the resilience of the system. The principles were linked to the attributes to characterize the type of resilience better.

2.1.1 Preparation phase

Before the workshop was realized, it was carefully prepared in the team of researchers. In the first step the farming system was identified, in the second step the challenges of the farming system were defined and in the third step the functions and indicators of the farming system were identified.

The farming system was identified by the main farm type, the actors of the farming system and the dependency of the actors in the farming system. The researcher team of the case studies was defining the farming system with literature research and also through the deliverables D1.3, D3.1, D8.2 of the project. To define the actors of the farming system certain boundaries, had to be drawn (see Figure 4).

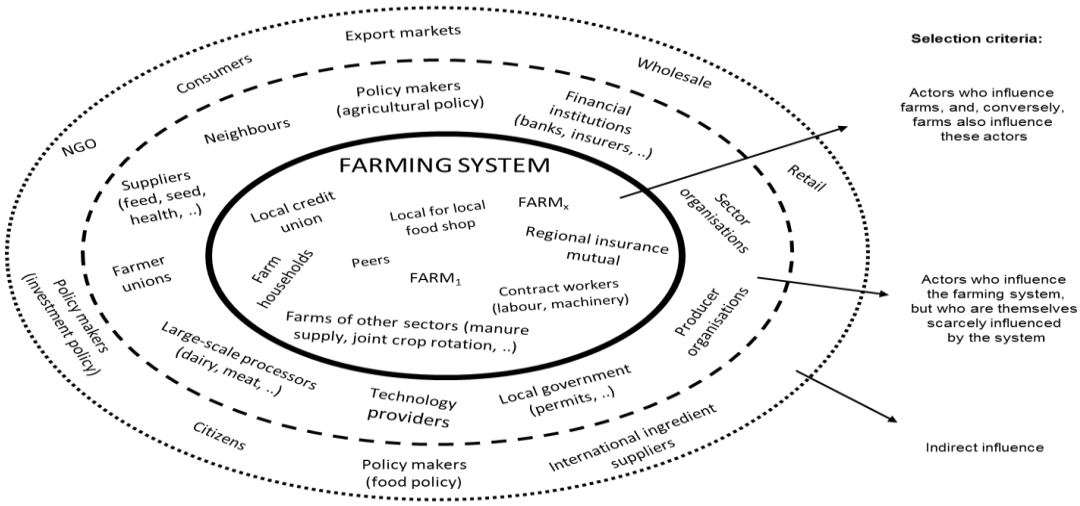

Figure 4: Example of actors in relation to a farming system. From SURE-Farm Deliverable 1.1 (Meuwissen et al., 2018).

The first types of actors are those, who are influencing the farming system, and which are vice versa influenced by the farming system (inner circles in Figure 4). For FoPIA-Surefarm these actors are most relevant. The second type of actors are those, who are influencing the farming system but who are not influenced by the farming system (middle ring in Figure 4). The third types of actors are those, who are neither influencing the farming system not influenced by it. These questions were answered:

- What are the main actors/stakeholders in the farming system?
- For which of these actors/stakeholders there is strong mutual dependence (actors influence farms, and conversely, farms also influence these actors)?

Challenges were defined in the second step of the resilience framework (Figure 3). They were distinguished between four dimensions, which are environmental, economic, social and institutional and 2 types of challenges, which are shocks and long-term pressures. This question was answered:

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

In the third part the **functions** of the farming system were determined. The SURE-Farm project defines eight functions. The functions are categorized into two groups: private goods and public goods. The four functions categorized as private goods are: food production, bio-based resources, economic viability, and quality of life. The four functions categorized as public goods are: Natural resources, biodiversity and habitat, attractiveness of the area, and animal health and welfare.

The case study develops between 1 and 3 specific indicators for the functions in the region. This question was answered:

- Which indicators reflect the essential functions provided by the farming system?

2.1.2 Workshop realization

The data collection was done in the SURE-Farm workshop, which was conducted in one day (see 7.1). For the workshop different stakeholders were invited, who are representing the farming system. Ideally, 30 stakeholders were invited, who are representing farmers, government, NGOs and industry preferable in a ratio of 40 : 20 : 20 : 20. In the beginning of the workshop the defined farming system with actors, challenges and essential functions was presented to the participating stakeholders. The purpose of this was to explain the farming system but also to ask the stakeholders if some important information is missing from their expert perspective.

Then the importance of both the **functions and the indicators** were scored. The functions were scored by dividing 100 points between the eight functions. In case the 100 points which were allocated to the eight functions did not add up to 100, the points were normalized. This was done make them sum up to 100. At the same time the scores for the function was used to sum them up to assess the sores for importance of the private and public goods.

Then, the indicators were scored by dividing 100 points between the indicators of the farming system's functions. Depending on the number of defined indicators per functions, the 100 points were divided between either two, three or four indicators. Afterwards, the values for the importance of the indicators were transformed according to Equation 1.

$$Transformed\ value = function\ scoring * (indicator\ scoring/100) * nr\ indicators\ for\ the\ function \qquad \textit{Equation 1}$$

In Equation 1 *transformed values* stands for the transformed importance score of the indicators. The *function scoring* stands for the score of the importance allocated to the function, while the *indicator scoring* stands for the score of the importance allocated to the indicator. *Nr of indicators for the function* indicates the amount 0f indicator defining the function, which was chosen beforehand.

Also, the performance of the indicators of the functions were scored in a scale from 1 to 5 (1: does not perform and 5: very good performance). Already during the workshop, the importance and performance of the functions and indicators were transcribed into an Excel sheet and evaluated in a graph. By analyzing both the importance and the performance of the indicators, the most important once could be selected to continue with. The selection was done in discussion with the participants and is focused on the important indicators, which were performing relatively poor compared to the others. These questions were answered:

- 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?

- What is the current performance of the indicators?
- Which indicators shape the identity of the farming system? Which are most relevant to evaluate in next steps: historical trends, resilience and current performance?

Resilience capacities were determined during the workshop with the attending stakeholders. This was done by sketching the performance of selected indicators of functions over a timespan of the last 18 years (year 200 till 2018). This was done during a discussion in groups of at least three people (group involving different stakeholders). One group was discussion the dynamics of the performance of only one indicator. In total the three indicators "gross margin", "wages" and "animal welfare" were discussed. The discussion was moderated by a researcher. Challenges, which are affecting the performance of the specific indicator, were captured. Also, the strategies which are used to counteract the impacted performance were noted. Stakeholders in the groups draw the perceived performance of the indicators on a printed graph. The y-axis was indicating the timespan of the last 18 years (2000 till 2018) and the y- axis indicated the perceived performance in a scale of 80 to 140 percent. After the group discussions all three groups came together to the plenary group. Here the three groups presented the dynamics of the indicators they were discussing to the plenary. This was done by drawing the dynamics of the indicators in one graph where the performance of the three indicators over the timespan of 18 years was compared. At the same time while presenting the dynamics of the stakeholder performance, the stakeholders indicated in an oral way which challenges, and strategies were impacting the performance of the indicator. Also, they indicated in a oral way to which extent (how many percent) the performance was increased or reduced. In the end this information was used by the evaluating researchers to create graphs of the performance of the three indicators in Microsoft word.

On the basis of this assessment **resilience capacity** was measured by the participants individually. Stakeholders scored the implementation of the strategies from a scale from 1 to 5 (1: no implementation and 5: full implementation). One step further the stakeholders were asked to correlate the used strategies with the three resilience capacities (robustness, adaptivity, transformability). This was done by scoring the strategies contribution to the three capacities with values between -3 and +3 (-3: strong negative impact of the strategy and resilience capacity, 0: no impact and 3: strong positive impact).

These following questions were answered:

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

Resilience attributes were assessed also by the stakeholders individually (see 1.3). First the13 attributes were presented by the moderator of the workshop and explained in their meaning. Then the participants were scoring the implementation of the attributes from a scale from 1 to 5 (1: no implementation and 5: full implementation). One step further the participants again scored the correlation between the attribute and the three different resilience capacities from -3 to +3 (-3: strong negative impact of the attribute on the resilience capacity, 0: no impact and 3: strong positive impact).

The level of application of the resilience attributes and the contribution to the resilience capacity was combined to assess the overall score of the resilience capacities of one or several attributes. This was calculated following the Equation 2 and Equation 3.

$$Overall\ resilience \text{ capacity} = (\sum i \text{ application level} * potential\ contribution) / \text{nr } of\ scored\ attributes \qquad \textit{Equation 2}$$

$$\text{Application level} = (\text{application level} - minimum\ level) / (maximum\ level - minimum\ level) = (\text{application level} - 1) / (5 - 1) \qquad \textit{Equation 3}$$

These following questions were answered:

- What is the relationship between general resilience attributes and the resilience (robustness/adaptability/transformability) of main indicators of the farming system?
- Are there additional resilience attributes, specific for the case-study area? And how do they relate to resilience (robustness/adaptability/transformability) of main indicators of the farming system? Which resilience attributes are most important for the different resilience capacities of the farming system?
- To which of the of the defined four processes and five principles can the most important attributes be linked and is that in line with the SURE-Farm framework? What does the linkage of the attributes with the four processes and five principles imply for the farming system resilience?

2.1.4 FoPIA-Surefarm workshop setting

The FoPIA-Surefarm workshop was conducted on the 9th of January in community Zethlingen in the Altmark region. A diverse set of stakeholders participated in the workshop. The participants were grouped into 3 groups, which are “farmers”, “politicians and NGOs” and “researchers and consultants”. The distribution of the participants into the groups is presented in Table 1. The whole participants list can be found in the appendix in Table A1.

Table 1: Division of the participants into the groups with further description of stakeholders.

Stakeholder group	Amount	Description
Farmers	5	3 conventional, 1 organic and 1 student/successor
Politicians and NGOs	4	1 from the green party, 1 from the Social Democratic Party and 2 from NGOs
Researchers and consultants	3	1 consultant, 1 consultant from a local credit union and 1 from applied science

2.1.3 Data evaluation

The collected Data were processed in Excel. This was mainly done by calculating averages and standard deviations (using a p-value of 0.05), considering the values for each category of stakeholders separately. Differences between stakeholders were assessed for importance and performance score of functions and indicators with the Kruskal test. Significance between resilience capacities of the strategies and resilience attributed was assessed with the Kruskal Wallis test. All group discussions were recorded by the researcher team for the further evaluation.

2.2 Scenario development for the Altmark region

The development of Shared Socioeconomic Pathways representing the Demographic Dynamics of the Altmark region (DDA-SSPs), was executed using the protocol developed by Mitter et al. (2018). In the work of Mitter at al. (2018), the Shared socioeconomic pathways for European agriculture (Eur-Agri-SSPs) were developed by scaling the global Shared Socioeconomic Pathways (SSP) (O'Neill et al., 2014) to an European level in the context of the agricultural sector. The concept of the SSP's is briefly explained in the introduction (1.4). In this thesis those Eur-Agri-SSPs were adjusted to Socio-economic Pathways for the Demographic Dynamics in the Altmark region (DDA-SSPs).

2.2.1 Used information from participatory approach

For the scenario development certain steps (explained in section 2.2.2), were executed using results of the 1) FoPIA-Surefarm workshop, 2) AgriPoliS Focus Group Workshop (AFGW) and 3) Farm Demographic survey (FDS). All those studies were part of the SURE-Farm project (see 1.2) and were conducted in a participatory approach to assess resilience in the Altmark region. Hence, the information gained in those studies is further referred to as "data from participatory approach". None of the studies has the primal purpose to be used for the regional scenario development. The purpose of those three studies and which results were used are briefly explained in Table 2. The results and the whole structure of the AgriPoliS Focus Group Workshop is presented in Pitson et al. (2019); results and structure of the Farm Demographic Survey is presented in Klein, (2019) and the results and the structure of the FoPIA-Surefarm workshop is presented in the first results part of this thesis.

Table 2: Description of purpose and used results of three studies for the regional scenario development.

	FoPIA-Surefarm workshop	**AgriPoliS Focus Group Workshop**	**Farm Demographic Survey**
Purpose	Assessment of the past and current resilience and sustainability of the farming system	Focus group discussions to assess the demographic change in the region and on farms	Surveys identifies factors of the demographic change on farms
Used results	Identified challenges (for the farming system performance) which are influencing the demographic dynamics of the farming system	Identified factors of the demographic change; and analyses how labor issues (as factors of the demographic change) impact demographic dynamics on farms	Identified factors of demographic change (internal and external factors) and their influence demographic dynamics on farms

2.2.2 Steps for the scenario development

The executed steps for the scenario development are 1) defining key characteristics 2) setting-up the actors' groups 3) defining storyline elements 4) drafting storylines, and 5) consistency check (Figure 5). The emphasis was set on steps three to five, since they are at the core of the scenario development.

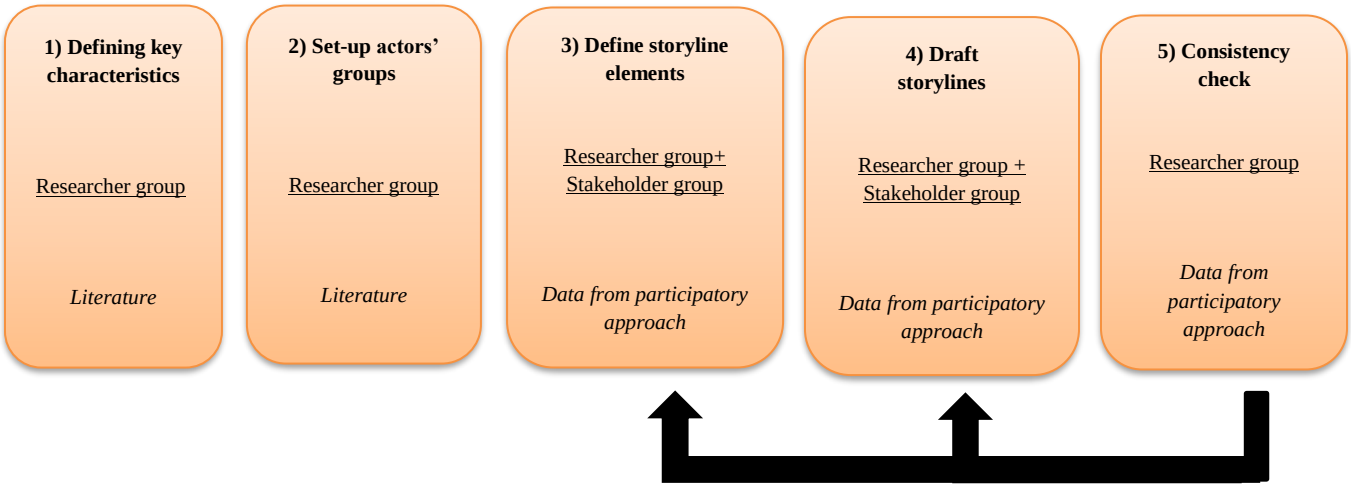

Figure 5: Five steps for scenario development (bold font) with involved actors (underlined) and used information (italics) for execution (Adapted from: Mitter et al. 2018). Step five is also applied in step 3 and four, which is indicated by the black arrow.

In the steps different actors contributed and different information sources were used to execute the steps. The "researcher group" consisted of researches from the "Leibniz Institute of Agricultural Development in Transition Economies" (IAMO) in Germany and researchers from Wageningen University and Research. The "stakeholder group" refers to the stakeholders that participated in the different participatory approaches (will be explained in Step 2 of this section).

Following (in this section), all steps are elaborated in their sequence. The findings of steps three, four and five are presented in the results section. The consistency check (step five), is used in step three and four to guarantees the consistency of the used methods.

Step 1: Defining key characteristics

The key characteristics comprise the major goals and purposes of the scenario's storylines. The major goal was to extend the Eur-Agri-SSPs that they are applicable for *integrated assessments of agricultural systems (IAAS).* In the Altmark region the Agricultural Policy Simulator (AgriPOliS) is one part of the integrated assessment tool (explained in 1.4). AgriPoliS is an agent-based spatial model that facilitates one to simulate the development of regional agricultural structures over time in response to different scenarios of e.g. specific policies (Happe, 2004; Happe, et al., 2008; Sahrbacher et al., 2012; Balmann, 1997). In this thesis regional scenarios were developed to indicate trends of the demographic dynamics by extending the Eur-Agri-SSPs. Those storylines had the main purpose to find a description of trends in the scenarios, through an internally consistent logic of the main causal relationships (Riahia 2017). The developed regional scenarios were used to support the AgriPoliS model in delivering trends of the demographic dynamics. Those discovered trends help to cope with uncertainties of the future by quantified descriptions of the future (Reed et al. 2013; Swart et al. 2004). This step is conducted by the "researcher group".

Step 2: Set-up actors' groups

In this part of the thesis, as mentioned above, two actors' groups are defined: the "researcher group" and "stakeholder group". As already stated, the "researcher group" consist of researchers from IAMO and Wageningen University and Research. The "stakeholder group" consists of the stakeholders that already participated in one of the participatory approaches. After they participated, their input was used for the scenario development (explained in section 2.2.1). The stakeholder group consisted of stakeholders from different farming systems domains, and comprised of farmers, politicians, consultants, people from NGOs, and scientists. The biggest share of the stakeholder group belonged to the farmer community. The number of stakeholders involved in each study is presented in Table 3.

Table 3. Number of stakeholders involved in the three studies used for the scenario development.

	FoPIA-Surefarm workshop	**AgriPoliS focus group workshop**	**Farm Demographic survey**
Number of Stakeholders	12	4	12

Step 3: Defining storyline elements

The regional storyline elements to describe the demographic dynamics were developed by scaling down and adapt the Eur-Agri-SSPs. The five Eur-Agri-SSPs pathways are structured according to challenges for mitigation and adaption. The organization of the Eur-Agri-SSPs follow the same structure as the global SSPs (1.4). Therefore, Eur-Agri-SSP 1 is the "sustainable" scenario, Eur-Agri-SSP 2 is the "middle of the road" scenario, Eur-Agri-SSP 3 is the "unsustainable scenario", Eur-Agri-SSP 4 is the "inequality" scenarios and Eur-Agri-SSP 5 is the "fossil-fuel driven" scenario (Mitter et al., 2018).
A list of 10 storyline elements were selected from the Eur-Agri-SSPs by the researcher team, during the process of scaling down and adapting the storyline (Table 4).

To identify the regional storylines, the storyline elements of the Eur-Agri-SSPs had to be scaled down. This was done in a nesting approach. Nesting entails that qualitative storylines are identified and enriched at the smaller scale (Kok et al., 2006; Leadley et al., 2010). In case the element is identified by e.g. geo-biophysical, socio-economic, and cultural background conditions or political guidelines specific for the region, the boundary conditions of the elements had to enriched (Schönhart et al., 2017; Mitter et al., 2018). One example is that the storyline element "population size" is identified by socio-economic boundary conditions for the region and therefore has to be enriched to "population size in region". On the other hand, the storyline element "predominant type of support scheme" is identified by the political guidance for whole Europa and therefore does not have to be enriched. This enrichment of the storyline elements was conducted and is presented in Table 4.

Table 4: Selected storyline elements from the Eur-Agri-SSPs (Mitter et al., 2018), for the scenario development for the demographic situation in the Altmark region, organized according their domain and subdomain and assigned to the boundary conditions.

Domain	**Storyline Elements**	**Boundary conditions**
	Population size in region	Regional

Population and urbanization	Immigration to the region	Regional
	Level of infrastructure development in rural regions	National
	Age structure of farming population in region	Regional
	Educational level of the farming population in region	Regional
Economy	Economic growth in region	Regional
	Availability of labor in agriculture in region	Regional
	Type of work in agriculture in region	Regional
Policies	Predominant type of support scheme in Europe	European
Technology	Technological uptake in region	Regional

To adapt the regional storylines, there was a need to define *causes* and *effects* of demographic dynamics (challenges and factors) for the selected demographic elements (Loibl et al, 2010). The three participatory approaches (2.2.1) were used to deliver information on the *causes* of the demographic dynamics and their *effect* on the storyline elements. The participatory approaches were used to capture first the *causes* of demographic dynamics. All *causes* were marked in the reports of the information source, which were available as written document. Also, the *effects* (of those *causes*) on the storyline elements were marked in the report of the participatory approaches. Depending on the *cause*, either an increase/strengthening of the storyline element was observed and therefore a positive cause-effect relationship was given. Or in case the demographic dynamics effected a decreasing/weakening of the storyline element, a negative cause-effect relationship was given. The change in the storyline element can be defined as direction of change. Those cause-effect relationships were clustered to the storyline elements, (depending which storyline element was changed by the *effect*) to increase transparency of the process (Mitter at al. 2018).

Step 4: Drafting storyline

New storylines are necessary to identify trends of demographic dynamics in the regional scenarios. Focus was set to have clear narrative descriptions of the regional scenarios. This was reached by having understandable storylines structured according to the five scenario directions, which describe the future in a useful way (Alcamo et al., 2008). As indicated by Mitter et al. (2018) the regional scenarios should follow the same structure as the global and European SSP scenarios to maintain the **vertical consistence**. Therefore, the identified cause-effective relations with the assigned directions of change of the storyline elements, were assigned to the five scenarios. For this purpose, the *cause* of the cause-effect relations was analyzed in its statement and compared to the five scenarios narratives of the Eur-Agri-SSPs (see 2.2). Depending in which scenario narrative the statement of the *cause* is reflected (multiple scenario narratives are possible), the changed storyline element is assigned to one or several regional scenarios. With assigning the cause-effect relations to the regional storylines the **plausibility** of the regional scenarios is increased.

Step 5: Consistency check

The consistency check is part of the quality control (Mitter et al. 2018). It evaluated the connection of the storyline elements with the cause-effect relations and the drafts of the storylines. Those have to be evaluated and adapted until an acceptable level of consistency is reached. The consistency check was conducted through a causal- loop-diagram (CLD). A causal loop diagram is a diagram that visualizes the dynamics of elements in a system. The dynamics are simplified through cause-effect relationships given in a system which either strengthen/enrich or weaken/ reduce elements (Mathijs et al., 2018; Vervoort et al., 2016). By connecting all the causes and effects with the storyline elements, the internal logic of the system dynamics was tested and therefore the cause-effect relations were evaluated. In this process cause-effect relations

were withdrawn or adjusted, depending if they support the internal logic. Since the cause-effect relations are captured by the individual opinions of the stakeholders (taken from participatory approaches) those have to be evaluated if they reflect the general dynamics of the regional, agricultural sector. Also, it was evaluated if the regional storylines are described sufficiently by the used cause-effect relations to provide a comprehensive picture of future development.

The **plausibility** of the drawn storylines was evaluated by assessing if the direction of change was assigned to the right scenario. The CLD was used as visual facilitation to capture all directions of changes of the chose elements in the scenarios (see p. 57). By doing so contradictions of the changed storyline elements in the scenarios could be prevented. The CLD is created using the Vensim software (©Ventana Systems, 2015).

3. Results – FoPIA-Surefarm workshop

This results part comprises the outcome of the FoPIA-Surefarm workshop to assess the current resilience of the German farming system in the Altmark. It starts with a presentation of the farming systems actors (3.1). Following are presented the scores of the farming systems functions and indicators in their importance and performance (3.2, 3.3). In section 3.4 the selected indicators with the historical dynamics of the performance are described. The identified strategies and resilience attributes to increase current and past resilience and how they contribute to the resilience capacities are presented in section 3.5.

3.1 Farming system

Figure 6 presents the results of the farming system figure after the workshop. In the inner circle are actors which both influence and are equally influenced by the farming system. In the second circle are the actors which influence the farming system, but (relative to the actors in the inner circle) are only slightly influenced by the farming system. Finally, in the outer circle are actors that have an indirect influence on the farming system and are not influenced by the farming system. To reiterate, influence is a relative measure in this figure. The actors belonging to the three circles are described in the following sections.

During the workshop, the participants rearranged the position of the actors in the farming system figure based on their expert knowledge. As a result of the workshop, seven actors were added to the farming system. These additions are seen in green text in Figure 6 and the descriptive text. The actor, "local grocery store," was moved from one circle to another, which is indicated by a green arrow in the figure.

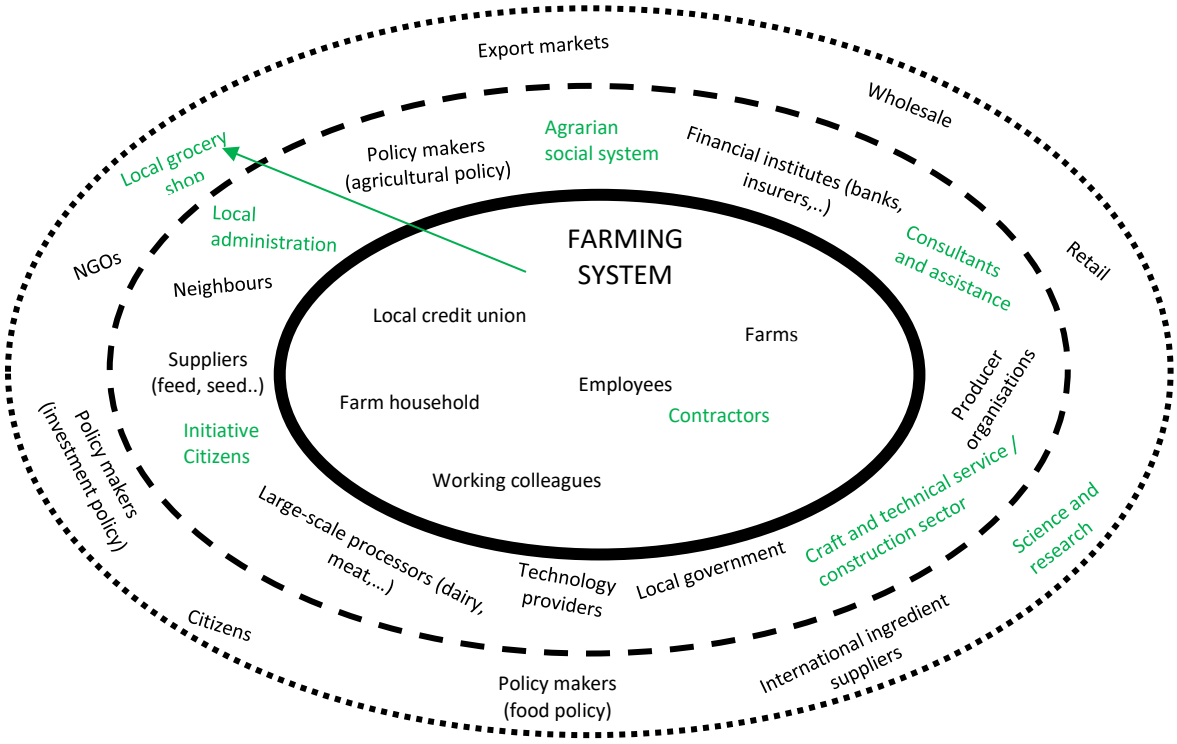

Figure 6. Updated farming system visualisation after feedback from participants. Updates are presented in green. Actors which moved between circles are indicated by a green arrow.

3.1.1 Actors in the inner circle

"Farms" and the "farm household" are providing jobs in the farming system which are executed by the "employees" and "contractors". "Local credit union" is providing the system with loans, but its performance depends on the investment of the farming system into loans. "Contractors" was added as an actor by the participants. "Contractors", which are service providers, are next to the family members and employees, an important part for the business of the farming system (e. g. for large-scale producers, suppliers). Service providers are essential because they deliver a certain quality of service and know-how, and therefore belong to the inner circle.

3.1.2 Actors in the second circle

In the Altmark region, actors like "seed and feed suppliers", "technology providers", the "construction sector," and "large-scale processors" are providing the farming systems with inputs. "Policy makers" in agricultural politics, "local government" and "administration" are steering the farming system through a given legal framework. "Craft and technical service and construction sector" was added because the agricultural and construction sectors have a mutual positive relationship. As one of the participants stated,

> *"[the] craft and technical service and construction sector" play a big role in generating income in rural areas. This is important because the industry itself in the Altmark region is not strong enough to generate income. If agriculture did not exist, then the craft and construction sector could not survive either. "*

An additional actor next to the local government is, according to the participants of the workshop, the "local administration". The role of this actor is on a community level and it is responsible for permits, e.g. it gives orders to block streets and roads. The "producer organisation" ("Deutscher Bauernverband") has influence by representing farmers' interests during policy-making processes. "Consultants" also have been added to the visualisation of the farming system. This actor has the function to give advice for funds, modification of buildings, assessments of the farms among other tasks. "The agrarian social system" was added as an actor by the participants. Quoting one of the participants:

> *"The agrarian social system", like health insurance, pension insurance for farmers is an actor in the farming system, which is influencing the farm performance".*

The system covers the farmer in case he or she is not able to work because of sickness and physical inability. The participants of the workshop suggested to add the actor "initiative citizens". The participants named this actor in this specific way. This actor may be distinguished from the actor, "citizens" because *initiative citizens* are representing a more active role. For example, those initiatives may include discussion rounds about agricultural topics. Those initiatives are influenced by present issues and the agricultural discourses. *Initiative citizens* also have to be distinguished from the actor "NGOs" because they are less structured and organized.

3.1.3 Actors in the outer circle

"Wholesalers" and "retailers" are actors of the third circle, which are important for the Altmark region. Other actors are "policy makers" in national politics and actors who are purchasing the products outside of Germany and suppling ingredients from abroad. Also, "non-governmental organisations" and "citizens", which are aligned with agricultural topics, are influencing the farming system. "Scientists" were missing,

as an actor. Not the fundamental research but the applied research. Applied science delivers new ideas for innovation in a farming system. Lastly the participants agreed to move the "local grocery shops" from the inner circle to the outer circle. It is very difficult for the farmers to use the supermarket as a selling platform to earn sufficient money because of the price competition. Also, direct marketing is not reached easily by the farmers because of the rural structures and lack of sufficient demand.

3.2 Functions

3.2.1 Importance private goods vs. public goods

On average, among the stakeholder groups, the importance of private goods scored marginally higher than private goods (Figure 7). This preference is highest for the stakeholder group *researchers and consultants* and smallest for *politicians and NGOs*. For the private goods the function "food production" scored highest with 20 points on average between the stakeholders (see Appendix B, Table A2). The function "economic viability" follows with 17 points on average. For the public goods the function "natural resources" scores highest, with 14 points on average. The function "animal health and welfare" (also belong to public goods) is scored lowest overall with 9 points on average.

3.2.2 Differences among stakeholders

For the function "food production" there is a high scoring (30) from the stakeholder group of *researchers and consultants* (Figure 7). Their score is more than double compared to the one from the *farmers (14)*, but the standard deviation is also highest for *researchers and consultants* (Table A2). For the function of "economic viability" the score from the *farmers* is by far highest with 27 points. Also, here the standard deviation for *farmers* is rather high. Standard deviation is highest for "economic viability", followed by "food production", indicating different points of view among participants (Table A2). "Animal health and welfare" is scored highest by *politicians and NGOs* compared to other stakeholder groups. There is no significant difference in the scoring of the functions between the stakeholders using a significance level of 5%. However, the function "economic viability" indicates the biggest differences in the stakeholder opinion with a p-value of 0.06.

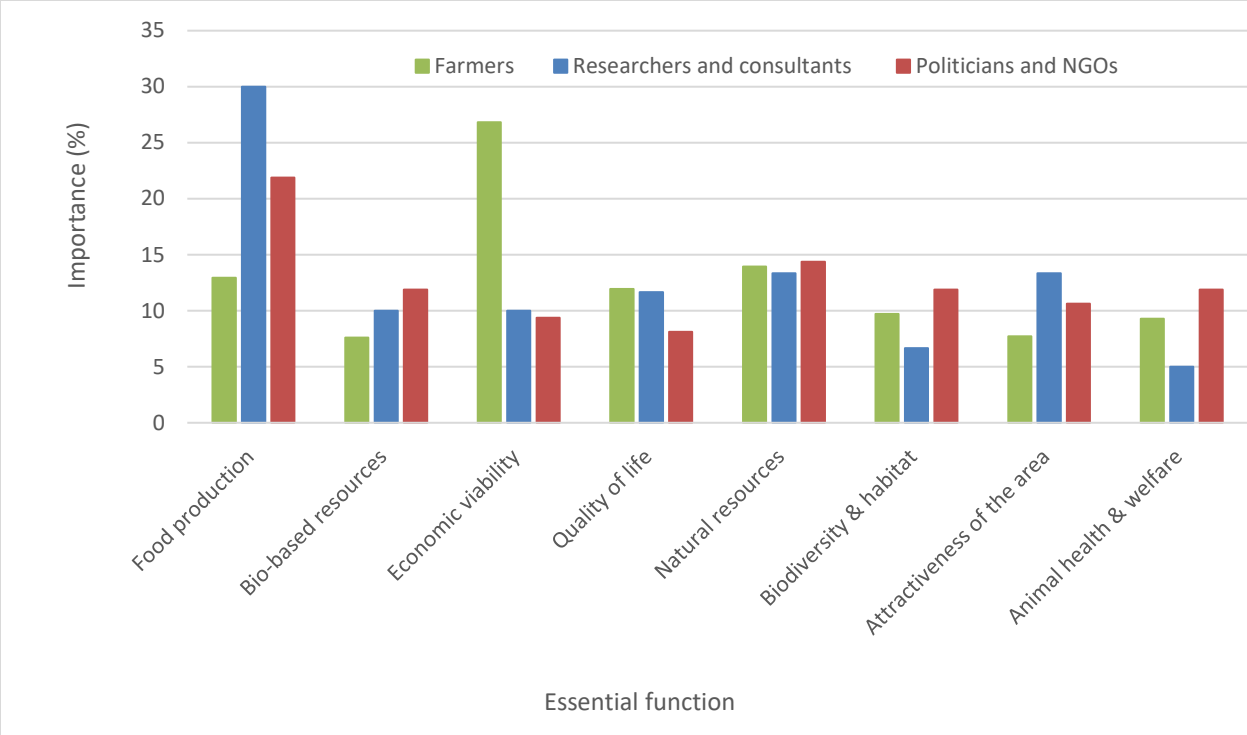

Figure 7: Bar graph with scoring per function, aggregated by stakeholder group. 100 points needed to be divided over eight functions.

The plenary discussion revealed some disagreement between participants in terms of their perception towards the functions as defined in SURE-Farm. In general, it was stated that agriculture has to provide decent wages. One participant wanted to widen the defined function "improve quality of life" with the addition of "providing employment **with decent salary** and offering decent working conditions". As he/she stated,

"It is observed more and more that labour in the European Union is hired from abroad and beyond that. These people are earning low wages, which cannot be the aspiration of fairness in the agricultural sector."

The stakeholder groups *politicians and NGOs* and *farmers* discussed about the definitions of "decent salaries" and which sources are appropriate to use to raise the salaries. The consensus of the plenary discussion was that the farming system is working but is not sustainable because wages did not rise in the last years, in the same level as the products upstream the value chain.

3.3 Indicators of functions

Before the ranking of predefined indicators, the participants intervened to exchange and add some additional indicators. For the function "delivery of bio-based resources" the participants wanted to add the indicator **share of crop rotation.** It describes the share of crops in the crop rotation, which are used for the production for bio-based outputs, e.g. the share of rapeseed in the crop rotation for biodiesel. For the function "economic viability" the indicator **ability to invest** was additionally chosen by the participants. Also, for the function "quality of life" the indicator "share of women" was replaced by the indicator **wages**.

Lastly, the indicator **attractive village life** was selected by the participants for the function "attractiveness of the area". Per function maximum 100 points could be used to score the importance between the defined indicators.

3.3.1 Indicator importance

Overall score

Most important in total scored the indicator "gross margin" (see transformed data Appendix B, Table A3) with on average 31 points and representing the function "economic viability". The second most important indicator was "milk production" (24) representing the function "food production". Also, relatively high importance received the indicator "wages" (21) representing the function "quality of life". With on average 18 points, both indicators "soil quality" and "water quality" also scored relatively high, which are representing the function natural resources". Also "internet connection" (16), which is representing the function "rural area", scored high.

Least important with on average 5 points was the indicator "cultural, social offerings" (belonging to function "quality of life), followed by "production of biogas" (belonging to function "bio-based resources), "agritourism" (belonging to function "attractiveness of rural areas) and legal framework of animal welfare (belonging to function "animal health and welfare"), which all scored 7 points.

There are differences between scores of the stakeholder groups, as presented in Figure 8. In the following section, the stakeholder groups are separately analysed to observe their perspectives towards the indicator importance.

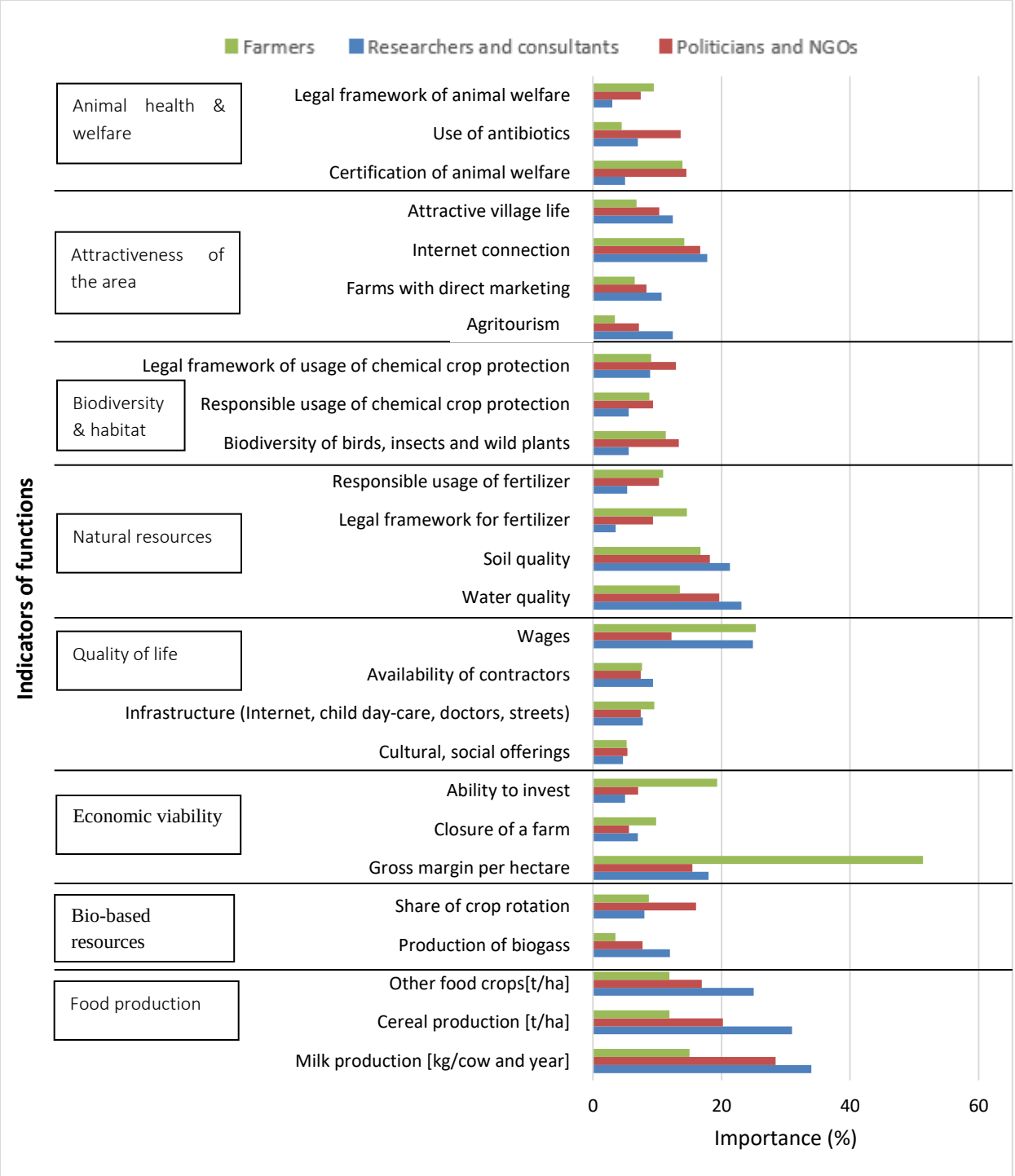

Figure 8. Bar graph with scoring of importance per indicator, aggregated by stakeholder group. Per EF, 100 points were divided over the indicators. Values are transformed to include the importance and number of indicators of the function that the indicators represent.

Farmers

It is observed that for the *farmers* mostly the indicators for the function "economic viability" ("gross margin", "ability to invest") and the indicator "wages" (function: "quality of life") are important (Figure

8). “Gross margin” is perceived circa three times more important by the *farmers* than by the other groups and shows a significant difference between the stakeholder groups. The high overall standard deviation for “wages” is caused by differences between the groups, which reflects the difference in perception. *Farmers* and *researchers and consultants* have a similar perception while *politicians and NGOs* score it with half the importance (see transformed data, Table A3). However, also two of the four indicators of natural resources, which are “legal framework for fertilizer” and “responsible usage of fertilizer”, are relatively more important for *farmers* compared to the other stakeholder groups.

Researchers and consultants

For the *researchers and consultants* all indicators of “food production” and “attractive rural areas” are relatively more important than for the other stakeholder groups. All three indicators of food production (“milk production”, “cereal production” and “other food crops”) have a significant difference between the stakeholder groups. The indicator “milk production” is scored more than twice as important by *researchers and consultants* than by *farmers*. Also, for the group *researchers and consultants* two of the four indicators of the function “natural resources”, are more important, which are “water quality” and “soil quality”. However, only for the indicator “water quality”, there is a significant difference in the stakeholder perception. In addition, “availability of contractors” (function: “quality of life”) is in focus of *researchers and consultants*.

Politicians and NGOs

Indicators of animal welfare (“certification of animal welfare”, “use of antibiotics”, “legal framework of animal welfare”) are more in focus of *politics and NGOs* than other stakeholder groups. However, only for the indicator “certification of animal welfare” there is a significant difference between the stakeholder groups. Next to that two indicators of the function “biodiversity” (which are “biodiversity of insects, birds and wild plants” and “legal framework of chemical crop protection”) the indicator “share of crop rotation” (function: “bio-based resources”) is in more focus of the stakeholder group *politics and NGOs*. For both indicators “biodiversity of insects, birds and wild plants” and “share of crop rotation” there is a significant difference between the stakeholder groups.

3.3.2 Indicator performance

The performance of the indicators is scored between one and five points, where 5 points is the score for very good performance and one for very poor performance.

Overall score

To present the results, the indicators are grouped depending on performance and importance.

Indicators with relatively good performance and relatively high importance are “milk production” (4.2), “water quality” (4.1) and “soil quality” (3.8) (Figure 9). “Production of biogas” is the best performing indicator (4.4) but scored low in importance. “

Indicators with relatively low performance but relatively high importance are "internet connection" (1.6) and "wages" (2.0).

Other indicators with a low performance and low importance are "infrastructure for streets, hospitals, schools etc." (2.0), "agritourism" (2.0), "cultural, social offering" (2.4), "availability of contractors" (2.4) and "farms with direct marketing" (1.7).

High standard deviation is observed for the three indicators of the function "animal health and welfare" which are "legal framework of animal welfare", "use of antibiotics" and "legal framework of animal welfare" (Appendix B, Table A4). This indicates contrasting views of the stakeholder groups.

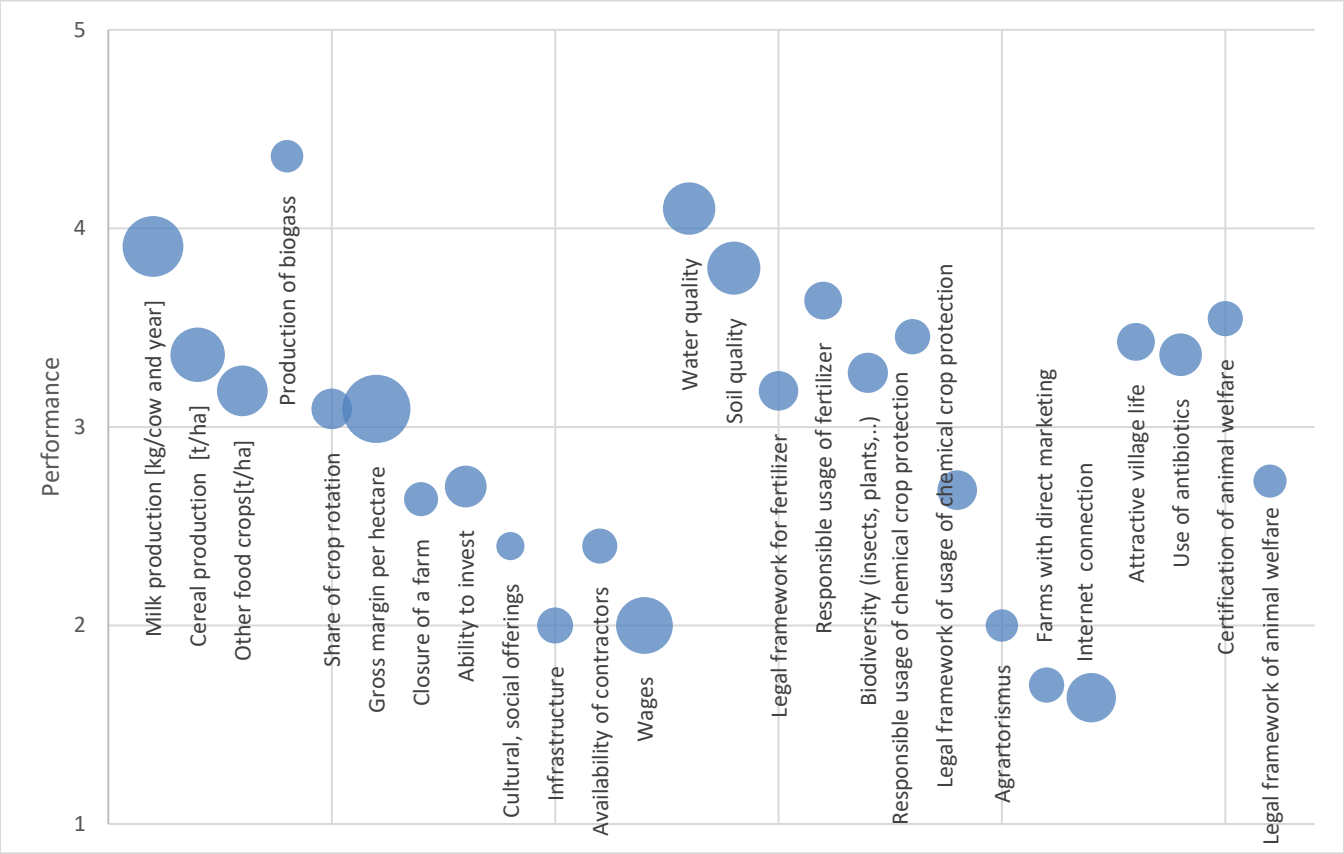

Figure 9. Bubble graph presenting averaged scores on performance of indicators (from 1 to 5), while also indicating their importance (size of the bubbles), relative to each other.

Stakeholder disagreement

The performance of "milk production" is scored lower by the *farmers* compared to the other two stakeholder groups (see Figure 10).

However, the largest disagreement among the stakeholders was observed when comparing the perspective of *politicians and NGOs* with the other groups. "Gross margin", "farms with direct marketing", "attractive village life", "infrastructure" and "availability of contractors" are scored higher in the performance by the *politicians and NGOs* compared to the other two stakeholder groups. On the other hand many of the indicators of the public goods, like "legal framework of fertilizer", "responsible use of

fertilizer", "biodiversity", "responsible use of chemical crop protection" legal framework of chemical crop protection", "use of antibiotics", "certification of animal welfare and "legal framework of animal welfare" are scored lower in their performance by the *politicians and NGOs* compared to the other two stakeholder groups.

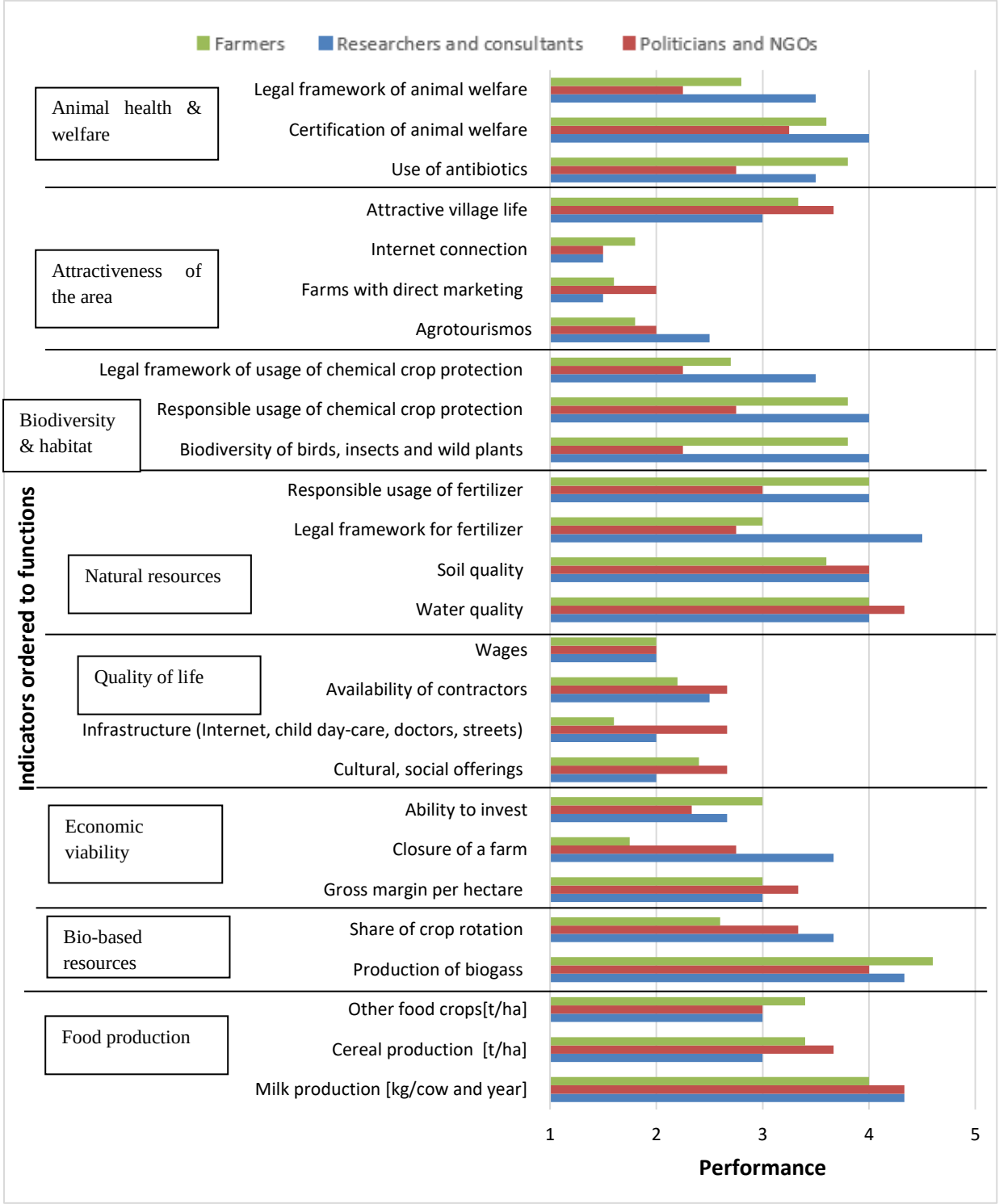

Figure 10. Bar graph with scoring of performance per indicator (from 1 to 5), aggregated by stakeholder group.

To summarize the farming system performance, a reflection on the farming systems functions (importance and performance), with their classification into private and public goods, can be conducted. This is presented in Figure 11. In the following text also the most relevant indicators for those functions are mentioned in brackets. In total the private goods are scored more important compared to the public goods (Appendix Tab. A2). However, the function "natural resources" (indicator: soil and water quality) is after "food production" (indicator: milk production) and "economic viability" (indicator: gross margin) the third most important function. For these three functions "natural resources" scores best in performance and "economic viability" lowest. Overall the function "quality of life" (indicator: wages) is scoring lowest in performance while having an average importance of the functions, which is indicating a bottleneck for the Altmark region. Both private and public goods scored equally in their performance on average (Appendix Tab. A5).

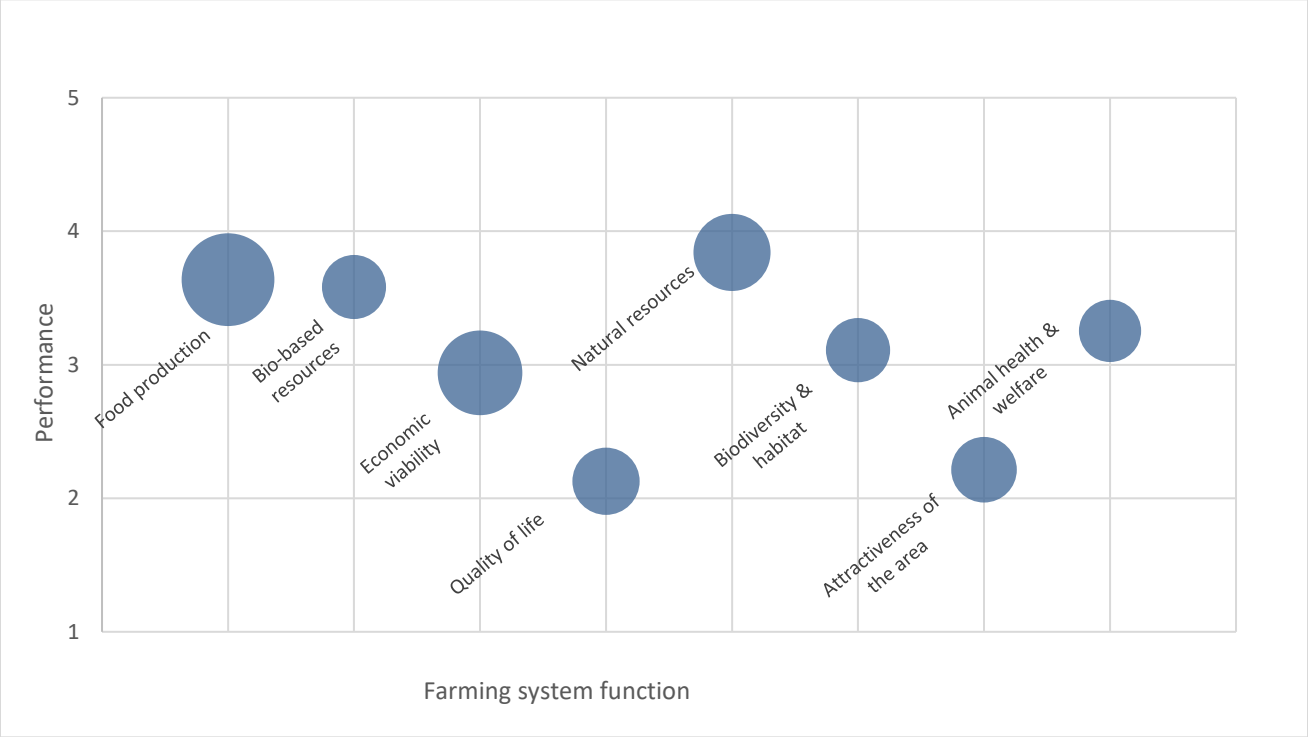

*Figure 11: Bubble graph presenting averaged scores on performance of **functions** (from 1 to 5), while also indicating their importance (size of the bubbles), relative to each other.*

3.3.3 Indicator selection

During the workshop, 3 indicators were chosen as a result of the indicator scoring exercise. The three indicators were further discussed in terms of their performance for the past 18 years. The results of this assessment are described in this section.

Gross margin was selected as indicator during the workshop for assessing the performance of the farming system. The importance of the indicator was scored relatively high by the participants. However, the importance is perceived controversial among the stakeholder groups. Quote from a farmer:

"In case of not receiving a sufficient gross margin, the farming business is not able to survive."

The performance of the gross margin was also scored medium and therefore challenging the farming system.

Legal framework of animal welfare was chosen as an indicator during the workshop, because it was mentioned during a discussion. Also, during the plenary discussion participants were wondering why the animal welfare scored unexpectedly high in the performance (in their perspective). Quote from a participant:

"The question is, whether the legal framework has many different regulations, or if they are good ones."

The participant implied that only because there are many regulations the good performance is not justified. Also, the stakeholder groups disagree in the score of the performance, because animal welfare is a controversial point. A participant explains this because animal welfare is linked to ethical questions and emotional connections.

Wages was chosen as an indicator during the workshop because it was heavily discussed in the beginning. Also, the Figure 9 shows a high importance and low performance at the same time. Quote from a participant:

"The current farming system is working, but it is not working sustainably because the wages are not decent and not adjusted in the last 30 years."

This means that the wages are not sufficiently high, but the farmers see it as the responsibility of the whole farming system to adjust the wages.

3.4 Resilience of indicators

3.4.1 Indicator 1 – Gross margin

Performance dynamics in the last 18 years and impacting challenges

According to the participants, the gross margin depends on the following main factors: weather influences, politics and the condition of the financial system. The performance of the gross margin was gradually increasing, but already had a plateau in the year 2002 till 2005 (Figure 12). In the year 2002 there were flooding events and in the year 2003 was a drought, which were impacting both the crop yield and the grassland productivity. In the year 2005, the agricultural reforms took place which was the cause for a slow increase of the of the gross margin's performance due to a liberation process on the market. During the agricultural reform, commodities were adjusted to the world market. This means that already in 2005, the prices for cereals where liberated to compete on the world market, while sugar beet started to compete on the world market in 2017. According to the participants, the global financial crisis impacted gross margins negatively in 2009 (Figure 12). The financial crisis was a big challenge because commodities were competing at the global price world market. According to the participants the highest performance of gross margin was reached in the year 2013 with a performance of 130%. Also, the year 2013 was a year of flooding and resulted in a year with lower crop yields in arable farming. After that year the performance was deceasing continuously again till the present year. The decrease after 2013 was among others due to the milk quota abolishment and especially in the year 2018 the negative impact of the drought on the yields of (fodder) crops. Next to this, political decisions are challenging a stable gross margin. The implemented legal framework for animal husbandry in the year 2014 made it necessary for

farmers with livestock to invest in new stables. In some cases, this is challenging, because the farmer didn't even pay off the credit of the current stable yet.

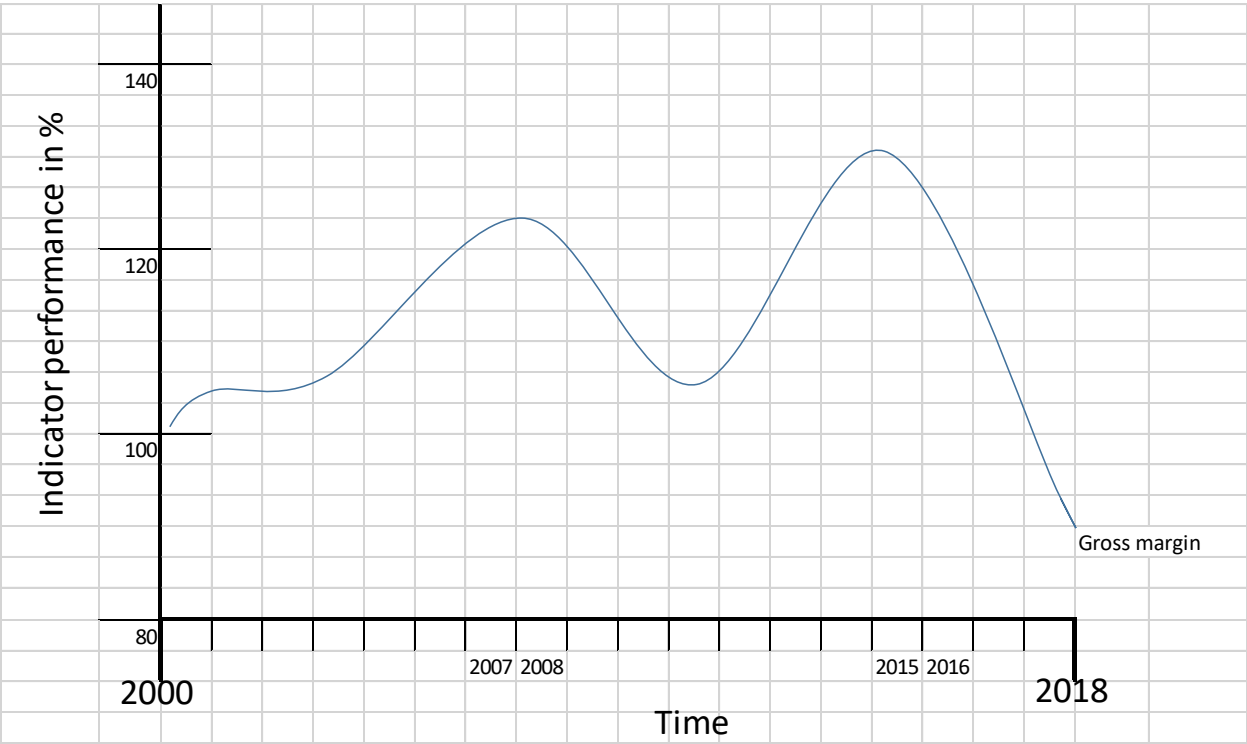

Figure 12: Performance of the Indicator "gross margin" in period 2000 till 2018.

A challenge in the future is the upcoming probation of Glyphosate in the next three or five years and also the usage of seed dressing will stop. This will be challenging because these types of crop protection are cost saving measures. Stop of Glyphosate and seed dressing usage, also makes tillage with plough necessary again and complicates the cultivation of rapeseed. At the same time, the production of maize and its profit, will decrease in the next years due to legal frameworks which will stop the promotion of biogas through subsidies.

Strategies to address the challenges

Several strategies were used in the last 18 years to increase the performance of the gross margin. In the beginning of the 2000's, an intensification of the bio-based resources was observed, especially the extension of rapeseed production. A synergy between this strategy and the "German Renewable Energy Sources Act (REA)" in the beginning of the 2000's was mentioned. The REA implies regulations which are economic incentives for farmers to extend bio-based resources. The economic incentive is due to financial support of the government for bio-resources production for electricity generation. This led to an increase of the rapeseed production area, which had a financial benefit, especially for the Altmark region. Another strategy was the cultivation form "tillage without ploughing". This was a cost saving measure because financial reserves for the cultivation practice were saved. Instead, Glyphosate was used which was cheaper compared to the soil tillage. There is also a synergy between the usage of Glyphosate and the extension of rapeseed production, since the production of rapeseed was facilitated by the usage of Glyphosate. By usage of Glyphosate a cost saving cultivation could be realized, which was beneficial for the gross margin. During

the last years of low yields, also the strategy of reducing investment was chosen e.g. to choose not to invest in a new tractor. The increase in milk production and pig farming was a passive way of improvement.

Comparison of perceived performance with literature and data

The trend of the drawn performance of the gross margin (Figure 12) is well reflected by the participants according to the data of the agricultural reports of Saxony-Anhalt. It was still not possible for the participants to draw all details of the performance on paper. The perceived stagnation of the gross margin due to flooding was correct as confirmed by the data in the agricultural reports. To illustrate the impact, the agricultural report 2002 estimated a loss of 51,352,000 Euro. Half of it was caused through damage of grassland productivity, which is used for cattle fodder in milk production (Agrarbericht Sachsen-Anhalt, 2003). However, contrary to the drawn plateau of the gross margin in the year 2003/2004, the performance decreased in reality, due the decreasing producer price for milk and cattle compared to the previous years. At the same time costs for fodder were increasing in those years which negatively impacted the gross margin (Agrarbericht Sachsem-Anhalt, 2003). In the year 2005, for the first-time subsidies were decoupled from production and payed to the farms, which was a cause for an increasing gross margin in all types of farms (Agrarbericht Sachsen-Anhalt, 2006). This was an important event for the agricultural sector and correctly illustrated in the drawn performance of the gross margin by the participants. In the year 2008 an increasing demand for the agricultural production was observed on the international market with stagnating production levels. This led to an increase of the prices and therefore increasing income. The better performance of the gross margin in the year 2008 compared to the previous ones was not perceived by the participants. Still the overall tendency of the gross margin is well reflected by the participants, also regarding the end of the observed time span of 18 years (Agrarbericht Sachsen-Anhalt, 2016).

3.4.2 Indicator 2 - Animal welfare

Performance dynamics in the last 18 years

The performance was separately assessed for the pig, cattle and the poultry sector. The performance of all three sectors is presented in three curves and set 100% in the year 2000. For all three sectors the participants considered that the policies help to adapt in a long term rather than causing a sudden change. **Pig farming**: In the year 2008, the agricultural investment funding programme (AFP) was implemented and gave a positive impact for the performance of 10 percent after the year 2008 till 2018. Over the time span from 2007 till 2013 the legal framework for pig keeping in boxes was changed. This gave also a positive impact for the performance of 10 percent after the year 2007 till 2018. Therefore, the performance level of the indicator reaches 120% in the year 2018 (Figure 13).

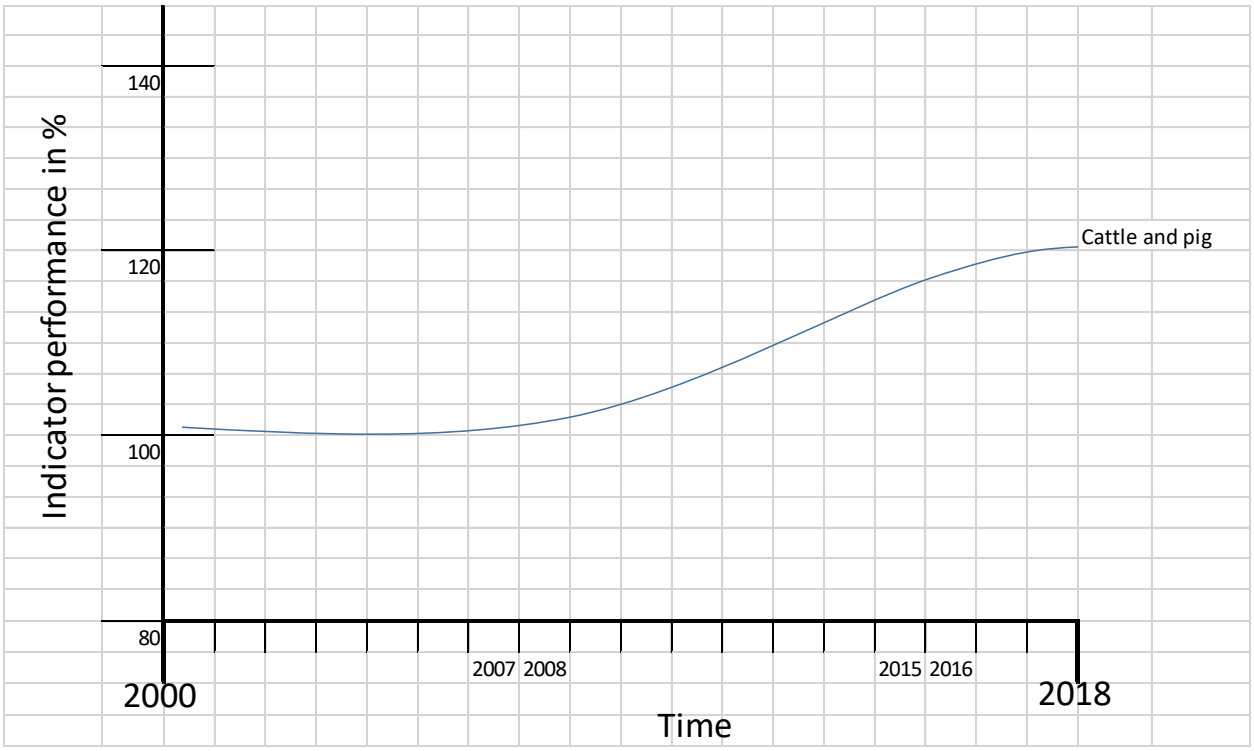

Figure 13: Performance of the Indicator "animal welfare in case of cattle and pig farming" in period 2000 till 2018.

Cattle farming: In the year 2008, the agricultural investment funding programme (AFP) was implemented and gave a positive impact for the performance of 10% after the year 2008 till 2018. The AFP resulted in increase of the performance to a level of 110%. In the year 2014 Animal Protection Keeping of Production Animals Order (German designation: TierSchNutztV) was implemented which gave also a positive impact for the performance of 10% after the year 2014 till 2018. Therefore, the performance level of the indicator reaches 120% in the year 2018 (Figure 13).

Poultry farming: In the year 2004 the labelling requirements were introduced, which had a quite large positive impact on the performance with an increase to a 120% performance. This increase took place in the time period 2004 to 2010 (Figure 14). In the year 2010, production of hens in cages was prohibited. This leads to a slow and constant increase of the performance, which reached around 135% in 2018.

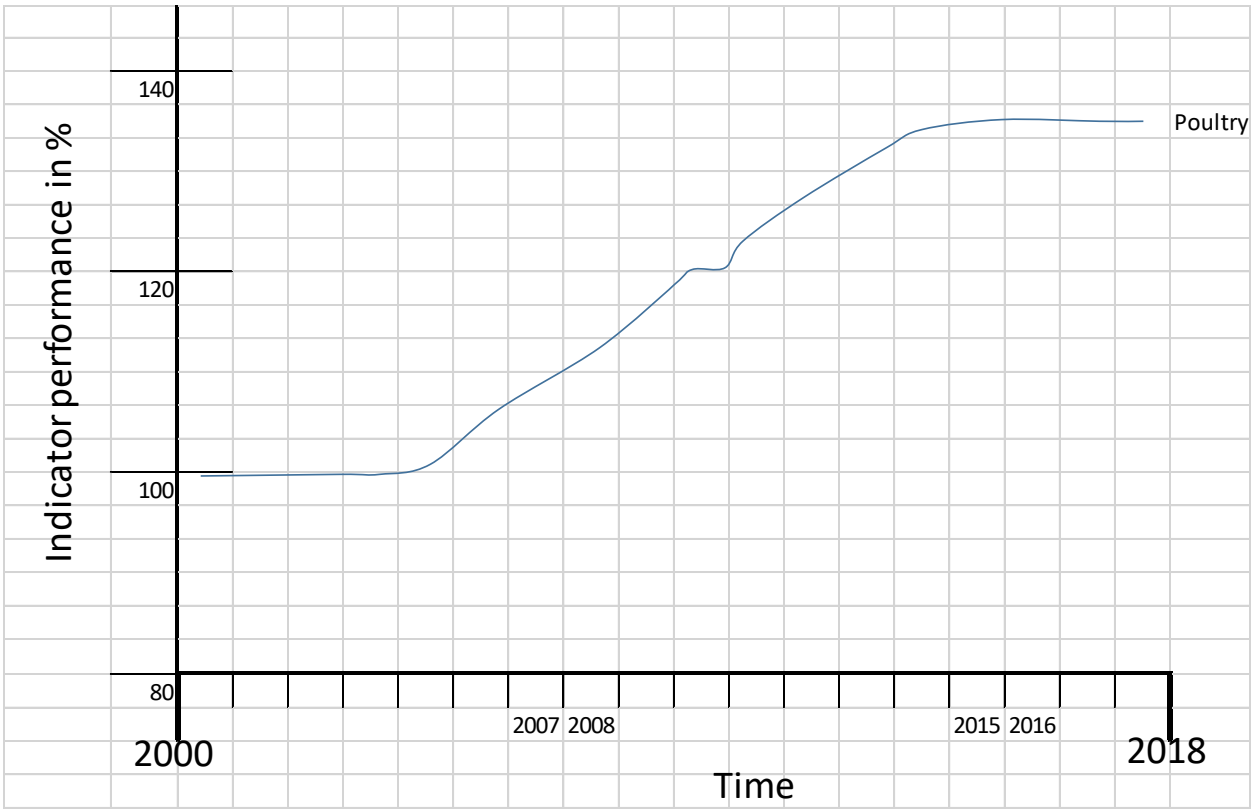

Figure 14: Performance of the Indicator "animal welfare in case of poultry" in period 2000 till 2018.

Impacting challenge

A challenge for the animal production sector is social resistance against large scale livestock production and the perceived missing transparency of production conditions in marketing. For the customer it is a challenge to choose products because e.g. before 2004 there were no regulations to label the eggs according the housing conditions for the chicken. A big challenge for animal welfare is the fulfilment of the legal frameworks by the farmers. The animal keeping facilities, which are according to the regulations, are cost intensive. Also, for the farmer it can be challenging to understand the requirement of the regulations and how to apply for the financial support for the implementation.

Strategies to address the challenges

A strategy to improve the performance of pig and cattle farming was the "Agricultural Investment Funding Programme (AFP)" implemented in the year 2008. This program has the purpose to financially support the investment in economic viable agriculture which is environmental- and animal friendly. Between the years 2007 and 2013, the legal regulations of boxes for the pig keeping was changed. This strategy ensured a shorter period in boxes and more space for the pigs. For cattle farming," The Order on the Protection of Animals and the Keeping of Production Animals (German designation: TierSchNutztV)" was implemented in the year 2014. This especially strengthened the regulations to improve the animal welfare of calf keeping. For the poultry sector two strategies were used: "labelling requirements for eggs" introduced in the year 2004 and the "ban caged poultry" in the year 2010. After the implementation of

labelling requirements, the consumers had the opportunity to decide on the keeping conditions for the hens.

Comparison of perceived performance with literature and data

Since animal welfare is a qualitative indicator it is difficult to measure the accuracy of the participants' perception with reality. Only assumptions can be used to measure the indicators performance. As published in articles, the animal welfare of pigs is observed critical and therefore new forms of animal keeping are suggested to improve the animal welfare (Bündnis 90/Die Grünen, 2017). Another article states that resources are invested to improve the animal welfare of pig keeping in the future. This is due to the critic that the mother is restrained in the cage after four weeks of giving birth were she cannot turn (Dörthe Hein, 2015). But the score of animal welfare performance certainly depends on stakeholder groups. As observed in the previous results that, politicians and NGOs score the performance of legal framework of animal welfare worse than *farmers* and *researchers and consultants*.

3.4.3 Indicator 3 – Wages

Performance dynamics in the last 18 years

Considering the nominal wages, an increase was observed over the last 18 years. But it was agreed, to consider them in relation to the inflation, meaning that the real wages were presented. The trend of the real wages was decreasing over the illustrated timespan. The wages do not show a parallel trend with the gross margin performance. This can be explained for instance by the fact that wages are fixed through contracts, which leads to a delayed adjustment of wages to the business performance. The performance started in the year 2000 at a score of 100%. Over the time span of the last 18 years, the real wages were decreasing constantly to a level of performance of 80% at the end of 2018 (Figure 15). Only the implementation of the minimum wage gave a short and small increase of the performance in the year 2015. Also, the attempt to make the working conditions more favourable and flexible had a minor impact to slow down the decrease of performance in the last years.

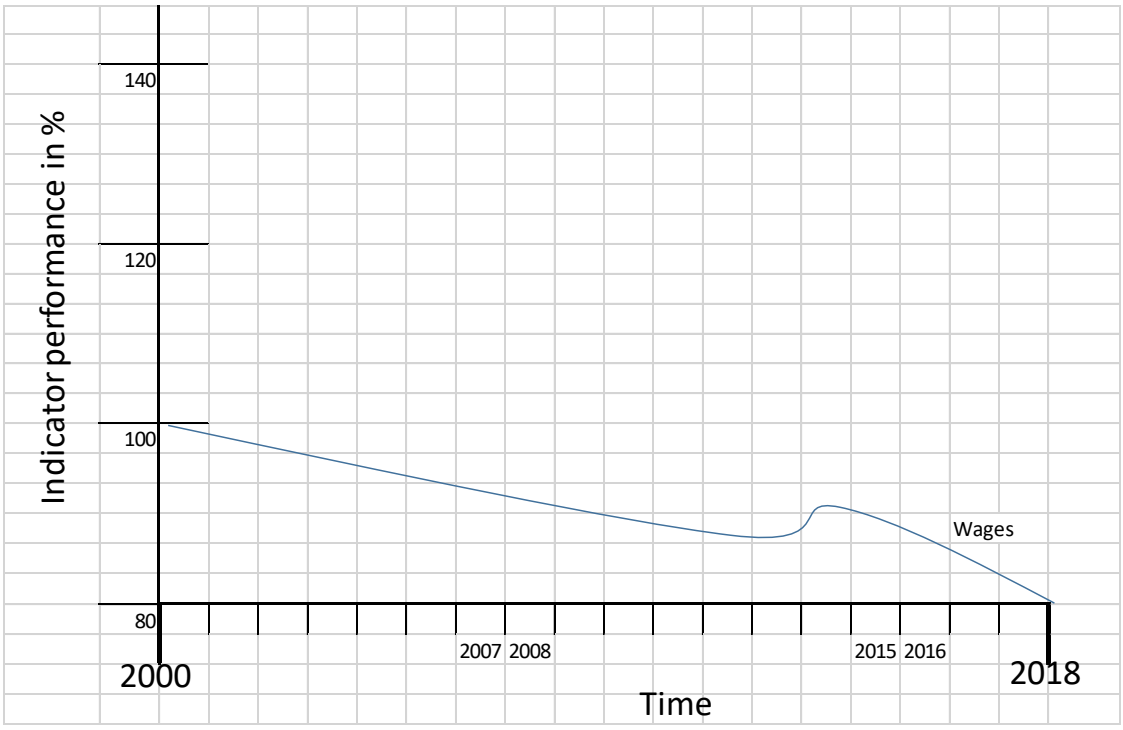

Figure 15: Performance of the Indicator "wages" in period 2000 till 2018.

Impacting challenge

Participants were stating that over the last years no adaption of the wages in the agricultural sector to the inflation level was taking place. One participant mentioned a national law, which should guarantee an adjustment of wages in the agricultural sector to inflation since agriculture production is at the beginning of the value chain. Therefore, mostly the legal framework for the politics, which leads to the decline of food prices, is seen as the challenge for the payment of decent wages. Other participants argued that the biggest challenge was in the level of the total revenue of farming businesses which hinders the payment of wages.

Strategies to address the challenges

A strategy to increase wages was the introduction of minimum wages in the year 2015. This is a governmental law, which defines the lowest remuneration that employers can legally pay their workers. Also, a strategy to improve the indicator's performance was to enhance working conditions. The participants see the indicator "wages" more broadly than only the pure amount of received income. In this case the participants took more social aspects into account, to characterize the indicator. Employers were taking more care that employees are able to take flexible holidays for instance. Also, the technological progress was used to increase the comfort at the working space, e.g. the utilization of a milking carousel with soft ground, to increase the comfort for the workers handling the machine.

Strategies to increase the income in total were also mentioned as a measure to increase the wages. In the opinion of some participants the reason for low wages is the unprofitable performance of the farms in

general (the average gross margin). Those strategies are e.g. production of niche products and increase productivity.

Comparison of perceived performance with literature and data

Since the participants were considering the real wage, while in agricultural reports the nominal wages are published, a direct comparison of the accuracy of the data is difficult. Still, the comparison of the perceived performance of the participants with real data published in the agricultural reports of Saxony-Anhalt, is confirming the tendency of decreasing wages. A steep decrease of the wages was noted in the agricultural report in the year 2007 when the financial crises took place. Since all businesses lost profit and could pay less for wages, the participants did not especially reflect this in the graph. This was not explicitly drawn by the participants. In the year 2011 an increase of wages was given in the data of the agricultural report of Saxony-Anhalt (Agrarbericht Sachsen-Anhalt, 2011/12). This could be explained by the relaxation of the financial situation after the financial crises. Also, this was not captured in the drawing exercise by the participants. As indicated by the participants the wages noticeably increased in the year 2015 after the implementation of the minimum wage. After this event the actual wages were on the same level than in the year 2000 (Agrarbericht Sachsen-Anhalt, 2018). Taking inflation into account it is assumed that real wages decreased over the last 20 years, which is in accordance with the participants perception.

3.5 Resilience attributes

3.5.1 Case-study specific strategies

Implementation level of strategies

The identified strategies to increase the performance of the three indicators were gathered. The level of implementation all strategies was scored from one to five, while one stands for not implemented and five for very well implemented. In general, strategies were considered to be moderately to well implemented (Figure 16).

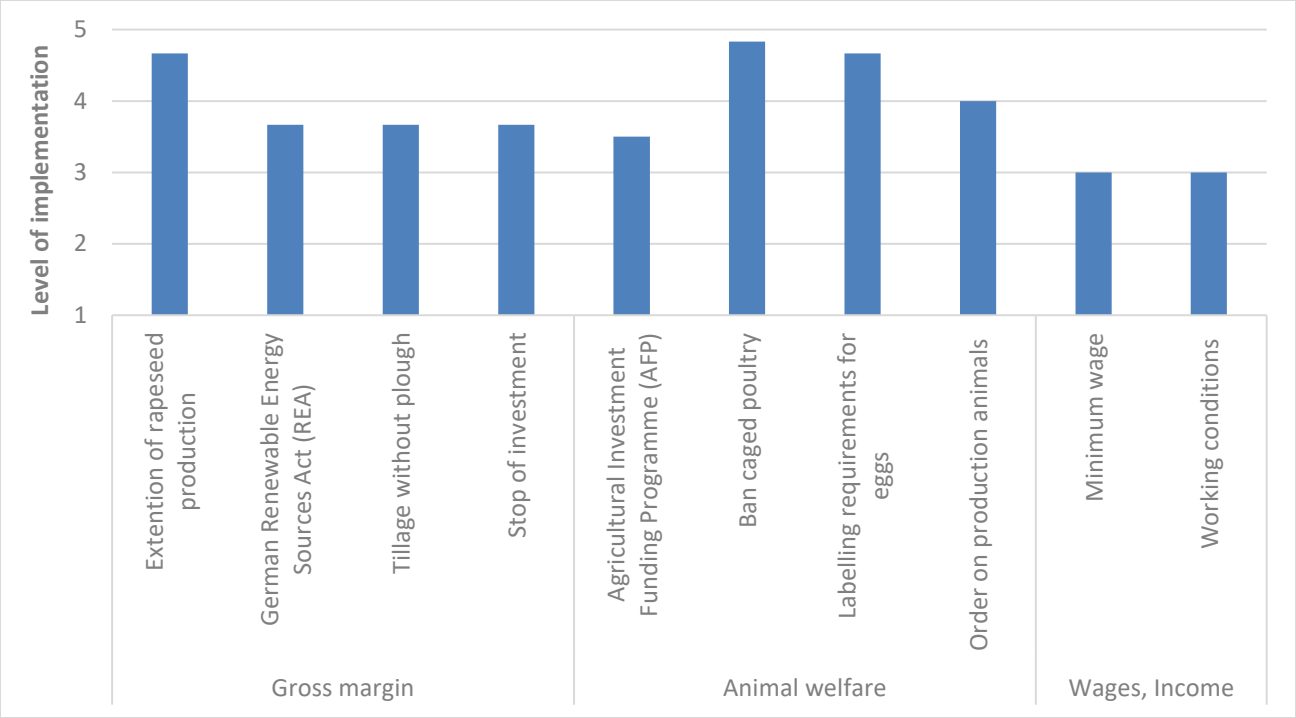

Figure 16. Bar graph showing level of implementation of strategies. 1 = not applied, 2 = slightly applied, 3 = moderately applied, 4 = adequately applied, 5 = perfectly applied, which were applied to address challenges of the three indicators "gross margin", "animal welfare" and "wages".

For the indicator **gross margin**, the strategy "extension of the rapeseed production" was scored highest in implementation, with a score of 4.5 (Figure 16). The other three strategies for the same indicator were scored with a value of 3.7. For the indicator **animal welfare,** the strategy "ban caged poultry" was scored highest in implementation (score 4.8), followed by the strategy "labelling requirements for eggs" (score 4.7). "Order on the protection and keeping of production animals" was scored with a value of 4 and the "Agricultural Investment Funding Programme" is scored lowest in implementation (3.5). The strategy for the indicator **wages**, which are "minimum wages" and "working conditions", score both a value of 3.

Contribution to resilience capacities

Further the contribution of the strategies to one of the three resilience capacities (robustness, adaptability and transformability) was scored. It was scored from -3 (strong negative) to +3 (strong positive relationship).

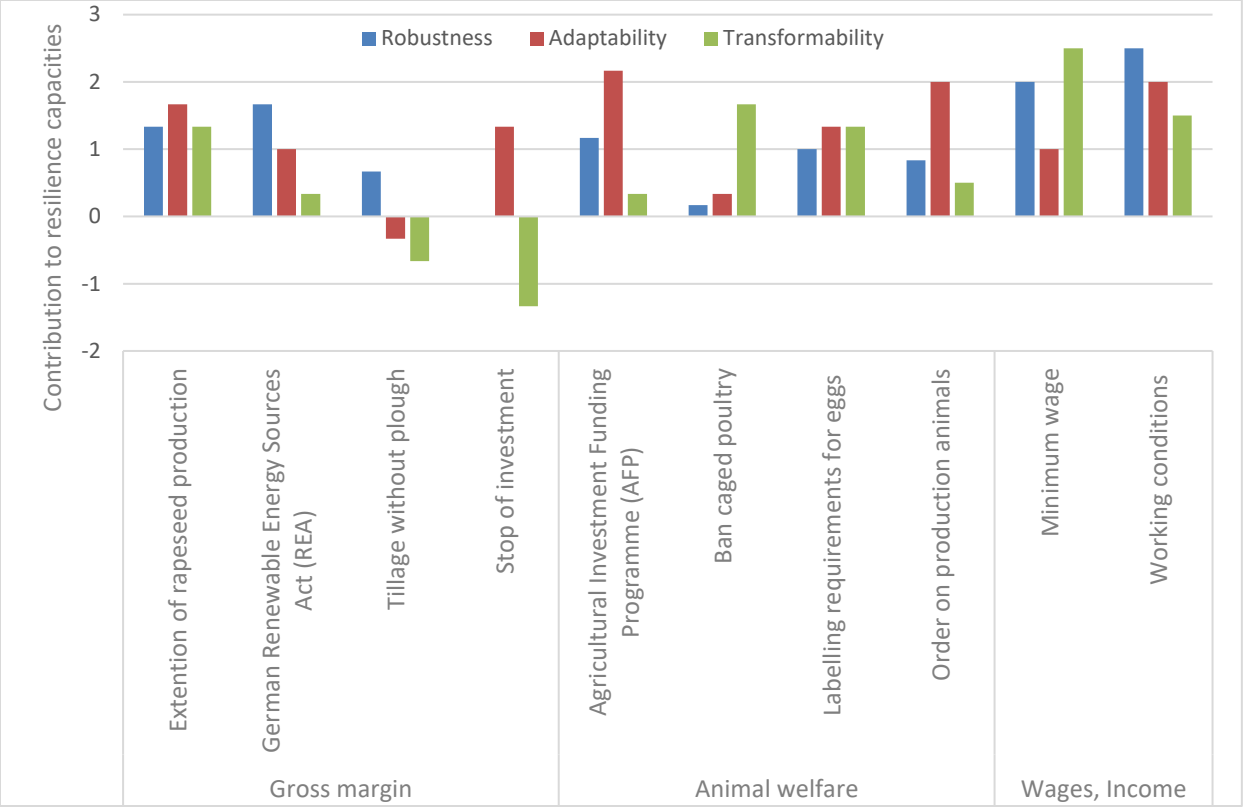

Figure 17. Bar graph showing average scoring of contribution of strategy to robustness, adaptability and transformability of the farming system. A "0" implies no relationship, a "1" a weak relationship, a "2" a relationship of intermediate strength and a "3" is a strong relationship.

Strategies in relation with gross margin

The strategy **stop of investment** contributes to the adaptability of the system but counteracts the transformability of the system (Figure 17). At the same time, it does not contribute to robustness because the current performance of the system cannot be maintained in the first place. **Tillage without ploughing** makes the system robust since it is a cost saving method. Hence the income can be increased, which contributes to stabilization of the current system. However, there is a trade-off between both the capacity of adaption and transformation because the system relies on external inputs, which prevents transformation. **The German Renewable Energy Sources Act (REA)** contributes most to the robustness of the system since the income of the current system becomes more stable through subsidies. The strategy with the highest level of implementation **extension of rapeseed production** contributes most to adaptability. By extending the cultivated area of bio-based resources the farm is adapting. The other strategies have the same level of implementation and contribute to adaptability and robustness. Therefore, a tendency towards an adaptable and robust but not transformable system is observed.

A synergy between the strategy "extension of rapeseed production" and "REA" is given. The REA provides an incentive for farmers to extend the production of those bio-based resources crops.

Strategies in relation with animal welfare

In relation to animal welfare, the **Agricultural Investment Funding Programme (AFP)** is mostly contributing to the adaptability of the system, because it provides economic incentives through political regulations to use existing capital to adapt the production in a sustainable way (Figure 17). **Order on the protection and keeping of production animals** (German designation: **TierSchNutztV**)", contributes to adaptability too. The system is forced by new regulations to adapt to higher animal welfare standards but is not transforming. There is a **synergy** between the strategy "AFP" and the "TierSchNutztV", since both contribute to a strengthening animal welfare through governmental incentives. **Ban caged poultry** is a strategy contributing to the transformability since the system has to change in order to follow the regulation of the strategy. This is also the strategy with the highest level of implementation, showing a potential for the system to transform. **Labelling requirements for eggs** follow the same mechanism as "ban of caged poultry" and contribute mostly to adaptability and transformability. Therefore, a tendency towards an adaptable and transformable system is observed.

Strategies in relation with wages

In relation to wages, the increase of **working conditions** is a strategy contributing mostly to the robustness of the system since it is strengthening the performance of the unchanged system (Figure17). On the other side **minimum wage** is contributing to the transformability and less to the robustness of the system. The system had to transform in order to fulfil the strict governmental regulations. Both strategies have the same level of implementation but contribute to robustness and transformability.

3.5.2 General resilience attributes

Application level of the resilience attributes

The current application level of resilience attributes in the farming system was scored from one to five. One means no application and five means the attribute applied very much in the farming system.
On average, all attributes were evaluated to be applied in a (very) small to moderate extent (Figure18). The highest application rate over all attributes has the attribute "socially self-organized" (score 3.5) followed by the attribute "coupled with local and natural capital (production)" (score 3.1). The following attributes are "response diversity" (score 2.9) and "spatial and temporal heterogeneity of farm types" (score 2.8). The attribute applied the least in the farming system are "reasonable profitable" (score 1.6), "functional diversity" (score 1.9) and "diverse policies" (score 1.9).

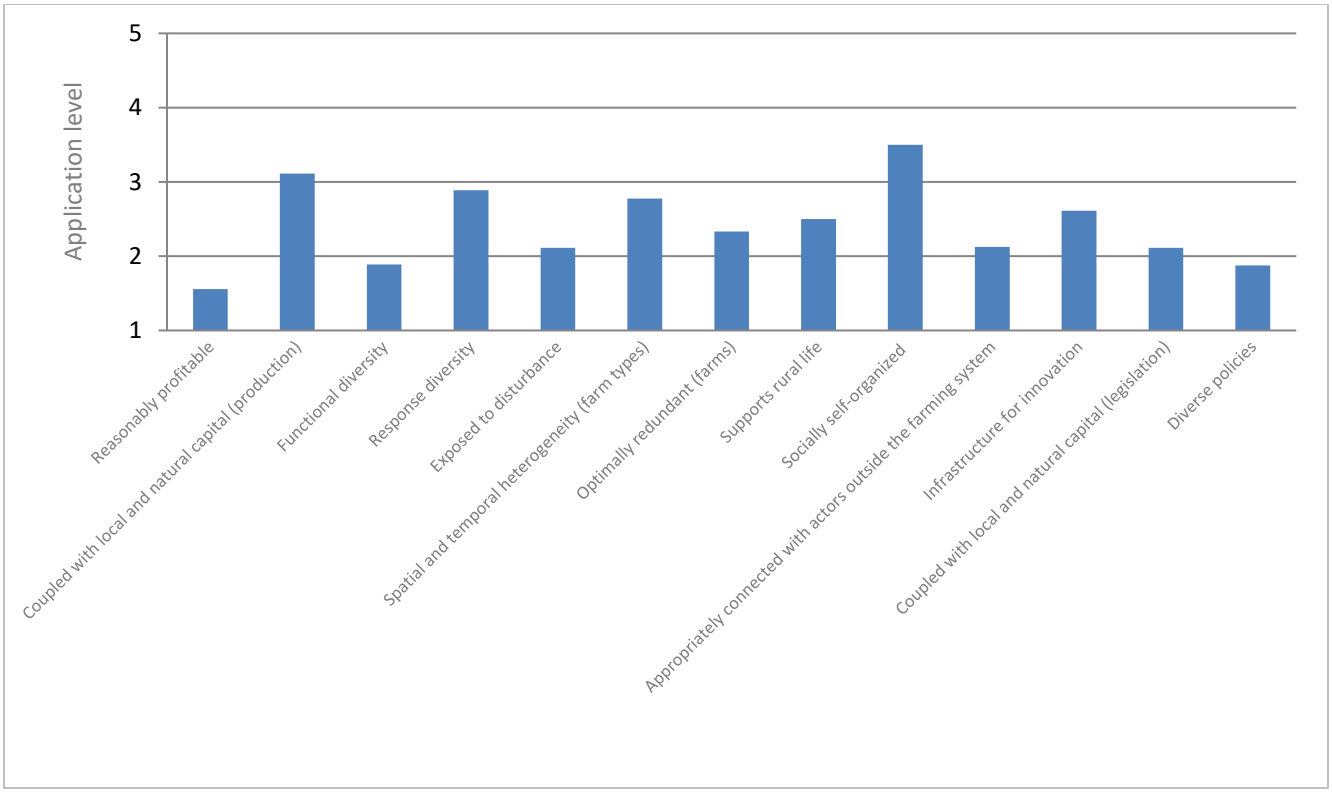

Figure 18. Bar graph showing current performance level of resilience attributes. Performance is scored as 1 = not at all, 2 = small extent, 3 = moderate extent, 4 = big extent, 5 = very big extent.

Attributes related to the five general resilience principles

The resilience attributes are related to the resilience principles and SURE-Farm processes (see 1.3.3). The list of the 13 attributes and to which resilience principle and process they relate is presented in Table A9 (Appendix 7.5).

In the guidelines are **five general resilience principle**s mentioned: **diversity, openness, tightness of feedbacks, system reserves, and modularity** (The Resilience Alliance, 2010).

The high performing attribute "socially self-organized" in the Altmark region is defining the system with the principle of **system reserves (social capital)** and **tightness of feedbacks,** since the social components of the agroecosystem are able to form their own institutions such as community associations, co-ops or advisory networks. The system is using additional and alternative ways of connections for marketing and purchasing purpose, and therefore fewer feedbacks introduced by managers are necessary. This leads to an increase of the resilience. The second highest attribute "coupled with local and natural capital" is a characteristic to strengthening the principle of **system reserves (natural capital)**. The resources have to be maintained in the region due to poor soil fertility and unfavourable weather patterns. Because of the limited productivity of the land, the Altmark has access to few resources and therefore has rather extensive agriculture (does not refer to organic production). Because of those conditions the farms developed "response diversity" to adjust to and gain diversity in the management. The two attributes "spatial and temporal heterogeneity" and "response diversity" are related to the principle of **diversity** which is enhancing resilience performance. A diverse production system increases the resilience due to distribution of the income in case one component is failing. In the Altmark the farms are mostly quite

diverse in their production because of the low soil quality, unfavourable climate conditions and rural structures. The rather low performing attribute “reasonably profitable” and “supports rural life” are characterized by the principle system reserves. While “reasonably profitable” represents the financial capital, “supports rural life” represents human capital. Therefore, the financial and human capital are rather limited while the social and natural capital are more redundant.

Attributes related to the four SURE-Farm processes

Within SURE-Farm, four processes are studied: **agricultural practices, governance, risk management and farm demographics** (Meuwissen et al. 2018). The resilience attributes are also linked to those four processes (see 1.3.2).

The best performing attribute for the Altmark, which is “socially-self organized”, contributes to the process **governance**. By building their own networks and institutions, the stakeholders in the case-study initiate new opportunities to govern the system e.g. through new selling options by skipping one or multiple actors. The attribute “coupled with local and natural capital (production)”, contributes to the process of **agricultural production**. Like mentioned above the agricultural system has to be adapted to limited resources and therefore implement specific agricultural production practices to produce in the longer term. The attribute “response diversity” as well as the attribute “spatial and temporal heterogeneity (farm type)” contributes to the process of **risk management**. Risks which are mostly managed with this attribute in the Altmark are short term environmental and economic risks (e.g. weather extremes and fluctuating market prices). It is observed that two attributes which define the **farm demographics** of the farming system are scored rather low, compared to the other attributes. Those two attributes are “support of rural life” and “optimally redundant (farms)”. The low level of infrastructure development and the aging farming population causes a rather low score for the process of farm demographics.

Contribution of resilience attribute to resilience capacities

Scored by the participants, most of the attributes contribute to robustness and least to transformability (Figure 19).

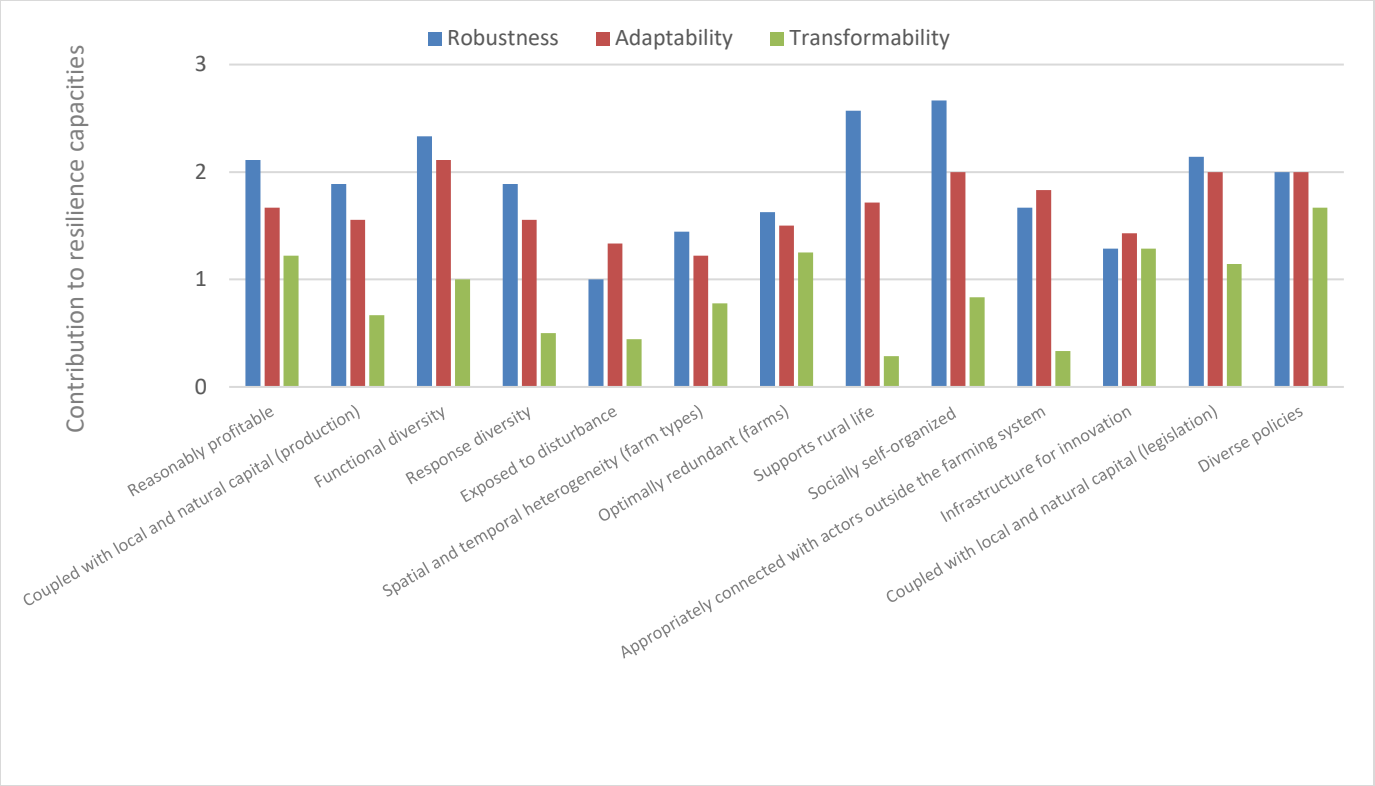

Figure 19. Bar graph showing average scoring of contribution of attribute to robustness, adaptability and transformability. A "0" implies no relationship, a "1" a weak relationship, a "2" a relationship of intermediate strength and a "3" is a strong relationship.

For the attributes there are no **trade-offs** seen, in the sense that one positive relation causes a negative relation of another capacity. The participants score the attribute "expose to disturbance" as contributing to **adaption**, since a system faced with many challenges is forced to adapt more frequently. Also, the attribute "appropriately connected to actors outside the farming system" contributes mostly to **adaptability**, since the network of actors raises modularity which increases option for **adaption**. This attribute is significant in the differences between resilience capacities. The attribute "infrastructure of innovation" is equally contributing to **robustness** and **transformation**. In case innovation is accessible, the transformation of a farming system is possible. A **synergy** is given because innovation can also lead to an investment into a more robust system. The same can be seen for the attribute "diverse policies", which is scored by the participants to have influence on all capacities depending on the direction of the policy. Those attributes, which contribute to the **robustness** of the system and are significant in the differences between resilience capacities, are "socially-self organized", "response diversity" and "support of rural life".

Combining implementation level and contribution to capacities of attributes

When comparing the level of implementation of the attribute and contribution to the resilience capacity, the farming system is **robust, adaptable and less transformable**, for all attributes, which score higher in implementation, contribute most to the robustness of the system and least to the transformability. The attribute "socially-self organized" is contributing mostly to **robustness** and is the only attribute showing significant differences between the resilience capacities when compared to the level of implementation

multiplied with the contribution to the resilience capacity. However, given the moderate level of application of the attributes, a high level of robustness performance is not ensured.

4. Results - Scenario development

In this results section the scenario development of the Shared Socio-economic pathways of the Demographic Dynamics of the Altmark region (DDA SSPs) is presented. For the scenario development certain steps are executed (explained in 2.2.2). Here the outcome, which is captured in step in step 3,4 and 5 is presented. The trends of the DDA SSPs are presented in section 4.4.

4.1 Defining storyline elements - Step 3

The storyline elements were defined for the regional scenario. For doing so, *causes* of the demographic dynamics of the Altmark region were identified and linked to resulting *effects*, which are impacting the storyline elements. This resulted in a creation of cause-effect relations. One example is that "low social opportunities in the rural area" is a *cause* of the demographic dynamic. This *cause* ("low social opportunities") *effects* "no opportunities for e.g. entertainment and lead to emigration". By identifying this *effect* on the storyline, the polarity of the cause-effect relation is captured. Back to the example, the *effect* (no opportunities for e.g. entertainment and lead to emigration") decreases the storyline element "population size in the region", and therefore a negative polarity of the cause-effect relation is given. The outcome of this process is presented in Table 3, in the first four columns. All this information was captured by using the reports of the three participatory approaches (2.2.1). In which of the three reports of the participative approaches the information was found is indicated in the last column of Table 5.

4.2 Drafting storyline - Step 4

The fourth step is about drafting the regional storylines. The identified cause-effective relations with the assigned directions of change of the storyline elements were assigned to the scenarios (see 2.2.2). This is presented in Table 5 in row "highlighted in Scenario".

To draft the new storylines, all directions of changes of the storyline elements in the scenarios had to be summarized. For this Table 5 with all directions of changes of the storyline elements and the CLD (see 4.3) as visual facilitator was used. To do so, a text of the new regional scenario narratives was formulated (see Appendix), which takes all the changed storyline elements in the five scenarios into account. At the same time a table with the regional storylines for the selected element in the five scenarios was developed (Table 5). Here all changed storylines were given a qualitative value in the same scaling system as the Eur-Agri-SSPs (see Table 5). This Table was used to compare the qualitative storyline elements with the Eur-Agri-SSPs. It was also used to capture the differences between the future regional scenarios and the current situation of the storyline elements. The current states of the storyline elements are also presented in Table 5.

Table 5: Causes of the demographic dynamics and their effect, with the named effected storyline element (and domain). Polarity of the cause-effect relation indicates the storyline element is increasing/ strengthened (plus symbol) or minimized/weakened (minus symbol). Row "found in study" indicated in which of the three participatory study this cause-effect relation was found (AFGW = AgriPoliS Focus Group workshop; FDS = Farm Demographic Survey; FoPIA = FoPIA-Surefarm workshop). Row "highlighted in scenario" indicated in which of the five scenarios the cause-effect relation is highlighted. If the row of a scenario is marked with a "X", the corresponding cause-effect relation is highlighted in the scenario. If the row of a scenario is marked with a "x", the corresponding cause-effect relation is highlighted to a small extent in the scenario. If the row of a scenario is marked with a "U", the corresponding cause-effect relation is highlighted unequally between farms in the scenario. Scenario 1 = Sustainable scenarios; 2 = middle of the road scenario; 3 = unsustainable scenario; 4 = inequality scenario; 5= fossil fuel driven scenario.

Effected storyline element (Domain)	**Cause**	**Effect**	**Polarity of the cause-effect relationship effecting the storyline element**	**Found in study**	**Highlighted in scenario**				
					1	**2**	**3**	**4**	**5**
Population size **(Population and urbanization)**	Low social opportunities in the rural area	No opportunities for e.g. entertainment and lead to emigration	-	AFGW		X	X	X	X
	No doctor available	Discourages potential e.g. young families to move to rural areas	-	AFGW		X	X	X	X
	Lack of internet	Deceases communication and life comfort leads to emigration	-	AFGW		X	X	X	X
	Lack of other jobs	No options for extra income in the rural area leads to emigration	-	AFGW		X	X	X	X
	Poor infrastructure	Difficult for labor to work outside agriculture and leads to emigration	-	AFGW, FDS		X	X	X	X
	Raising farm income	Farm income can be spill over to population and keep people in rural area	+	FDS	X				X
	Investment in infrastructure development	Raising social opportunities and medical infrastructure keeps people in rural area	+	FDS	X	x			X
Level of infrastructure development in rural regions **(Population and urbanization)**	Population size is decreasing	Level of priority to invest in infrastructure decreases	-	AFGW		X	X	X	X
	Investment in infrastructure development	Increasing infrastructure development	+	FDS	X	x			
Immigration to the region **(Population and urbanization)**	Refugees have no clear regulations for asylum rights (not clear how long they can stay in Germany)	Farmers do not train the immigrated workers because they don't have the certainty if they can stay at the farm	-	AFGW		X	X	X	
Age structure of farming population **(Population and urbanization)**	Skilled labor is reaching retirement	Farmer reaching higher age	+	AFGW, FDS		X	X	U	
Education level of farming population **(Population and urbanization)**	Stable availability of working force	Gives security to the farm manager to train employees	+	FDS	X			U	
	Decreasing regional population	Counteract the stable availability of working force and minimizes the education of working force	-	FDS		X	X	X	X
	University education is not suitable for agricultural job	Not enough practical work is taught at university level	-	AFGW, FDS		X	X	U	
Economic growth **(Economics)**	Implementation of direct marketing strategies	Farmers receive bigger share of prices	+	FDS	X			x	
	Decreasing population size	Counteract the implantation of direct marketing because no costumer	-	FDS		X	X	X	X
	Low agricultural price level because of strong position of trading partner in the value chain	Farm income is negatively impacted	-	FDS		X	X	X	
	Political vision/direction unclear	In case of change of governmental support for innovation farmers loose economically	-	FDS		X	X	X	

Availability of labor in agriculture **(Economics)**	Skilled labor is reaching retirement	Less successors and working force available	-	AFGW		X	X	U	
	Lack of internet	Administration for farmer to run the business is difficult	-	AFGW		X	X	X	X
	Deceasing population size	Number of working forces is decreasing	-	AFGW		X	X	X	X
	High immigration rate to the region	Immigrating people are potential working force	+	AFGW	X				X
	University education is not suitable for agricultural job	Number of successors and working force is decreasing	-	FDS		X	X	U	
	Skilled labor is reaching retirement	Strengthen the farm Succession difficulties	-	AFGW		X	X	U	
	Predominant type of support scheme easier succession through credit to young farmers	Counteract the difficulty of farm succession	+	FDS	X				X
	Low wages in agriculture	Number of successors and working force	-	FoPIA		X	X	U	
Type of work in agriculture **(Economics)**	Mechanization helps to be independent from labor market	Level of technology usage	Technology oriented	FDS	X			X	X
	Predominant type of support scheme supports technology uptake	Level of technology usage	Technology oriented	FDS	X			X	X
Predominant type of support scheme **(Policies)**	Strengthening of the second pillar at EU level	benefit the allocation of public goods	Strengthen the allocation of public goods	FDS	X	x		X	
	Support of technological uptake from Predominant type of support scheme	Investment in technological uptake	Strengthen technological uptake	FDS	X			X	X
Technology uptake in agriculture **(Technology)**	Higher Farm income	Strengthen innovation and growth	+	FDS	X			U	X
	Cost of agricultural technology is very high	Hinder level of technology uptake	-	FDS		X	X	X	
	Predominant type of support scheme supports technology uptake	Investment in technological uptake	+	FDS	X			X	X

4.3 Consistency check - Step 5

To ensure the internal logic of the storyline elements the CLD was created. Here all causes-effect relations were linked with the elements. The created CLD is presented in Figure 20. The storyline elements are presented in boxes with grey background and are formulated in a neutral status. All other boxes, which have a white background are causes, which were identified in step 3 and presented in Table 5. Those are formulated to have a positive or negative influence, which is indicated by the plus or minus symbol on the arrow connecting to the elements or other causes. The plus or minus symbol indicates if the cause increase/strengthening or decreasing/weakening the storyline element.

In the visualization of the CLD the frames of the boxes presenting “causes” and “elements” are assigned to a certain color, representing a domain of the storyline elements. This was done according to the classification executed in 2.2.2 (see Table 4). Orange box frames represent demographic dynamics belonging to the domain of “economy”; blue box frames represent demographic dynamics belonging to the domain “policies”; green box frames represent demographic dynamics belonging to the domain “technology” and pink box framed represent demographic dynamics belonging to the domain “population and urbanization”.

In step three the consistence check was conducted to guarantee the internal logic of the system dynamics. By connecting all the causes and effects with the storyline elements the internal logic of the system dynamics was tested and therefore the cause-effect relations were evaluated. In step four, the CLD visualizes the relationship’s polarity to ensure the logic of element change to prevent contradictions.

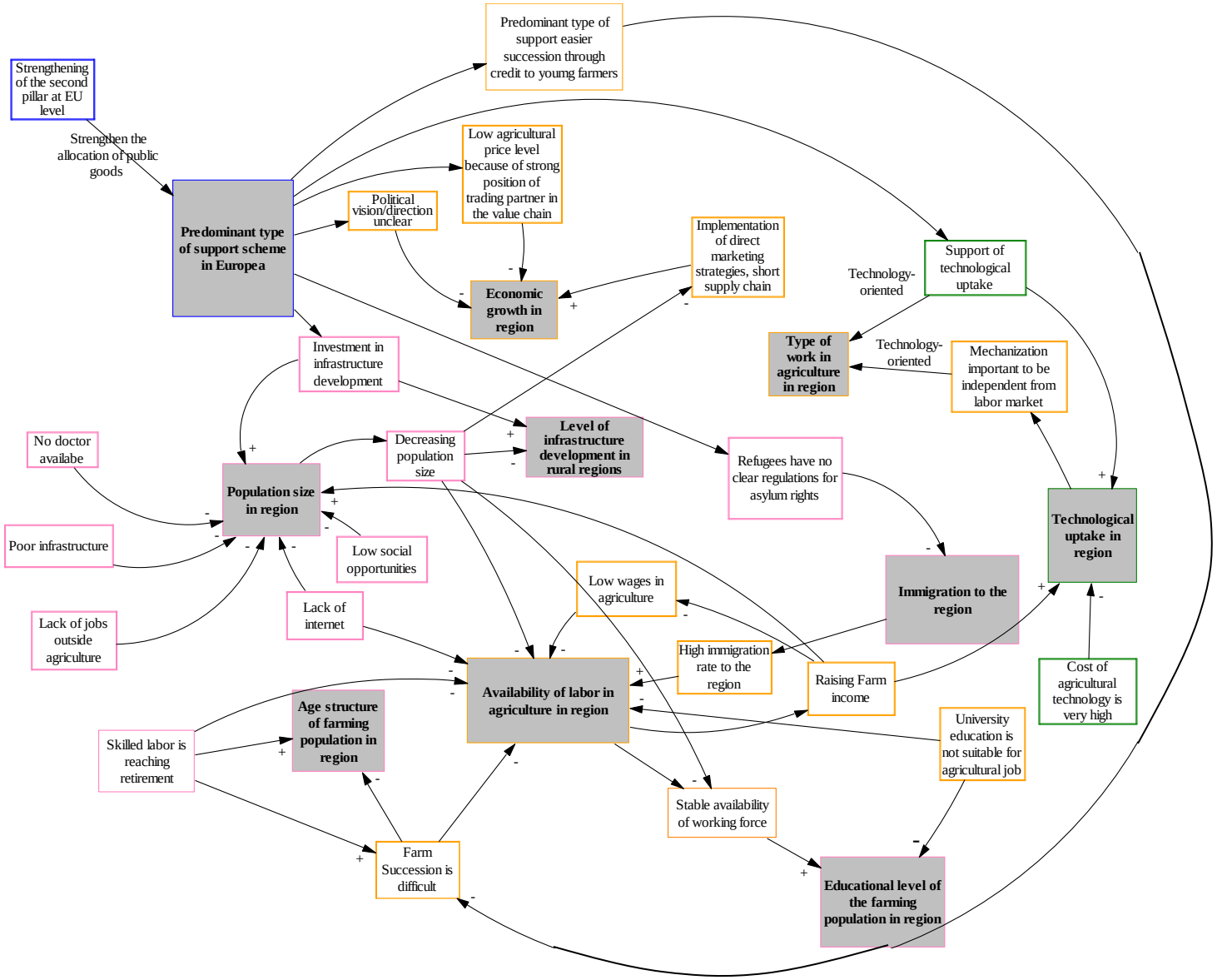

Figure 20: Casual-loop-diagram of selected elements (grey background) and causes (white background) illustrate storylines for demographic situation in the Altmark region. The colors of the boxes indicate the domain the element and causes and belong to. Orange: Economy; Blue: Policy; Green: Technology; Pink: Population and urbanization.

4.4 Trends of the Shared Socio-economic pathways for Demographic Dynamics of the Altmark region

Comparing storyline elements

Table 5 shows that certain storyline elements are more effected by demographic dynamics than other, since more cause-effect relations are impacting them. The storyline elements “population size” and “availability of working force” have the most cause-effect relations impacting. This indicated the importance of those storyline elements in capturing the demographic dynamics. The CLD visualizes the several directions of change impacting the storyline elements (Figure 20). **Population size** is mostly influenced by the characteristics of the infrastructure (internet, doctors), and the effort of the government to invest in infrastructure development. Also, the level of farm income, which can serve as income for people living in rural areas, influences the population size of the region. **Availability of labor in agriculture** is influenced by several demographic dynamics. The population size and the level of immigration dictate how many people are available in the rural area, as potential working force. The height of wages, a farming business can offer, influences how many people are willing to work in agriculture. Also, the difficulties of finding successors and the aging population has a negative influence on the availability of the labor in agriculture.

Several of the storyline elements are influenced by the **predominant type of support scheme.** This is especially noticeable for **infrastructure development**, **immigration to the region**, **economic growth** and **technological uptake**. The Predominant type of support scheme depends on the regulations of the European Union, and which support scheme the Common Agricultural Policy (CAP) is financing. The CAP can allocate payments on either socio-environmental payment, rural development payment, payment for technological support or payment coupled to production. Meaning that depending on the political support scheme infrastructure development, economic growth and technological uptake can be accelerated or decelerated. The immigration to the region is also regulated by the government.

The **age structure of the farming population** is influenced by age structure of the skilled labor and how difficult it is for potential successors to take over a farming business. This depends if also young farmers receive incentives through e.g. credits to make a succession possible. **Education level of farming population** depends if the university education is adjusted to prepare for agricultural jobs. It also depends if enough working forces are available. This is because farm managers only train the employees in case, they stay for the amount of time that his/her investment into the training pays off. **Type of work in agriculture** in the region depends on the speed of the technological uptake of the region. Additionally, it also depends if the predominant type of support scheme is directed to invests in a faster technological uptake.

Table 6. Storyline elements and in the current situation and in the five Eur-Agri-SSPs (in bold font) and DDA SSPs (in italic font).

Storyline Elements	Current	**Eur-Agri-SSPs** and *DDA SSPs*				
		1	2	3	4	5
Population size	Low	**Medium** *Medium*	**Medium** *Low*	**Low** *Very low*	**Low** *Low*	**High** *Medium*
Immigration level	Medium	**Medium** *Medium*	**Medium** *Low*	**Low** *Low*	**Medium** *Low*	**High** *Medium*
Level of infrastructure development	Low	**High** *Medium*	**Medium** *Low*	**Low** *Very low*	**Low** *Low*	**Medium** *Low*
Age structure of farming population	Overaged	**Balanced** *Balanced*	**Aging** *Overaged*	**Overaged** *Overaged*	**Diverse among countries** *Diverse among farmers*	**Young** *Balanced*
Educational level of the farming population	Medium	**High** *High*	**Medium** *Low*	**Low** *Low*	**Unequal** *Unequal*	**High** *Medium*
Economic growth	Slow	**Medium** *Medium*	**Medium** *Slow*	**Slow** *Very slow*	**Medium** *Unequal*	**High** *Medium*
Availability of labor in agriculture	Low	**Medium** *Medium*	**Medium** *Low*	**Low** *Very low*	**Medium** *Low*	**High** *Medium*
Type of work in agriculture	Production oriented	**Technology-oriented, production-oriented** *Technology-oriented, production-oriented*	**Production oriented** *Production oriented*	**Production oriented** *Production oriented*	**Diverse: production oriented, technology-oriented** *Diverse: production oriented, technology-oriented*	**Technology-oriented** *Technology-oriented*
Predominant type of support scheme	Income support and some rural development policies and environmental payments	**Socio-environmental payments, payments for rural development** *Socio-environmental payments, payments for rural development*	**Income support and some rural development policies and some environmental payments** *Income support and some rural development policies and environmental payments*	**Payment coupled to production** *Payment coupled to production*	**Income support, investment technological uptake** *Income support, investment technological uptake*	**Investment technological uptake** *Investment technological uptake*
Technological uptake	Medium	**Rapid** *Rapid*	**Medium** *Slow*	**Slow** *Very slow*	**Uneven: high in high income countries and low in low income countries** *Uneven: high in high income farms and low in low income farms*	**Very rapid** *Rapid*

Comparing DDA SSP scenarios

Table 6 shows that the current situation of the storyline elements of the Altmark region is most similar to the DDA SSP 2. This is because the DDA SSP 2scenario reflects the “business as usual” scenario. What is noticed is that some storyline elements of DDA SSP 2 perform lower than the Eur-Agri-SSPs. This applies for storyline elements population size, level of infrastructure development, education level, economic growth, among others (Table 6). Also, the DDA SSP 5 scenario shows lower performance of certain storyline elements compared to the Eur-Agri SSP 5. This applies for availability of working force, population size, level of infrastructure development, among others (Table 6). Population size is characterized as medium in DDA SSP 1 and 5 and low in the other scenarios. Level of infrastructure development has the trend to decrease in all scenarios, except for DDA SSP 1, where a medium level is given. A medium economic growth is given in DDA SSP 1 and 5, while it is unequal between farmers in DDA SSP 4 and slow in the other scenarios. Availability of labor in agriculture is medium in DDA SSP 1 and 5 and low in the other scenarios.

The DDA SSP 4 is not much different compared to the European level. DDA SSP 1 is the scenario, which is desirable, while the DDA SSP 3 is completely the opposite with the highest challenges for the demographics.

5. Discussion

In the first sections of this chapter (5.1 through 5.3) the results of the FoPIA-Surefarm workshop are discussed to analyze the current resilience of the Altmark's farming system. In section 5.1 the performance of the farming system is identified. Section 5.2 discusses the resilience strategies and attributes and to which resilience capacities they contribute. Options to increase resilience are discussed in section 5.3. The outcomes of the scenario development with the identified trends of the demographic dynamics and what this implies for the case study's' resilience is discussed in section 5.4. Methodological challenges of the FoPIA-Surefarm workshop are elaborated in section 5.5. And a conclusion of the farming system's resilience is drawn in section 5.6.

5.1 Functions to identify the farming system

The most important function of the farming system is the "provision of food", which is performing well (score 3.6 on a scale of 1 to 5), followed by the function "economic viability", which is performing worse (score 2.9 on a scale of 1 to 5). Economic viability is perceived most important by *farmers*, while the food production is scored most important by researches and consultants, which is as expected. The importance of "economic viability" can be explained by the findings of previous studies. Those found that the Altmark has a weak capital base, high share of rented land, and low proportion of high-quality arable land (Appel and Balmann, 2018) and therefore represents an important challenge. Overall "natural resources" is the third most important function and scores the best performance (3.8 on a scale of 1 to 5), which is due to the extensive way the agricultural system is typically managed (Appel et al., 2016; Appel and Balmann, 2018). Overall functions to deliver private goods are more important than functions to deliver public goods, but perform equally good in the German CS.

Farmers perceive the performance of public goods lower compared to the stakeholder group *researchers and consultants*. It was expected that *farmers* perceive the performance better than the other stakeholders, considering that for them, them factors for production are more relevant. However, as seen in other literature, *farmers* represent the position of conserving the resources, especially in case they are limited (Lange et al., 2015). This is even strengthened by the fact that the year 2018 was a drought year with negative impact on resources and yields. *Politicians* and *NGOs* perceive the performance of the public goods lowest, because they represent the critical view and establish laws for regulation.

5.2 Robustness, adaptability and transformability of the farming system

The resilience of the farming system can be assessed through the implementation level of identified strategies and resilience attributes and their contribution to the resilient capacities, which are robustness, adaptability and transformability.

5.2.1 Strategies

The strategies, identified by the participants, can be categorized into three different groups. One is categorized by strategies which contribute to adding value to the production. In the Altmark the added value is the biogas production. This is reflected in the overall highest performance of the indicator

“production of biogas”. The strategy to extend the rapeseed production was applied for that purpose and increased the adaptability of the system in the short term. The German Renewable Energy Sources Act (REA) was the law to stimulate the biogas production. Through previous research it is known that the REA did not increase the profitability of biogas farms on average. This is due to a transfer of a significant fraction of the added value to the landowner, because of increased rental prices on agricultural land (Appel et al. 2016). The REA could not contribute to adaptation or transformation of the gross margin but rather contributed to robustness of the system. Those strategies that contribute to added value in the production can be characterized by the attribute “response diversity” of the farms.

Strategies for cost saving purposes, which are used to affect the performance of the gross margin, are important for the Altmark. Strategies, such as “tillage without plough” and “stop of investment” are associated with that category. Such strategies are contributing to robustness and adaptability but show a trade-off with transformability. Those strategies for cost saving purposes, could be defined by a new attribute "balanced system reserves". In resilience literature the attribute is defined as “the degree to which a system is skewed toward one strength at the expense of others” (Kerner and Thomas, 2014). This implies a system has balanced reserves when system inputs, outputs or processes change but does not undergo a weakening of the system. The system reserves can be balanced according Abel et al. (2006) between “natural, human, social, physical and financial capital”. Input and output are defined as certain capital going into or leaving a system, while processes means the capital undergoes certain procedures e.g. saving or spending. Through the strategy “tillage without plough” more was invested to use glyphosate (physical capital) for the cultivation to save financial capital, which was at risk due to lower agricultural prices (less income). “Stop of investment” was a shift of financial capital (e.g. investment into a new tractor) to maintain the human capital pools. This makes the system adaptable in the short term but shows a trade-off with transformation: a transformation of the system is hindered because investment enables fundamental change (Abel et al., 2006).

Other strategies are associated with regulatory incentives of the government to increase the sustainability of production (strategies related to animal welfare). Those are the “AFP” and the “order on the protection and keeping of production animals” which are political regulations on standards of animal keeping and contribute to the long-term adaptability of the system. Those strategies can be categorized by the attribute “coupled with local and natural capital (legislation)” because they are incentives to use the existing capital to improve the production system. However, other strategies can be categorized into the group of strict government regulations which are improving the production quality. Strategies of this group are “ban of caged poultry” and “labelling requirements for eggs”. Both strategies contribute to adaptability and transformability of the system. Also, the strategy “minimum wage” can be categorized by this group since it is a strict government regulation. Those strategies can be categorized by the attribute “diverse policies”. Diverse policies score highest in the contribution to the capacity transformability compared to the other attributes. But since this attribute is scored rather low in application, it can mean that other policies are needed for a transformation. Also, policies that apply fixed rules to increase income tend to cause a system to lose on resilience in the long term (Holling 1986, 1995).

The applied strategies are defining the farming system mostly as adaptable and robust. However, the transformability of the system is limited due to the low economic capital.

5.2.2 Attributes

None of the attributes scored a high level of application (Figure 18), but rather low to moderate (1.9 to 3.5 on a scale of 1 to 5). Also, the participants assessed that the attributes mostly contribute to the robustness of the system. The attribute with highest presence in the farming system is “socially-self organized”. This implies opportunities for increased resilience in the Altmark region through networks between farming system actors.

Despite that, there are also attributes that were assessed to be applied in the Altmark which were associated with adaptability: “spatial heterogeneity” and “coupled with local and natural resources”. The attribute “production coupled with natural resources” reaches a higher value for adaptability, compared to the other capacities. Spatial heterogeneity is an important attribute contributing to resilience (Resilience Alliance, 2010). High levels of application are due to the heterogeneity in size, production and specialization of farms in the Altmark.

None of the attributes was scored to contribute to transformability of the farming system. The attribute which scored highest in the contribution to transformation overall is “diverse policies”. However, since the implementation of this attribute scores rather low there is a need for future political regulation to enable a transformation. An attribute which scores low in implementation for transformation is “supports rural life”, which indicate a low availability of human capital (working force).

5.2.3 Assessing the accordance with different rationales

To assess the capacities of the Altmark system, the accordance of system characteristics with rationales defined by Hoekstra et al. (2018) can be assessed. Hoekstra et al. (2018) defined two narratives in their work, which characterizes the management of socioecological systems under uncertainty of disturbances. The first rational is the control rational, which is characterized mostly by the focus on robustness and efficiency. Secondly, the resilience rational is characterized by a focus on adaptability and transformability.

The potential of a resilient system, through adaptive and transformative capacities is mainly based on diversity of the farming system in the Altmark region. Complementary strategies used in the past to adapt to several governmental changes (end of second world war and reunion of Germany) was creating heterogeneity in size, production and farm type (Levin, 1999. Also, the strategies in the past (strategies to increase animal welfare) were applied to use the existing resources in an adaptive way. The extensive management of resources in the Altmark region is a characteristic of the resilience rational (Hoekstra et al., 2018). At the same time, other attributes and strategies determine the narrative of a robust and less flexible system, which Hoekstra et al. (2018) defines as the control rationale. The increase of biogas production was intended to increase the profitability and according to Hoekstra et al. (2018) it represents a rationale of a controlled system. The strategies of cost saving measures are the economic use of limited resources and therefore also defining the control rationale (Blanchard and Fabrycky 2014).

5.2.4 Adaptive cycle to assess need for re-orientation

The SURE-Farm project is using the **adaptive cycle concept** to assess the current state of the farming systems to evaluate the potential room for improvement and the need for re-orientation (see 1.3.2). The agricultural system in the Altmark region in the current state, is characterized mostly through the "exploitation and conservation" phase in the adaptive cycle. The natural resources are conserved because they are used in an extensive way (Appel and Balmann, 2018). Strategies in the past to increase profitability (e.g. through extension of biogas production) and quality standards (e.g. through diverse policies), are characterizing the exploitation stage in the adaptive cycle. Also, implemented strategies in the past to increase the gross margin were mostly cost saving strategies. However, according to the participants of the workshop, the farming system is not resilient in financial and human capital and therefore it can be argued that those capitals are exploited. This is reflected in the low application of the resilience attribute "reasonable profitable". It is also reflected by the function "economic viability", which is scored important but not good performing like "food production" (see 5.1). However, the indicator "wages" scores even lower in performance and high in importance. Therefore, it identifies one of the main challenges for the farming system, where reorientation might be needed. Also, the access to human capital (working force) was identified as challenge in the Altmark region since the resilience attribute "support of rural life" was scored low in application (see 3.5.2). The resilience attribute "socially self-organized" scored the highest implementation level in the farming system compared to the other resilience attributes. According to Cabell and Oelofse (2012) this attribute is associated with the reorientation phase in the adaptive cycle. It can be argued that the Altmark farming system has to pass through this reorientation phase to reach more resilience.

5.3 Options to improve the resilience of the farming system

Based on the workshop results, conversations with research experts and related literature, options to improve the resilience of the farming system in the Altmark region can be suggested.

One of the challenges of the farming system is to find educated workforce (Bijttebier et al. 2018). To increase resilience, it could be beneficial to give incentives to raise attractiveness of education for the population in the rural area. The regional media of the Altmark published an article that the green party is in favor to open a technical school to teach production practices (Bündnis 90/Die Grüne, 2018).

To increase the profit of the farming system, participants mentioned the option of using niche products. A certain marketing strategy needs to be developed to sell the output. For farmers in the Altmark it is difficult to compete on the market. Direct sales could increase the profitability, because part of the profit does not have to be handed over to a middleman. This is evidenced by the resilience attribute "socially-self organized", which was scored to be applied in the farming system. The attribute implies that the farming system provides opportunities to use the created networks for better distribution and sales of agricultural produce. The concept of community supported agriculture (CSA) is one option used in the Altmark region to increase resilience of the system and increase the income in the Altmark region (Ritter-Findeisen, 2017).

The demographic change is one of the main challenges for the Altmark region, because of rural exodus and loss of potential working force and successors. First, the local government is investing in rural development projects such as increasing digitisation in rural areas (Schmidt, 2003). However, the used strategies in the past, which were defined as “strict government regulations” and “regulatory incentives of the government”, indicate that in the past, nnational government and European regulations were driving the direction of the farming system. The political framework at national level and European level, which is driving the support of rural areas and demographic change will influence the direction of the farming system resilience. For a resilient system in the long-term, adaptive legislations are needed, to invest in infrastructure of the region.

5.4 Shared socio-economic pathways for Demographic Dynamics in the Altmark region

By creating the Shared Socio-economic Pathways for the Demographic Dynamics in the Altmark region (DDA SSP) certain trends of the demographic dynamics and their implications on the farming system’s resilience of the Altmark region were observed. This was done by comparing the DDA SSPS with the Eur-Agri-SSPs and by analyzing the dynamics of the storyline elements in the five developed DDA SSPs.

What is noticed is that certain storyline elements of DDA SSP 2 perform lower than the Eur-Agri-SSP 2 (Table 6). In Table 5 many of the cause-effect relations which describe dynamics of low infrastructure and emigration were assigned to DDA SSP 2. This is due to the low level of current infrastructure (internet, hospitals, streets,..) in the Altmark region (Schmidt, 2003). This is reflected in the SSP 2, which describes the “business as usual” scenario. Also, the DDA SSP 5 is characterized by storyline elements with a lower performance of the storyline elements compared to the ones of the Eur-Agri-SSPs. The narrative for the SSP 5 scenario assumes higher investments in technology and infrastructure in the metropolitan region (Mitter et al., 2018). The Altmark is a rural area and therefore the SSP 5 pathways are not characterized to invest in all the challenges of the region (e.g. rural development). The storyline elements of DDA SSP 4 are not much different compared to those at the European level. In general, it is difficult to represent the DDA SSP 4 scenario because it is characterized by inequality between societies. At a regional scale this manifests as inequality between farming businesses.

In the FoPIA-Surefarm workshop the low economic viability and low wages in agriculture were identified as main challenges. In the scenario development it was recognized that the availability of labor in agriculture is a crucial element for the demographic dynamics in the Altmark region. This is evidenced by the fact this storyline element (Availability of labor in agriculture) takes a central role in the CLD and it is connected to many of the other storyline elements. This is important since low availability of labor is a constraint for innovation (Klein, 2018). The availability of labor in agriculture is medium in the DDA SSP 1 and 5 and therefore higher in those scenarios compared to the others. It is relevant to have sufficient labor available, which is not only determined by the level of wages. Availability of labor is also influenced by the population size of the region, which is directly influenced by the infrastructure development, as indicated by the CLD.

The resilience of the Altmark region is impacted by the demographic dynamics. A resilient system means it can maintain the delivery of farming systems functions in face of disturbance. The business as usual

pathway is not resilient since the demographic elements e.g. economic growth and availability of working force stay constantly low, which is identified as a challenge for the resilience in the Altmark region. DDA SSP 3 is even a worse scenario and therefore also not resilient. The DDA SSP 1 and 5 can be seen as resilient scenarios since they represent scenarios with medium availability of labor in agriculture. However, only DDA SSP 1 invests into infrastructure development, which is necessary to keep sufficient working force in the region and identifies the resilient pathway in the long-term.

In future research these created SSP DDA scenarios can be potentially used by the AgriPoliS model to assess regional agricultural structures changes. AgriPoliS can assess quantitatively how the identified demographic dynamics, change the agricultural structure (which was identified as challenge). Specific policies, for example, representing different predominant types of support scheme of the national or European government can be translated into different SSP DDA scenarios to assess the change in availability of labor. This can be used to prove information to decision makers, who decide under uncertainty of the future development.

5.5 Methodological challenges in FoPIA-Surefarm workshop

Challenges occurred during the explanation of the scoring system in the workshop. Especially during the exercise to score the importance and performance of the indicators, the participants were questioning the methodology and were first not willing to engage. Many questions and assumptions from their side were necessary to increase the cooperativeness to score the indicators. It is questionable if the participants confound the scoring for importance and performance of the indicators. The importance of e.g. the indicators “farms with direct marketing” was scored very low, which is reflected in the trend of the performance score. However, this is contradicting with the group discussion where the importance was highlighted despite the poor performance. Observation of the workshop shows that the participants perceived the performance of the indicators more important to assess than the importance. Therefore, it is crucial to explain the purpose of the exercise comprehensibly to ensure the engagement of the participants. In the future a short definition of the system functions and indicators with examples should useful to accelerate the exercise.

The exercise to score the resilience capacities for the strategies and attributes were complex and not enough time was available to explain the concept in the necessary depth. The capacity of robustness is caused through a change in a short term (month to years) (Anderies *et al.*, 2013). However, a transformation process can be realized in a longer period, comprising several decades to centuries. Depending on the time scale the participants are using to determine contribution to resilience, they might focus only on certain capacities. Also, examples of the three resilience capacities could have helped in this situation with a remark to take different time perspective into account. An improvement can be, to shorten this exercise and include an additional open discussion round, to ask stakeholders for personal examples of strategies and attributes and how they think they are influencing the resilience of the agricultural system in the Altmark region.

5.6 Conclusions

The agricultural system, in its current state, is characterized mostly by the "exploitation and conservation" phase of the adaptive cycle (Holling 2002). Strategies in the past to increase profitability (e.g. through extension of biogas production) and quality standards (e.g. through diverse policies), are characterizing the exploitation stage in the adaptive cycle. Those strategies contributed mostly to adaptability and robustness of the system but hamper the transformation of the farming system. Natural capital is conserved, because of the extensive management. The spatial heterogeneity of the production system combined with the extensive management are characterizing the system as adaptive, in the resilient rational according to Hoekstra et al. (2018). However, the financial and human capital is limited because the farming system is not sustainable in terms of profitability and consequently cannot pay decent wages to agricultural workers. Transformation might be needed because the resilience attribute of "reasonable profitable" and "support of rural life" were scored low. The highest scored resilience attribute is "socially-self organized" and contains a chance for the resilience in the Altmark region, through networks between the farming system actors. Lastly, many diverse policies were applied to raise the indicator "animal welfare". However, the attribute "diverse policies" was scored low in application in the system and might identify the need for other regulations.

The farming system is mainly adaptable and also robust in particular processes but experiences a lock-in due to low wages and infrastructure issues. Consequently, transformability of the farming system is considered to be low.

The scenario development highlights the trend that a business as usual scenario will lead to low availability of labor in agriculture due to rural exodus because of slow economic growth and a low infrastructure development and therefore challenge the resilience of the Altmark region. DDA SSP 1 and DDA SSP 5 represent scenarios where medium economic growth is given, and therefore represent pathways to increase the resilience of the farming system. Direct marketing is one future strategy identified to increase profitability. However, only DDA SSP 1 invests into infrastructure development, which is necessary to keep sufficient working force in the region and identifies the resilient pathway in the long-term. Infrastructure development depend on the predominated support scheme of the government. This means that the resilience of the farming system also relies on national and European government.

In future research these created SSP DDA scenarios can be potentially used by the AgriPoliS model to assess regional agricultural structures changes. This can be used to provide information to decision makers, who decide under uncertainty of the future development.

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7. Appendix

7.1 FoPIA-Surefarm workshop memo

The workshop was conducted in a conference room of a conference center in Zethlingen in the Altmark region. The facilities of the room were of good quality and sufficient for the purpose of the workshop. The used tables were arranged in a "U from" with the open end towards the screen of the presentation. The temperature was high enough since the caretaker pre heated the room already before the workshop. The light was a bit too low during some parts of the workshop. It was a cloudy day and not sunlight was entering the room. At the same time the ambient light was switched off to see the proception of the power point presentation better. It would have helped to switch it one when participants were filling out the survey papers to increase the concentration.

There was offered tea, coffee and small snacks during the whole workshop. This helped to increase the motivation of the participants. Also, the food for lunch was of good quality and the participants were satisfied after. It was noticeable that the concentration dropped before lunch time so maybe it would have been good to have the lunch break some minutes earlier. The lunch break helped to obtain a better atmosphere because the participants could get to know each other and had the option to talk about other topics besides the workshop.

The attitude of the participants was good on average. The highest attitude could be noticed in the beginning. After the doubts of the participants towards the scoring system of the indicators it dropped noticeable. Due to the good guidance of the moderator the workshop could proceed without major disruptions. Also, during the scoring of the three capacities of the attributes the concentration of the participants decreased. In this situation the one to one guidance offered by the researcher team helped the participants to increase their focuse.

The workshop started at 9:45 a clock with coffee, tea or other refreshments. The official start was at 10:00 a clock with the presentation. In between the participants were allowed to get a coffee, tea or other refreshments and fruits, but there was no official break. At 12: 15 a clock a lunch break took place for one hour. Also, in the afternoon participants were allowed to get coffee, tea or refreshments and fruits during the workshop, but there was no official break. The whole workshop ended at 16:00 a clock.

Table A1. Stakeholder overview

Participant's Function	**Organization**	**Stakeholder group**
Private Consultant	Berteuung und Beratung	Research and Consultant
Farmer	Agrargesellschaft GmbH	Farmer
Market-manager	Sparkasse	Research and Consultant
NGO	Friends of the earth (BUND)	Politics and NGO
Farmer	Farmer	Farmer
Farmer	Organic farmer	Farmer

Researcher and teacher	Anhalt University of Applied Science	Research and Consultant
Farmer, Student	Student and farmer	Farmer
Member of the parliament of Sachen-Anlaht	Politics green party	Politics and NGO
Member of the parliament of Sachen-Anlaht	Politics SPD	Politics and NGO
Manager	Bauernverband	Politics and NGO
Farmer	Agrargemeinschaft	Farmer

7.2 FoPIA-Surefarm workshop: Details on ranking and rating the functions and indicators

Table A2. Mean and standard deviation of scored importance of 8 functions per stakeholder group and for all participants. 100 points needed to be divided to 8 EF.

	Farmers		Researchers and consultants		Politicansand NGOs		All	
Function	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Food production	12.9	5.6	30.0	20.0	21.9	12.5	20.2	13.3
Bio-based resources	7.6	4.9	10.0	0.0	11.9	2.4	9.6	3.8
Economic viability	26.8	23.1	10.0	0.0	9.4	3.1	16.8	16.6
Quality of life	11.9	4.4	11.7	7.6	8.1	3.8	10.6	5.0
Natural resources	13.9	5.4	13.3	7.6	14.4	4.3	13.9	5.1
Biodiversity & habitat	9.7	4.6	6.7	2.9	11.9	2.4	9.7	3.9
Attractiveness of the area	7.7	6.3	13.3	14.4	10.6	1.3	10.1	7.6
Animal health & welfare	9.3	2.6	5.0	5.0	11.9	2.4	9.1	4.0

Table A3. Importance of indicators per stakeholder group; original values and transformed values to include importance of the function and number of indicators per function. Transformed values allow for direct comparison between all indicators across all functions.

	Transformed values								Original values.							
	Farmer		Politics and NGO's		Research and Consultant		Total		Farmer		Politics and NGO's		Research and Consultant		Total	
Indicator	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Milk production [kg/cow and y	15.0	4.6	28.4	7.6	34.0	9.6	24.2	10.6	38.6	13.4	43.3	11.5	37.8	14.1	40.0	11.7
Cereal production [t/ha]	11.9	2.3	20.2	5.5	31.0	4.6	19.4	8.7	30.6	6.7	30.8	10.0	34.4	7.1	31.7	7.3
Other food crops[t/ha]	11.9	2.3	16.9	4.5	25.0	6.2	16.9	6.6	30.6	6.7	25.8	5.8	27.8	7.1	28.3	6.4
Production of biogass	3.5	2.3	7.7	1.2	12.0	2.0	7.0	3.9	28.8	13.1	32.5	5.8	60.0	7.1	38.6	20.9
Share of crop rotation	8.7	5.0	16.0	1.2	8.0	2.0	11.0	4.9	71.3	37.7	67.5	5.8	40.0	7.1	61.4	26.5
Gross margin per hectare	51.4	17.8	15.5	9.6	18.0	5.2	31.1	21.6	63.8	23.9	55.0	40.0	60.0	0.0	59.9	25.1
Closure of a farm	9.8	10.3	5.6	6.1	7.0	9.6	7.7	8.3	12.2	14.7	20.0	26.5	23.3	7.1	17.6	17.2
Ability to invest	19.3	16.7	7.0	4.9	5.0	4.6	11.6	12.6	24.0	21.6	25.0	17.3	16.7	7.1	22.5	16.2
Cultural, social offerings	5.3	3.5	5.4	2.6	4.7	0.0	5.1	2.5	11.0	8.2	16.5	5.8	10.0	0.0	12.6	6.0
Infrastructure (Internet, child c	9.6	6.8	7.5	1.6	7.8	2.7	8.4	4.4	20.0	15.0	22.9	5.8	16.7	0.0	20.1	10.0
Availability of contractors	7.6	3.9	7.5	1.6	9.3	8.1	8.0	4.3	16.0	7.5	22.9	5.8	20.0	0.0	19.3	8.8
Wages	25.3	11.7	12.2	3.1	24.9	10.8	20.8	10.7	53.0	23.9	37.6	10.0	53.3	0.0	48.0	18.4
Water quality	13.5	4.6	19.7	3.7	23.1	3.1	18.0	5.5	24.2	9.5	34.2	7.6	43.3	7.1	32.3	11.5
Soil quality	16.7	4.4	18.2	3.6	21.3	0.0	18.4	3.8	30.0	8.5	31.6	7.6	40.0	0.0	33.0	7.9
Legal framework for fertilizer	14.6	11.4	9.3	13.1	3.6	3.1	10.1	10.8	26.2	21.0	16.3	24.7	6.7	0.0	18.0	19.8
Responsible usage of fertilizer	10.9	4.6	10.3	8.9	5.3	5.3	9.3	6.3	19.6	9.1	17.9	15.3	10.0	7.1	16.6	11.6
Biodiversity of birds, insects ar	11.3	4.8	13.4	5.3	5.6	1.4	10.6	5.1	38.8	18.5	37.5	17.3	27.8	2.3	35.6	14.7
Responsible usage of chemical	8.8	1.2	9.4	4.5	5.6	5.1	8.2	3.6	30.0	6.3	26.3	10.4	27.8	11.8	28.2	10.9
Legal framework of usage of ch	9.1	5.4	12.9	3.9	8.9	6.3	10.3	5.1	31.1	11.8	36.3	12.6	44.4	3.5	36.1	11.5
Agrartorismus	3.4	3.5	7.1	4.4	12.4	1.5	6.9	4.9	11.0	16.4	16.8	12.6	23.3	9.4	16.0	13.2
Farms with direct marketing	6.5	6.2	8.3	3.2	10.7	4.6	8.2	4.9	21.0	18.9	19.6	0.0	20.0	10.6	20.3	12.8
Internet connection	14.2	8.3	16.7	5.4	17.8	7.7	15.9	6.8	46.0	30.7	39.3	5.8	33.3	17.7	40.6	21.1
Attractive village life	6.8	3.9	10.3	6.0	12.4	1.5	9.4	4.6	22.0	8.7	24.3	12.6	23.3	3.5	23.1	8.6
Certification of animal welfare	13.9	1.5	14.5	3.1	5.0	4.6	11.9	5.0	16.0	5.0	38.3	10.0	46.7	14.1	31.1	13.0
Use of antibiotics	4.5	7.9	13.7	7.0	7.0	1.7	8.2	7.3	50.0	30.0	40.8	23.1	33.3	0.0	42.8	21.8
Legal framework of animal wel	9.5	6.7	7.4	5.3	3.0	3.0	7.2	5.7	34.0	26.3	20.8	15.3	20.0	14.1	26.1	20.9

Table A4. Mean and standard deviation of scoring on performance of indicators per stakeholder group and for all participants. Indicators were scored from 1-5 where 1 = very low, 2 = low, 3 = medium, 4 = good, and 5 = perfect.

	Farmers		Politicians and NGOs		Researchers and consultants		Total	
Indicator	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Milk production [kg/cow and year]	3.400	1.517	4.333	0.58	4.333	0.577	3.909	1.136
Cereal production [t/ha]	3.400	0.894	3.667	0.58	3.667	1.000	3.364	0.809
Other food crops[t/ha]	3.400	1.140	3.000	0.00	3.000	1.000	3.182	0.874
Production of biogas	4.600	0.548	4.000	0.00	4.000	1.155	4.364	0.674
Share of crop rotation	2.600	1.517	3.333	1.15	3.333	0.577	3.091	1.221
Gross margin per hectare	3.000	0.707	3.333	0.58	3.333	0.000	3.091	0.539
Closure of a farm	1.750	0.500	2.750	0.96	2.750	1.155	2.636	1.120
Ability to invest	3.000	1.414	2.333	0.58	2.333	0.577	2.700	0.949
Cultural, social offerings	2.400	0.548	2.667	0.58	2.667	0.000	2.400	0.516
Infrastructure (Internet, child day-care, doctors, streets)	1.600	0.548	2.667	0.58	2.667	0.000	2.000	0.667
Availability of contractors	2.200	0.837	2.667	0.58	2.667	0.707	2.400	0.699
Wages	2.000	1.732	2.000	0.00	2.000	0.000	2.000	1.155
Water quality	4.000	0.707	4.333	0.58	4.333	0.000	4.100	0.568
Soil quality	3.600	0.548	4.000	1.00	4.000	0.000	3.800	0.632
Legal framework for fertilizer	3.000	1.225	2.750	1.50	2.750	0.707	3.182	1.328
Responsible usage of fertilizer	4.000	0.000	3.000	1.41	3.000	0.000	3.636	0.924
Biodiversity of birds, insects and wild plants	3.800	0.447	2.250	1.50	2.250	0.000	3.273	1.191
Responsible usage of chemical crop protection	3.800	0.837	2.750	1.50	2.750	0.000	3.455	1.128
Legal framework of usage of chemical crop protection	2.700	0.975	2.250	1.50	2.250	0.707	2.682	1.146
Agrartorismus	1.800	0.837	2.000	1.00	2.000	0.707	2.000	0.816
Farms with direct marketing	1.600	0.548	2.000	1.00	2.000	0.707	1.700	0.675
Internet connection	1.800	1.304	1.500	0.58	1.500	0.707	1.636	0.924
Attractive village life	3.333	0.577	3.667	1	3.667	Value not available	3.429	0.535
Use of antibiotics	3.800	1.643	2.750	1.26	2.750	0.707	3.364	1.362
Certification of animal welfare	3.600	1.517	3.250	1.71	3.250	0.000	3.545	1.368
Legal framework of animal welfare	2.800	1.643	2.250	1.50	2.250	0.707	2.727	1.421

Legend: colour the scores of the means, with 1-2 = red, 2-3 = light reed, 3-4 = orange, and 4-5 = light green.

Table A5. Mean and standard deviation of scoring on performance of functions per stakeholder group and for all participants. Derived from scoring of importance and performance of indicators.

	Farmers		Politicians and NGOs		Researchers and consultants		Total	
Function	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Food production	3.3	0.9	2.7	1.8	3.4	0.6	3.1	1.2
Bio-based resources	3.1	0.8	3.3	0.6	3.6	0.4	3.3	0.6
Economic viability	2.6	0.9	2.4	1.4	3.0	0.3	2.6	0.9
Quality of life	2.0	1.0	2.4	0.3	2.1	0.1	2.2	0.7
Natural resources	3.6	0.2	2.9	1.8	4.0	0.1	3.4	1.1
Biodiversity & habitat	3.4	0.4	2.4	1.5	3.8	0.3	3.1	1.0
Attractiveness of the area	1.8	0.8	1.7	1.1	1.6	1.0	1.7	0.8
Animal health & welfare	3.3	1.4	2.7	1.4	3.6	0.4	3.1	1.2

Legend: colour the scores of the means, with 1-2 = red, 2-3 = light reed, 3-4 = orange, and 4-5 = light green.

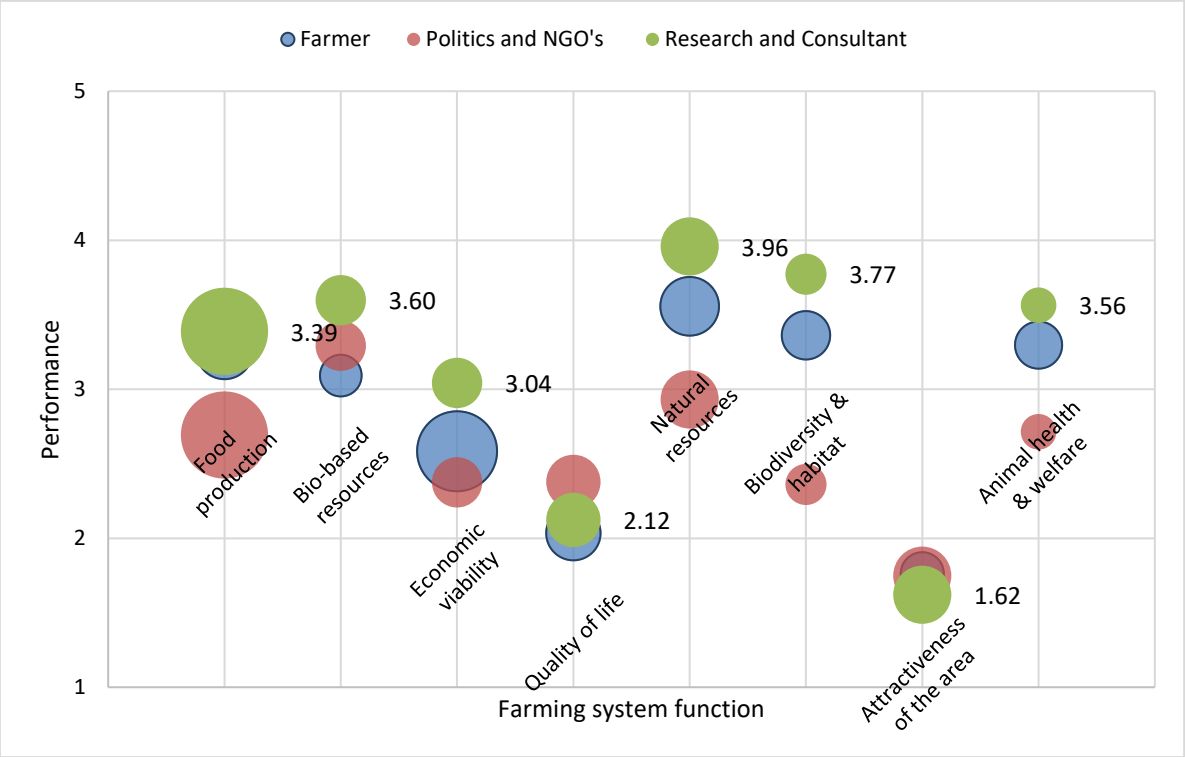

Figure A1. Bubble graph presenting averaged scores on performance of **essential functions** (from 1 to 5), aggregated by stakeholder group, while also indicating their importance (size of the bubbles), relative to each other.

7.3 FoPIA-Surefarm workshop: Dynamics of main indicators

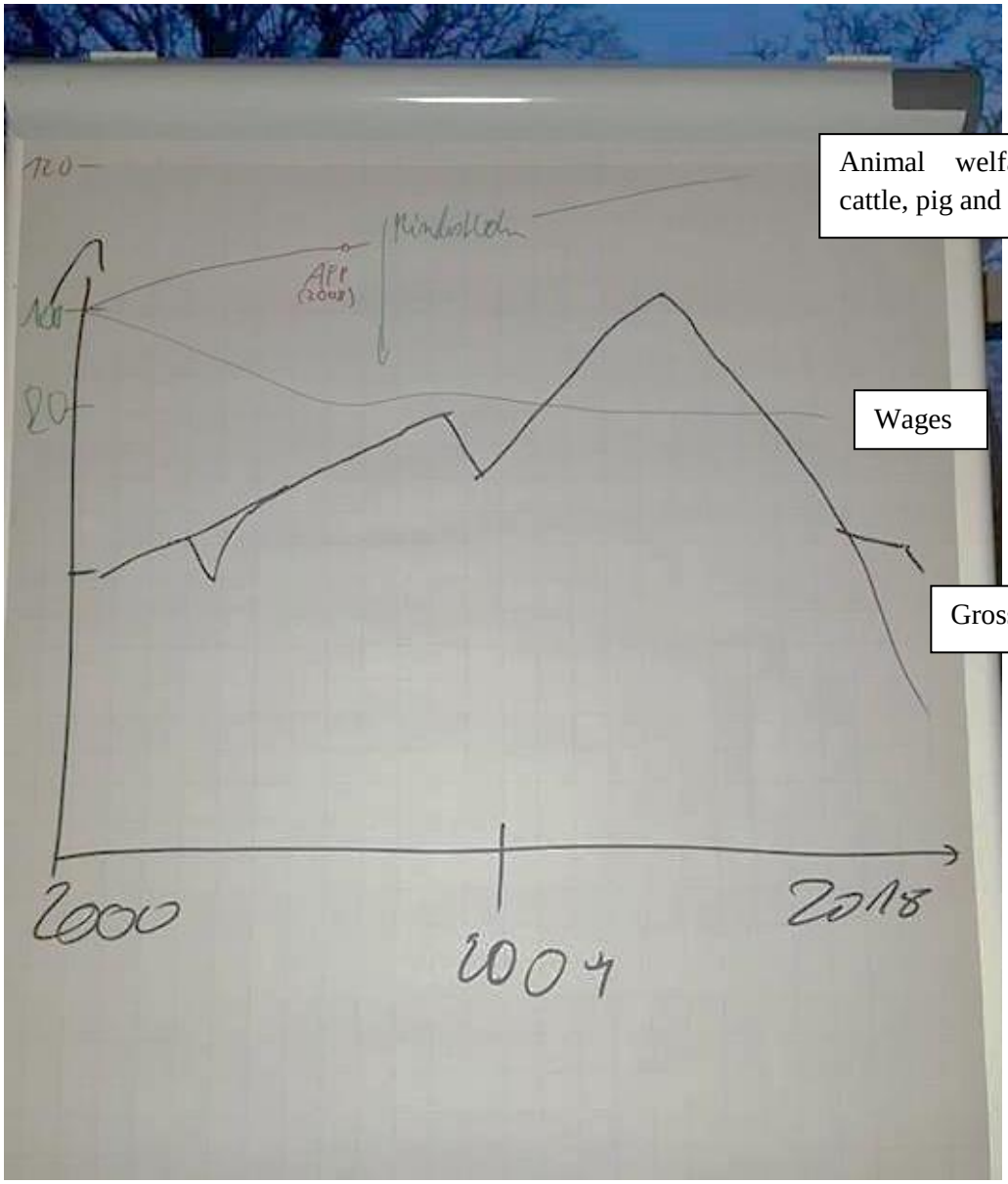

Figure A2. Photo of all the three drawn indicator (gross margin, wages, animal welfare) performance over the last 18 years. Drawn by the participants during the FoPIA-Surefram workshop.

7.4 FoPIA-Surefarm workshop: Details on scoring strategies and resilience attributes

Table A6. Mean (and standard deviation) of implementation scores of strategies and their potential contribution to robustness, adaptability and transformability

		Implementation score		Potential contribution to resilience capacities					
				Robustness		Adaptability		Transformability	
Selected indicator	Strategy	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Gross margin	Extension of rapeseed production	4.7	0.6	1.3	1.5	1.7	1.5	1.3	1.5
Gross margin	German Renewable Energy Sources Act (EEG)	3.7	1.5	1.7	2.3	1.0	1.7	0.3	2.5
Gross margin	Tillage without plough	3.7	0.6	0.7	1.2	-0.3	2.1	-0.7	2.3
Gross margin	Stop of investment	3.7	1.5	0.0	2.6	1.3	2.9	-1.3	2.1
Gross margin	Grand Total	3.9	1.1	0.9	1.8	0.9	2.0	-0.1	2.1
Animal welfare	Agricultural Investment Funding Programme (AFP)	3.5	1.0	1.2	1.2	2.2	1.2	0.3	0.8
Animal welfare	Ban caged poultry	4.8	0.4	0.2	1.9	0.3	1.4	1.7	1.8
Animal welfare	Labelling requirements of eggs	4.7	0.8	1.0	1.3	1.3	1.2	1.3	1.5
Animal welfare	Order on the protection and keeping of production animals	4.0	0.0	2.3	1.0	1.5	1.0	2.0	0.8
Animal welfare	Grand Total	3.0	0.9	0.8	1.4	1.5	1.4	1.0	1.6
Wages, income	Minimum wage	3.0	-	2.0	1.4	1.0	1.4	2.5	0.7
Wages, income	Working conditions	3.0	-	2.5	0.7	2.0	0.0	1.5	0.7
Wages, income	Grand Total	3.0	0.0	2.3	1.0	1.5	1.0	2.0	0.8
Gran Total		4.1	1.0	1.0	1.5	1.3	1.5	0.8	1.8

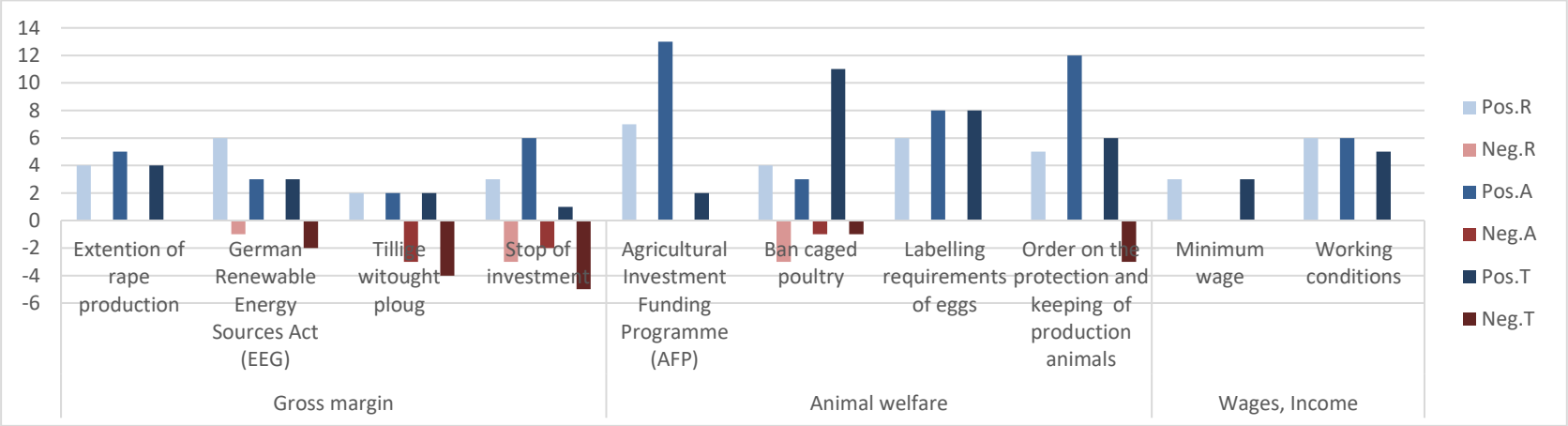

Figure A3. Bar graph presenting total positive and negative points allocated to a strategy's contribution to robustness, adaptability and transformability.

Table A7. Mean and standard deviation of performance scores of resilience attributes. Per stakeholder group and for all participants.

	Extent into which attribute applies in FS							
	Farmers		Politicians and NGOs		Researchers and consultants		Total	
Resilience attribute	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev	Mean	St. Dev
Reasonably profitable	1.3	0.5	3.0	1.4	1.0	0.0	1.6	1.0
Coupled with local and natural capital (production)	2.8	0.5	3.5	0.7	3.3	1.5	3.1	0.9
Functional diversity	2.0	0.0	2.0	1.4	1.7	0.6	1.9	0.6
Response diversity	3.3	0.5	2.0	1.4	3.0	1.0	2.9	0.9
Exposed to disturbance	2.3	0.5	3.0	0.0	1.3	0.6	2.1	0.8
Spatial and temporal heterogeneity (farm types)	3.0	0.8	3.0	1.4	2.3	0.6	2.8	0.8
Optimally redundant (farms)	1.5	1.0	5.0	0.0	1.7	1.2	2.3	1.7
Supports rural life	2.3	1.0	4.0	1.4	1.5	0.7	2.5	1.3
Socially self-organized	3.3	1.3	4.0	0.0	3.5	2.1	3.5	1.2
Appropriately connected with actors outside the farming system	2.0	1.4	3.0	1.4	1.5	0.7	2.1	1.2
Infrastructure for innovation	2.6	0.5	4.5	0.7	1.3	0.6	2.6	1.3
Coupled with local and natural capital (legislation)	2.0	0.0	2.5	0.7	2.0	1.0	2.1	0.6
Diverse policies	1.3	1.5	3.5	2.1	1.3	0.6	1.9	1.6

Table A8. Mean and standard deviation of resilience attribute's contribution to robustness, adaptability and transformability. Per stakeholder group and for all participants.

	Extent into which resilience attribute potentially can contribute to resilience capacities in FS											
	Farmers						Politicians and NGOs					
	Robustness		Adaptability		Transformability		Robustness		Adaptability		Transformability	
Resilience attribute	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Reasonably profitable	2.8	0.5	2.8	0.5	2.5	0.6	2.5	0.7	1.0	1.4	0.0	0.0
Coupled with local and natural capital (production)	2.0	1.4	1.5	0.6	1.0	2.2	2.0	1.4	1.5	0.7	0.0	1.4
Functional diversity	2.0	1.4	2.5	0.6	1.5	1.0	3.0	0.0	2.0	0.0	-1.0	0.0
Response diversity	1.5	1.3	1.3	2.2	1.0	1.7	3.0	0.0	2.0	1.4	0.0	0.0
Exposed to disturbance	2.0	1.4	2.5	0.6	1.5	1.7	0.5	3.5	0.0	2.8	-0.5	0.7
Spatial and temporal heterogeneity (farm types)	1.8	1.5	1.5	1.7	1.5	1.3	1.0	2.8	0.5	0.7	0.0	0.0
Optimally redundant (farms)	1.3	1.5	1.3	1.5	2.0	1.7	3.0	0.0	2.5	0.7	1.5	2.1
Supports rural life	2.7	0.6	1.7	1.5	0.3	0.6	2.5	0.7	2.0	1.4	0.5	0.7
Socially self-organized	3.0	0.0	2.0	1.0	1.7	1.5	2.0	-	2.0	-	0.0	#DIV/0!
Appropriately connected with actors outside the farming system	1.0	0.0	1.3	0.6	0.7	0.6	3.0	-	3.0	-	0.0	#DIV/0!
Infrastructure for innovation	1.0	1.0	1.3	1.2	1.3	0.6	3.0	-	3.0	-	3.0	#DIV/0!
Coupled with local and natural capital (legislation)	2.7	0.6	2.3	1.2	1.3	1.5	1.0	-	1.0	-	0.0	#DIV/0!
Diverse policies	2.5	0.7	3.0	0.0	3.0	0.0	3.0	-	3.0	-	3.0	#DIV/0!

	Extent into which resilience attribute potentially can contribute to resilience capacities in FS											
	Researchers and consultants						Total					
	Robustness		Adaptability		Transformability		Robustness		Adaptability		Transformability	
Resilience attribute	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Reasonably profitable	1.0	2.6	0.7	2.5	0.3	2.5	2.1	1.6	1.7	1.7	1.2	1.8
Coupled with local and natural capital (production)	1.7	1.5	1.7	1.5	0.7	1.2	1.9	1.3	1.6	0.9	0.7	1.6
Functional diversity	2.3	1.2	1.7	2.3	1.7	2.3	2.3	1.1	2.1	1.3	1.0	1.7
Response diversity	1.7	1.2	1.7	1.2	0.3	0.6	1.9	1.2	1.6	1.6	0.5	1.1
Exposed to disturbance	0.0	2.6	0.7	2.5	-0.3	1.5	1.0	2.2	1.3	2.0	0.4	1.7
Spatial and temporal heterogeneity (farm types)	1.3	2.1	1.3	1.5	0.3	0.6	1.4	1.7	1.2	1.4	0.8	1.1
Optimally redundant (farms)	1.0	2.6	1.0	2.6	0.3	2.5	1.6	1.8	1.5	1.8	1.3	2.0
Supports rural life	2.5	0.7	1.5	2.1	0.0	0.0	2.6	0.5	1.7	1.4	0.3	0.5
Socially self-organized	2.5	0.7	2.0	1.4	0.0	0.0	2.7	0.5	2.0	0.9	0.8	1.3
Appropriately connected with actors outside the farming system	2.0	1.4	2.0	1.4	0.0	0.0	1.7	1.0	1.8	1.0	0.3	0.5
Infrastructure for innovation	1.0	2.6	1.0	2.6	0.7	2.1	1.3	1.8	1.4	1.8	1.3	1.5
Coupled with local and natural capital (legislation)	2.0	1.7	2.0	1.7	1.3	1.5	2.1	1.2	2.0	1.3	1.1	1.3
Diverse policies	1.3	2.9	1.0	3.5	0.3	2.5	2.0	2.0	2.0	2.4	1.7	2.2

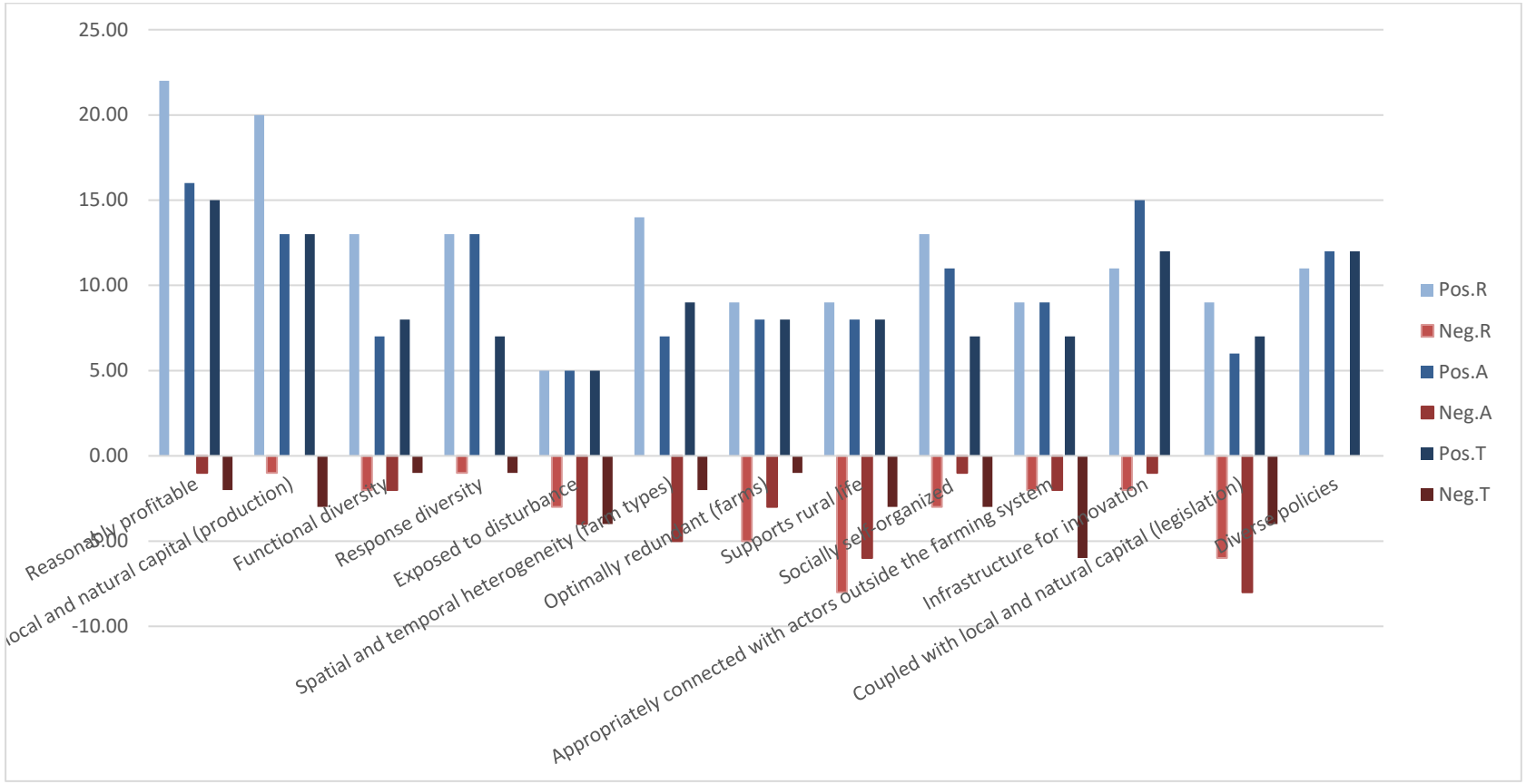

Figure A4. Bar graph presenting total positive and negative points allocated to a resilience attributes' contribution to robustness, adaptability and transformability

7.5 Overview of attributes

A9. Overview of attributes as proposed by Cabell & Oelofse (2012), including their definitions, implications, characteristics, link with resilience principles and SURE-Farm processes.

Resilience attribute	Definition	Implications	Characteristics	Link to SURE-Farm process	Link to resilience principles
Reasonably profitable	Persons and organizations in the farming system are able to make a livelihood and save money without relying on subsidies or secondary employment	Being reasonably profitable allows participants in the system to invest in the future; this adds buffering capacity, flexibility, and builds wealth that can be tapped into following release	Farmers and farm workers earn a livable wage; agriculture sector does not rely on distortionary subsidies	Agricultural production	Systems reserves (financial capital)
Coupled with local and natural capital (production)	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 or maintains soil fertility, recharges water resources, little need to import nutrients or export waste	Agricultural production	Systems reserves (natural capital)
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.	Risk management	Diversity
Response diversity	Response diversity is the range of responses of these components to environmental change	Diversity buffers against perturbations (insurance) and provides seeds of renewal following disturbance	Diversity of risk management strategies, e.g. different pest controls, weather insurance, flexible payment arrangements.	Risk management	Diversity

Exposed to disturbance	The system is exposed to discrete, low-level events that cause disruptions without pushing the system beyond a critical threshold	Such frequent, small-scale disturbances can increase system resilience and adaptability in the long term by promoting natural selection and novel configurations during the phase of renewal; described as “creative destruction”	Pest management that allows a certain controlled amount of invasion followed by selection of plants that fared well and exhibit signs of resistance	Risk management	Openness
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.	Farm demographics, risk management	Modularity, diversity
Optimally redundant (farms)	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	Farmers stop without endangering continuation of the farming system and new farmers can enter the farming system easily	Farm demographics; risk management	Modularity
Supports rural life	The activities in the farming system attract and maintain a healthy and adequate workforce, including young, intermediate and older people.	A healthy workforce that includes multiple generations will ensure continuation of activities and facilities in the area, and the timely transfer of knowledge.	A balanced population with young, intermediate and older people; Enough facilities in the nearby area to maintain an adequate standard of life.	Farm demographics	Systems reserves (social and human capital)
Socially self-organized	The social components of the agroecosystem are able to form their own configuration based on their needs and desires	Systems that exhibit greater level of self-organization need fewer feedbacks introduced by managers and have greater intrinsic adaptive capacity	Farmers are able to organize themselves into networks and institutions such as co-ops, farmer’s markets, community sustainability associations, and advisory networks	Governance	Tightness of feedbacks, system reserves (social capital)

Appropriately connected with actors outside the farming system	The social components of the agroecosystem are able to form ties with actors outside their farming system.	In case self-organization fails, signals can be send to actors that indirectly influence the farming system.	Farmers and other actors in the farming system are able to reach out to policy makers, suppliers and markets that operate at the national level	Governance	Tightness of feedbacks
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	Governance, agricultural production	Systems reserves (social capital)
Infrastructure for innovation	Existing infrastructure facilitates diffusion of knowledge and adoption of cutting-edge technologies (e.g. digital)	Through timely adoption of new knowledge and technologies, a farming system can better navigate in a changing environment.	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.	Governance, agricultural production	Openness, system reserves
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.	Governance	Diversity

7.6 Demographic Dynamics of Altmark region Shared Socioeconomic Pathways

DDA SSP 1 – Sustainable scenario

Population size is increasing moderately because farm income is increasing and provides income for the rural population. Also, no emigration is occurring because there is investment in **infrastructure development**. There is a medium **immigration to the region**, since the arriving people have a clear regulation for asylum rights. The **age structure of farming population** is balanced since not all skilled labor is reaching retirement. **Education level of farming population** is high because the working force is stable available, and the farm manager is therefore able to train those employees. Also, the university education become more suitable to train future farming working force. Because of implemented direct marketing strategies, the farms experience **economic growth.** Also, economic growth takes place because farmers receive higher prices due a strong position of the farmer in the value chain. Also, a clear political vision is given which enables the farmer to invest in innovation in the long term. There is a medium **availability of labor in agriculture**. The farm succession is difficult, but measures are used to counteract this. The political **predominant type of support scheme** allows easier succession through credit to young farmers. The **type of work in agriculture** is technology oriented, since the **technological uptake** in agriculture is rapid. The **predominant type of support scheme** benefits the allocation of public goods since the second pillar of the CAP (common agricultural policy) at EU level is strengthened.

DDA SSP2 – middle of the road scenario

Population size is decreasing in the long run, because emigration is occurring. Little money is invested from the government to maintain the **level of infrastructure of the rural area**. There is a low **immigration to the region** due to no clear regulations for asylum rights**.** There is an **overaged farm population** since the skilled labor is reaching retirement and farm succession for new farmers is difficult. **Education level of farmers** is low because the university education is not suitable and farm manager does not train their employees because there is no stable availability of the working force given. **Economic growth** is slow because no direct marketing strategies are used, and low agricultural prices and an unclear political vision is given. **Availability of labor in agriculture** is low, because of low wages in agriculture and the farm succession is difficult since the farming population is reaching retirement. **The type of work in agriculture** is production oriented since the work is not technology oriented. The **predominant type of support scheme** supports mostly income and some policies for rural development and environmental payments. Technological uptake in agriculture is slow because of the high costs and the low farm capital to invest in it.

DDA SSP3 – Unsustainable scenario

The **population size** is very low because of emigration due to no **investment into infrastructure development**. There is a low **immigration to the region** due to no clear regulations for asylum rights. The **farming population is overaged**, since skilled labor is reaching retirement. **Education level of farmers** is low because the university education is not suitable and farm managers do not train their employees because there is no stable availability of the working force given. **Economic growth** is very slow because no direct marketing strategies are used, and low agricultural prices and an unclear political vision is given. **Availability of labor in agriculture** is very low, because of low wages in agriculture and the farm

succession is difficult since the farming population is reaching retirement. **The type of work in agriculture** is production oriented since the work is not technology oriented. The **predominant type of support scheme** supports income. Technological uptake in agriculture is slow because of the high costs and the low farm capital to invest in it.

DDA SSP4 – Inequality

Population size is low since no investment into **infrastructure development** is given. Only it is invested into infrastructure which is closer to the urban areas. There is a low **immigration to the region** due to no clear regulations for asylum rights. The **age structure of farmers** is diverse, since investment into finding farm successors is unequal. The **education level of farmers** is unequal, since only some farmers receive suitable education. **Economic growth** is medium, since some farms profit from direct marketing but other farms suffer from low agricultural prices and an unclear political direction. **Availability of labor in agriculture** is medium, because only a certain amount of people is available for the farm succession and there is an unequal distribution of wages in agriculture. **Type of work in agriculture** differs, some farmers are technology oriented, some production oriented. **Predominant type of support scheme** supports income through the technological uptake. However technological uptake is high in high income farms and low in low income farms, and therefore unequal.

DDA SSP5 - Fossil-fueled Development

The **population size** is medium. Some people migrate due to low infrastructure development and some people stay in the rural area because of raising farm income which spills over to other people in the rural area. There is a medium **immigration to the region**, since the arriving people have a clear regulation for asylum rights. A low **level of infrastructure development** is experienced, since there is only investment in infrastructure development in the urban areas. The **age structure of farmers** is balanced because a balanced amount of skilled labor is reaching retirement. **Education level of farmers** is medium, since the university education is more suitable, but there is no stable availability of working force to receive education. There is a medium **economic growth**, since a clear political direction for investment is given, and the farmers receive a stronger position in the value chain, but no direct marketing strategies are implemented. **Availability of working force** is medium. Farm succession is eased because of support of young farmers. But still the people are migrating because the infrastructure development is low. **Type of work in agriculture** is technology oriented. Also, the predominant type of support scheme is oriented towards investment for technological uptake. This enables a **rapid technological uptake in agriculture**.