Project acronym: SURE-Farm
Project no.: 727520

Start date of project: June 2017
Duration: 4 years

# FoPIA-Surefarm Case-study Report The Netherlands

Work Performed by Partner 1, WU

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| Due date | 31 May 2019 |
| Version/Date | 31 May 2019 |
| Work Package | WP5 |
| Task | T5.2 |
| Task lead | WU |
| Dissemination level | Public |

## INDEX



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

Please, cite this FoPIA-Surefarm case-study report as:

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

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## Abstract

This report presents the results of a sustainability and resilience assessment for a farming system in Veenkoloniën, a rural region in the North-East of the Netherlands. In Veenkoloniën, more than 60 % of an area of almost 80,000 hectares is dedicated to agriculture. The soils in the Veenkoloniën are mainly peat soils mixed with sand, which makes them very suitable for growing starch potato. Farmers and the farming system in Veenkoloniën face multiple challenges that affect sustainability and resilience.

The assessment focused on 1) ranking the importance of functions and selecting representative indicators for these functions, 2) scoring the current performance of the representative indicators, 3) sketching dynamics of main representative indicators of functions, 4) linking these dynamics to challenges and resilience enhancing strategies, 5) assessing level of implementation of identified strategies and their potential contribution to the robustness, adaptability and transformability of the farming system, and 6) assessing level of presence of resilience enhancing system characteristics (resilience attributes) and their potential contribution to the robustness, adaptability and transformability of the farming system.

The farming system's functions of "providing economic viability" and "maintaining natural resources" are seen as most important by all participants. "Food production" is another important function. For "providing economic viability", the indicators "profit/ha" and "income from agricultural activities (%)" were evaluated to be both representative for the function. For "maintaining natural resources", the indicators "soil quality" and "water availability" were most representative. Overall, the farming system is assessed to perform moderately. The production of food is perceived to perform moderately to well. System functions related to economic viability and natural resources are perceived to perform moderately.

Over the years, the arable farming system has shown adaptive capacity to overcome multiple challenges. Adaptations have been made possible by adoption of mainly technological innovations at farm (production) level and at the processing level. Based on implementation and contribution levels of resilience attributes, we conclude with caution that 1) the general resilience of the farming system is low to moderate, 2) the farming system seems more robust than adaptable and transformable, 3) for overall resilience, the farming system depends on a combination of attributes, 4) for robustness, the farming systems depends mostly on local and natural capital and farm heterogeneity in the area, 5) for adaptability and transformability the farming system depends most on local and natural capital, infrastructure for innovation and diverse policies. The attribute "Reasonably profitable" shows high potential to contribute to all resilience capacities, but its current performance is low.

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# 1 Introduction

## 1.1 Aim of report

This report aims to evaluate sustainability and resilience of the farming system in the Veenkoloniën according to stakeholder views that were provided during a FoPIA-Surefarm workshop. This report is part of Deliverable 5.2 of the SURE-Farm project in which 11 EU farming systems are compared.

## 1.2 Case study

The Veenkoloniën is a rural region in the North-East of the Netherlands. More than 60 % of its area of almost 80,000 hectares is dedicated to agriculture. The soils in the Veenkoloniën are mainly peat soils mixed with sand, which makes them very suitable for growing starch potato. More than half of the agricultural land is dominated by farms that cultivate starch potatoes, typically in a rotation of 1:2 to 1:3 with other crops, which are mainly sugar beet and winter wheat. In general, with the current typical crop rotation, profit per hectare is low compared to other regions with arable farming. For the cultivation and processing of starch potatoes, farmers are organized in a cooperative (AVEBE). This provides certainty of income, but also co-dependency between farmers and the cooperative.

Arable farms in the Veenkoloniën are often medium-sized farms run by a family. Apart from arable farms, there are also dairy farms, intensive livestock farms and horticulture. Farmers and the farming system in Veenkoloniën face multiple challenges (Table 1) and the number of farms has gone down (D3.1; Bijttebier et al., 2018). Over the years, remaining farms have increased in size (economic output and area), and different farmers have diversified by including new crops in their rotation (onion, carrot, flower bulbs), by becoming mixed farms (currently about 10% of agricultural land) and by developing activities outside agriculture. Over time, also the intensity of land use has increased, i.e. more output per hectare.

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*Table 1: Identified challenges for the farming system in the Veenkoloniën. Challenges were identified by researchers in the preparation phase before the workshops.*

| Challenges | Economic | Environmental | Social | Institutional |
|---|---|---|---|---|
| **(Non-) permanent shocks** | Fluctuation of prices of agricultural products | Hard winds and wind erosion in fields with young plants | Mental health of farmer and his/her family | Change in agricultural policies of EC; decoupling of subsidies |
| | | Warm and wet summers increase risk of infection with Erwinia spp. or risk on second growth in potatoes | | Ban on certain crop protection products |
| | | Low water holding capacity and low drainage capacity make the region sensitive to extreme drought and rainfall. | | |
| | | Extreme quantities of rain in May - Sep can cause rotting in potatoes. | | |
| **Long-term pressures** | Low economic performance per hectare of land | Nematodes in the soil limit crop rotations | Number of farms in the region is going down. | Continuous change in policies and regulations |
| | High land prices and increasing rental prices | Climate change | Long working days | Energy transition |
| | Low prices for sugar beets because of expansion after abolishment sugar beet quota. | | Shortage of farm successors | |
| | | | Quality of hired staff is going down | |

## 1.3 Workshop

The workshop took place on 11 December 2018 on the Experimental farm “Valthermond” of Wageningen UR. “Valthermond” and “Innovatie Veenkoloniën”, a local NGO, helped organizing the workshop and facilitated the workshop location, food and drinks.

In the workshop, four farmers, one politician, one person from the processing industry, one person of the waterboard, two persons focussed on facilitating agriculture, one researcher and one person from a social oriented NGO participated. Details can be found in Appendix A. In the presentation of results, farmers are grouped in one sub-group called “Farmers”. To guarantee privacy of other participants, all other participants were grouped in a sub-group called "Others". All exercises were filled out by four farmers and five *Others*.

## 2 Farming system

The focal actors of the farming system are the arable farmers and their families. Another important actor is the cooperation AVEBE that processes starch potatoes, because there is a high degree of co-dependency with farmers; much more than with other organizations that process commodities like Friesland Campina (milk), Cosun (sugar beet) and Agrifirm (cereals) (all in the second circle in Figure 1) who get the largest share of agricultural produce supplied by other regions. Other actors in the farming system are fixed and hired employees because availability of (skilled) labour is key for farmers and AVEBE. Further, local organizations that aim at improvement of sustainable agricultural practices are included (Innovatie Veenkoloniën, Veldleeuwerik Drenthe, agricultural nature organizations, experimental farm Valthermond). In Veenkoloniën, much of the land is not owned by the farmers, hence landowners are included as separate actors. Interaction with dairy farmers occurs in the area through exchange of manure and land. Actors that were still missing at the start of the workshop were the water boards: on average about 50 million cubic meter of water per year is transported from the fresh water reserve IJsselmeer outside the case-study area to the Veenkoloniën (Jansen, Kwakernaak and Querner, 2011). The waterboards on their turn are dependent on cooperation of farmers with regard to (surface) water withdrawal for irrigation, landscape management and maintaining ditches along fields for drainage. Figure 1 provides an overview of more actors that are considered to be operating outside the farming system.

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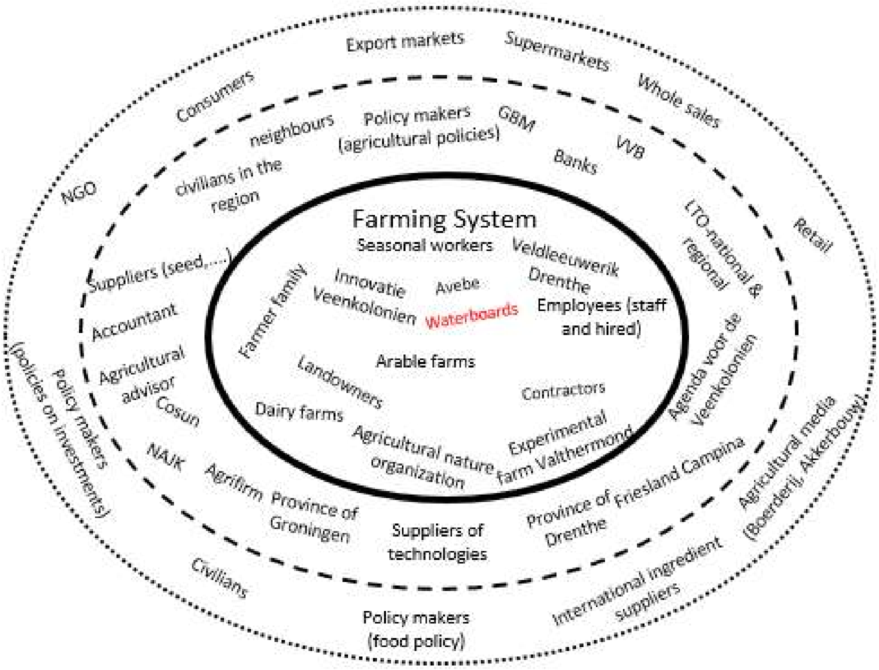


*Figure 1: Updated farming system visualization after feedback from participants. The actors in black were included by researchers and confirmed by participants. The actor in red was added by participants during the workshop.*

## 3 Functions

Participants were asked to individually allocate 100 points to eight farming system functions, according to their current importance. Results are presented in Figure 2. The farming system's functions of "providing economic viability" and "maintaining natural resources" are seen as most important by all participants. However, these two functions also show the highest difference between stakeholder groups. *Farmers* indicate that "provision of economic viability" is most important, while *Others* indicate that "maintaining natural resources" is most important. The other way round, *Farmers* and *Others* indicate respectively that "maintaining natural resources" and "provisioning of economic viability" is still important, but more at the level of the "function of food production", which is perceived as the third important function of the system. Overall, *Farmers* allocate less importance than *Others* to functions that represent the delivery of public goods. Standard deviations for importance of essential functions indicate differences in perceptions among participants within stakeholder groups and among all participants (Appendix B; Table A2).

In general, participants were not surprised by the outcome and there was not much response with regard to the results. *Farmers* were keen on seeing the differences between their scores and the scores by *Others*, while some-one of the latter group actually thought that it might work a bit polarizing, i.e. farmers against the rest. Some participants indicated that they perceive the

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functions that represent the 'public goods' as the base for all the functions that represent the 'private goods'. Especially the maintenance of natural resources was mentioned as key for supporting all other functions.

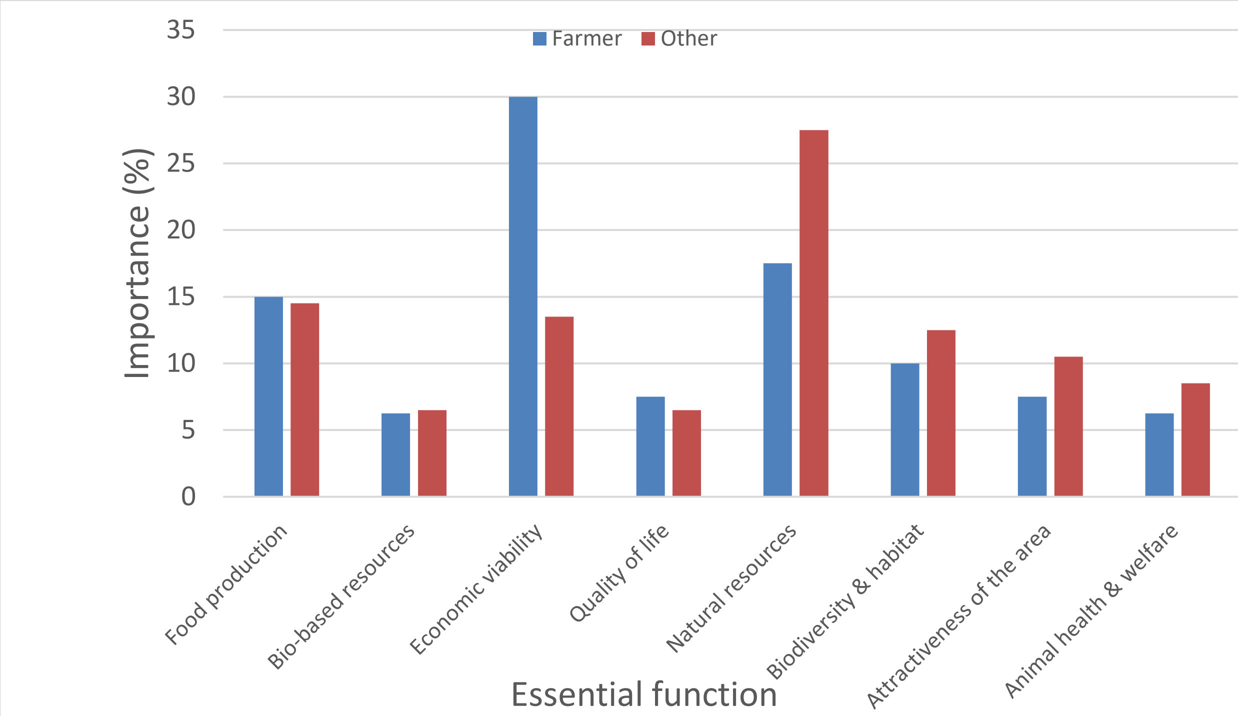


*Figure 2: Bar graph with scoring per function, aggregated by stakeholder group. 100 points needed to be divided over 8 EF. (n=9)*

# 4 Indicators of functions

## 4.1 Indicator importance

During a plenary discussion, participants indicated that the proposed list with indicators was fine, except for one: because agriculture provides a lot of employment in the region, the indicator "worked hours by hired agricultural workforce" was replaced by "employment related to agriculture" that encompasses employment in agriculture as well as employment in agricultural supplying and processing industries. Also the indicators "carbon emissions" and "soil structure" were mentioned as representative indicator for the function "maintaining natural resources". However, the majority of participants was more content with the broader defined indicators of respectively "greenhouse gas emissions" and "soil quality". When participants individually filled in the forms, farmers as well as other stakeholders often added indicators under the functions of "food production" (e.g. vegetable production, other crops) and "production of bio-based resources" (e.g. hemp) and "maintaining bio-diversity" (e.g. number of insects). As a result, scores

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for the proposed indicators often did not add up to hundred and were corrected afterwards. Table A3 provides an overview of indicators and associated stakeholders.

Figure 3 provides an overview of indicator importance, transformed for function importance and number of indicators per function, allowing for direct comparisons between indicators. The biggest differences between stakeholder groups in Figure 3 are a reflection of the differences in perceived importance of the functions. For instance, "profit per hectare" and "income of agricultural activities" is perceived as much more important by *Farmers* than *Others*. These indicators relate also more directly to the livelihood of farmers than other stakeholders. All indicators for the function "food production" are perceived as more or less of equal importance. This is an indication that participants have evaluated these indicators indeed for "food production" and not for instance for "economic viability" for which starch potato would probably get a higher importance as it is the more profitable crop in the region, compared to cereals and sugar beet. "Straw production" is seen as an unimportant indicator for the function "bio-based resources". One farmer even indicated that it should be prohibited, and another farmer considered it a good agricultural practice to leave the straw in field. For the function "Quality of life", "satisfaction of being a farmer" is seen as the most important indicator, while "% of women participating in agriculture" is seen as the least important indicator. While *Farmers* see the function "maintaining biodiversity" as less important than the *Others*, they rate the overall importance of "responsible use of crop protection products" higher than the other stakeholders (Figure 3; Table A4). This can be explained by the fact that this indicator is closer related to agricultural practices than the other proposed indicators for the function "maintaining biodiversity". Standard deviations for indicator importance (Table A4) indicate that among stakeholders from the same group, there was not always consensus on which indicator was most important. This is especially true for indicators representing the function "economic viability" (Table A4).

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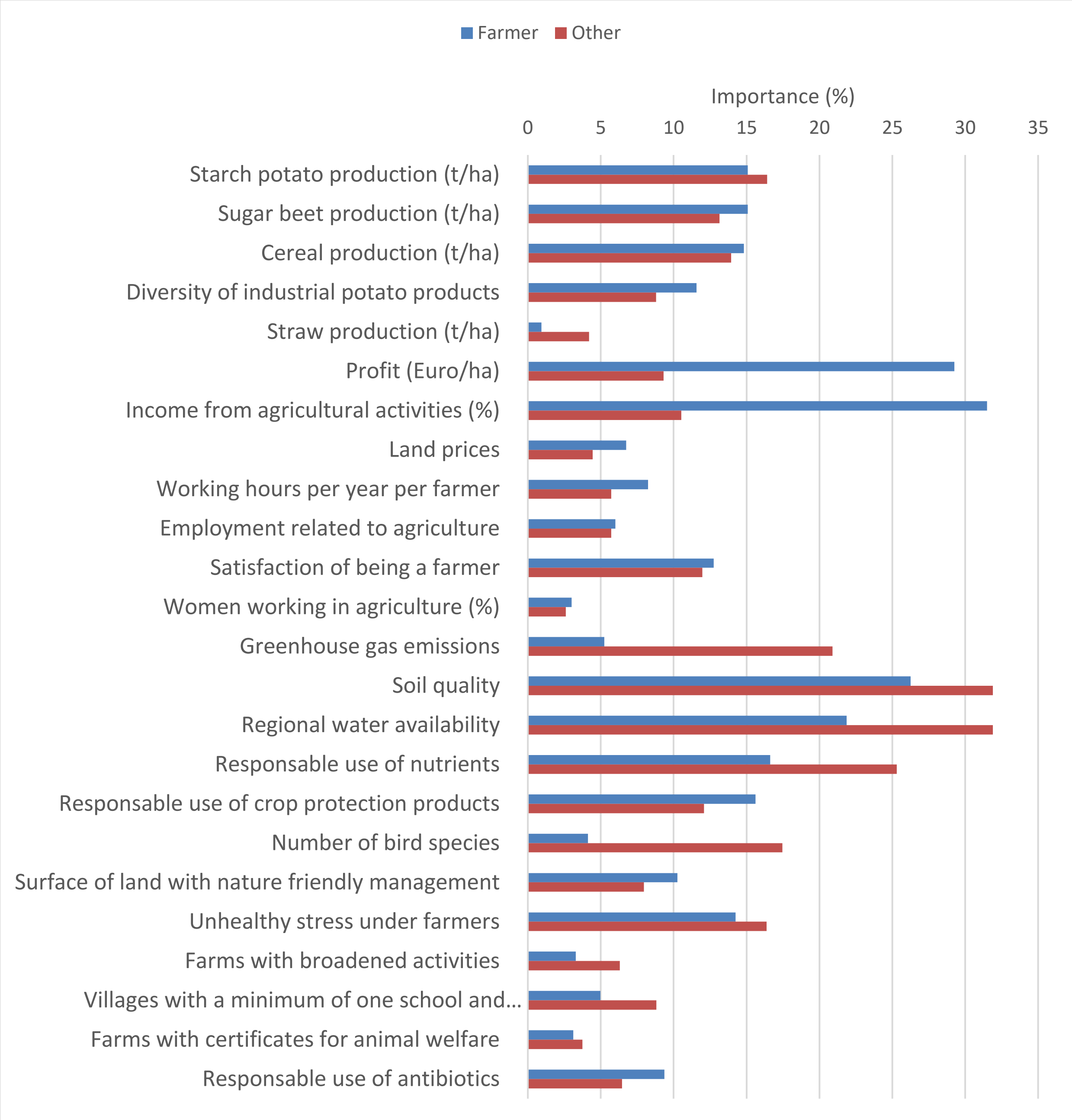


*Figure 3: Bar graph with scoring of importance per indicator, aggregated by stakeholder group. Per function, 100 points were divided over the indicators, after which results were transformed to include the importance and the number of indicators of the function that the indicators are representing. (n=9)*

## 4.2 Indicator performance

Overall, performance of indicators lies around three, indicating that the perceived sustainability of the farming system is moderate. Scores for the performance of indicators differ between stakeholder groups (Figure 4). The five most important indicators for farmers (see Figure 3) are

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performing moderately according to *Farmers* (Figure 4). The four most important indicators (all under functions that represent public goods; Figure 3) for *Others* are performing low to moderate according to *Others*. *Farmers* are often more positive than *Others*, especially for indicators that represent the delivery of public goods. For instance, performance of "soil quality" and "greenhouse gas emissions" are evaluated higher than 3 by farmers and lower than 2 by other stakeholders. "Straw production" was evaluated by only one farmer. More details can be found in Table A5.

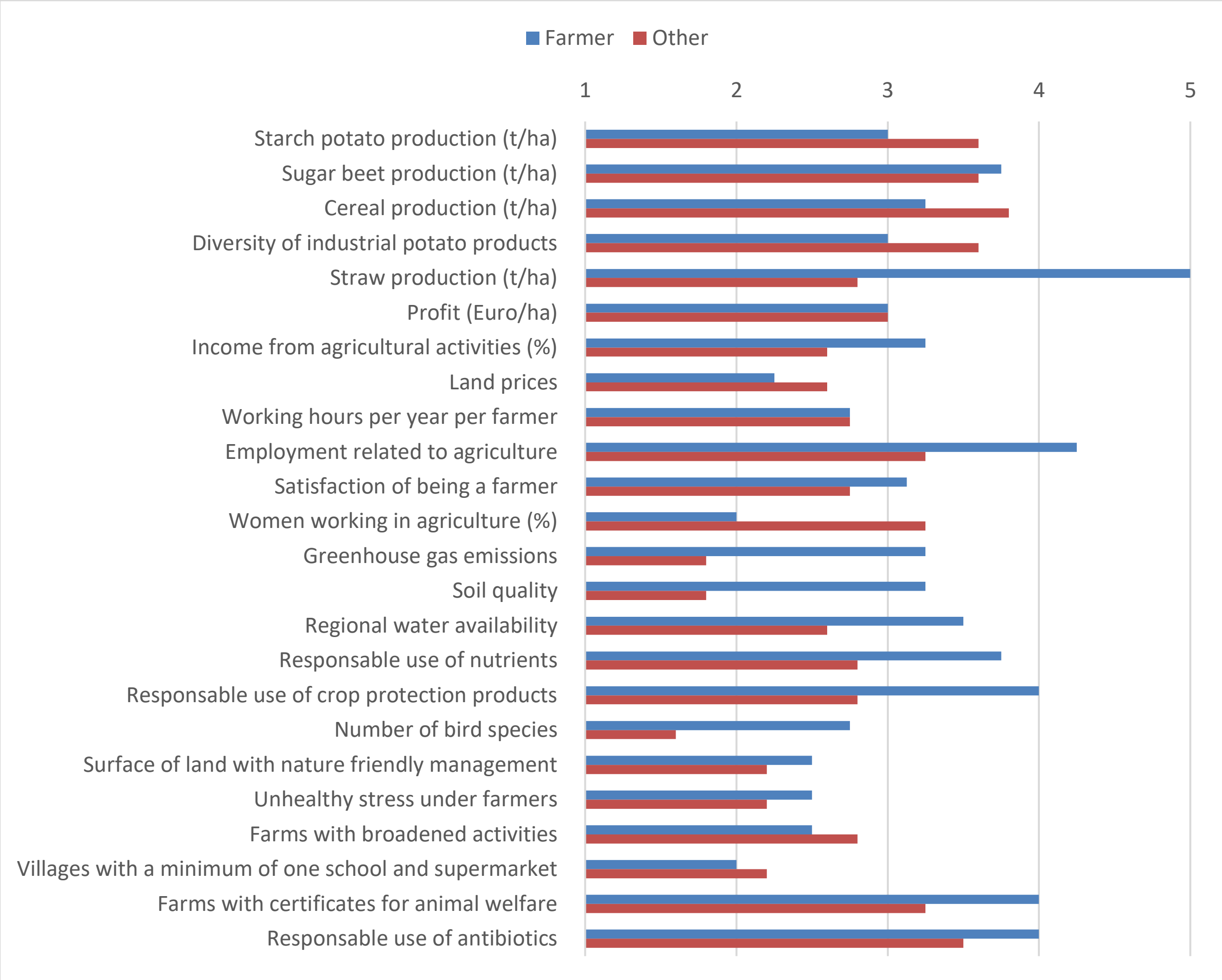


*Figure 4: Performance of indicators, aggregated by stakeholder group. Score from 1 (very poorly performing) to 5(perfectly performing).(n=9)*

Based on scores for average importance and performance, the five most important indicators have a moderate performance (Figure 5). The overall least important indicators that represent private goods perform moderately to well. The overall least important indicators that represent public goods often have a low to moderate performance. (Figure 5; Table A5)

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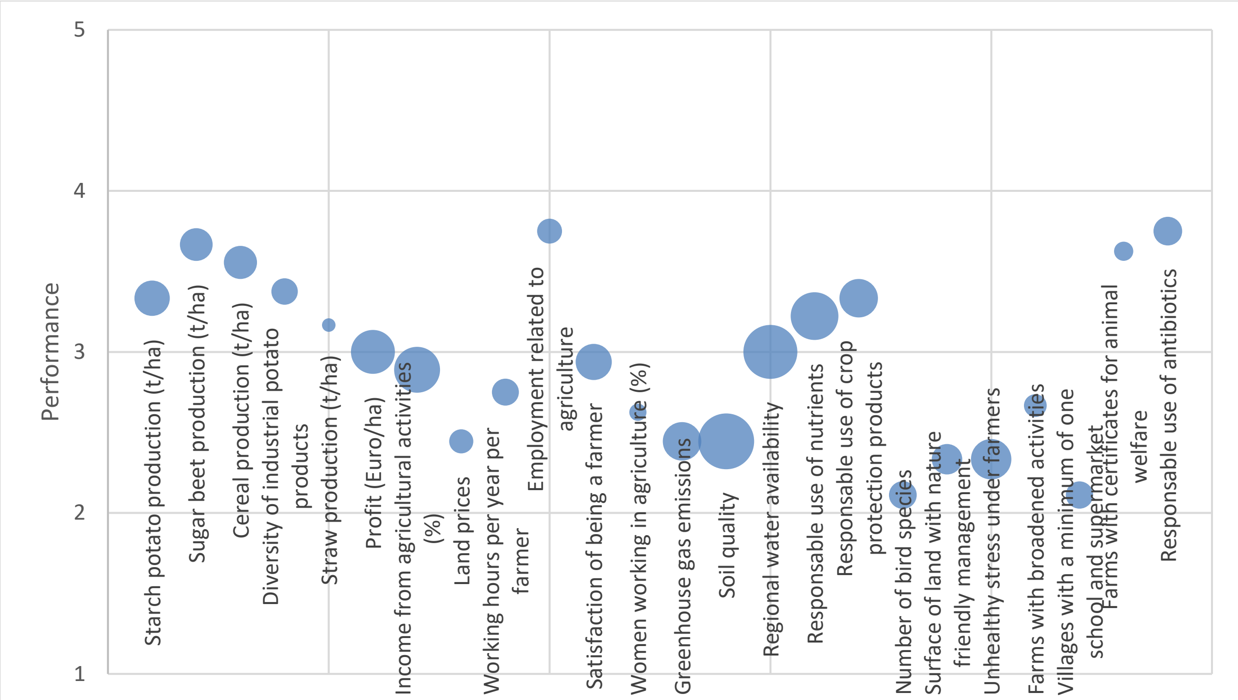


*Figure 5: Bubble graph presenting averaged scores on performance of indicators (from 1 to 5), while also indicating their importance (size of the bubbles), relative to each other.*

The performance scores aggregated to function level show that the farming system is performing on average moderately (scores between 2.3 and 3.5; Figure 6). The function related to food production performs moderately to well (3.5) as well as delivery of bio-based resources (3.3) and maintaining animal welfare (3.3); maintaining biodiversity has low performance (2.3). At function level, *Farmers* and *Others* agree mostly about the performance of functions that represent the delivery of private goods (Figure A1; Table A6). However, for three of the functions that represent the delivery of public goods, namely “natural resources”, “Biodiversity & habitat” and “Animal health and welfare”, there are divergent average scores between *Farmers* and *Others*, with a difference of 1 point or more (Figure A1; Table A6).

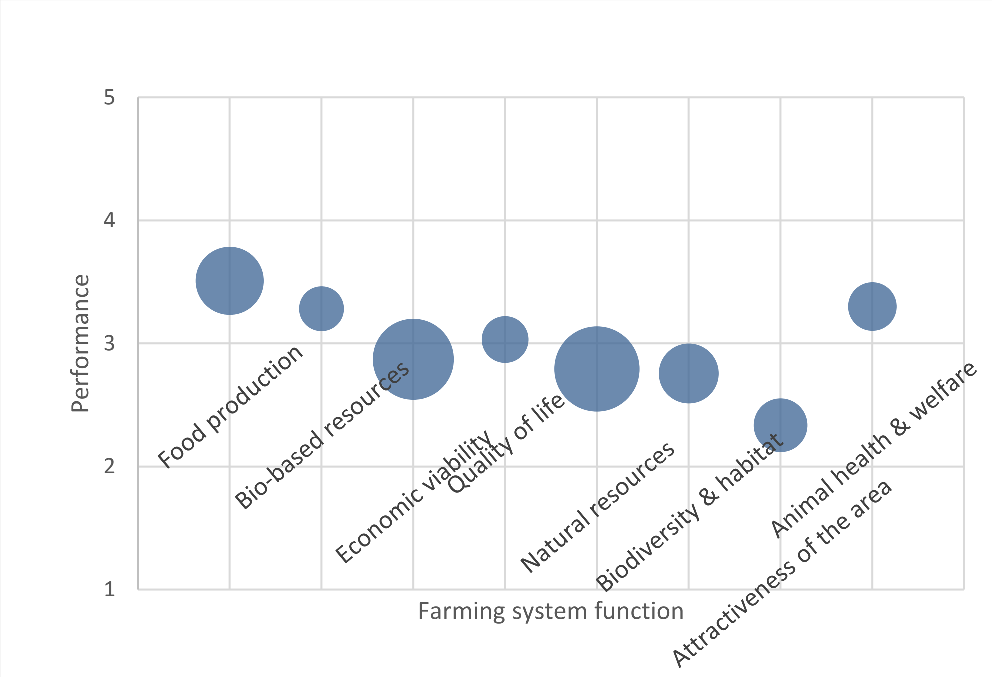


*Figure 6: Bubble graph presenting averaged scores on performance of functions (from 1 to 5), while also indicating their importance (size of the bubbles), relative to each other.*

### 4.3 Indicator selection

Until the moment of indicator selection, the subjects of farm economic performance and the actual state of the soils in the farming system had received already a lot of attention. Hence, consensus was easily reached to select “profit in euros per hectare” and “soil quality” as indicators for further study. Looking at indicator importance, “starch potato production” was a less obvious one. Still this indicator was selected because it represents the important FS-function of “food production” and because it is the most important crop in the area and related to the identity of the area. There were no suggestions for selecting other indicators for further investigation.

## 5 Resilience of indicators

### 5.1 Potato starch production.

The level of potato starch production in Veenkoloniën has not changed much according to participants. In 2018 there is an estimated drop of 30-35% due to the long-lasting drought in summer. Excessive rainfall in autumn and frost in spring and autumn are other causes of moderate yield reductions. The general stability of starch production in the period from 2000-2018 in the area can be explained by a steady increase in starch production per hectare (around 2% increase per year, due to increased starch content and nematode resistance of potatoes) on the one hand

(Figure A2) and a slow decrease in area with starch potatoes on the other hand, except for the last 5-6 years where the area with starch potatoes is stable according to participants (Figure 7; Figure A3). One exception for the decrease in area is 2011 in which farmers cultivated more starch potatoes to anticipate the change from production to area-based subsidies. The initial level of area-based subsidies was based on the shares of land of the different cultivated crops in previous years in which starch potatoes had a relatively higher impact on subsidy levels compared to sugar beets and cereals. For area cultivated with starch potato, the general trends and the peak in 2011 are confirmed by data (Figure 8). Figure 8 also shows year to year variations. The total area of starch potato differs between Figure 7 and 8. Figure 7 includes all area cultivated by members of AVEBE in and outside the farming system. The area at national level is a bit larger than indicated by participants as not all starch potatoes are processed by AVEBE (Figure 8). The yield increase of 2% over the period 2000-2018, mentioned by participants seems somewhat optimistic compared to a starch production increase of about 1% in the Netherlands over the period 1990-2005 found by Rijk et al. (2013).


*Figure 7: Trends and major deviations of area with starch potato and starch production per hectare. The area with starch potato is the total area that members of AVEBE have cultivated.*

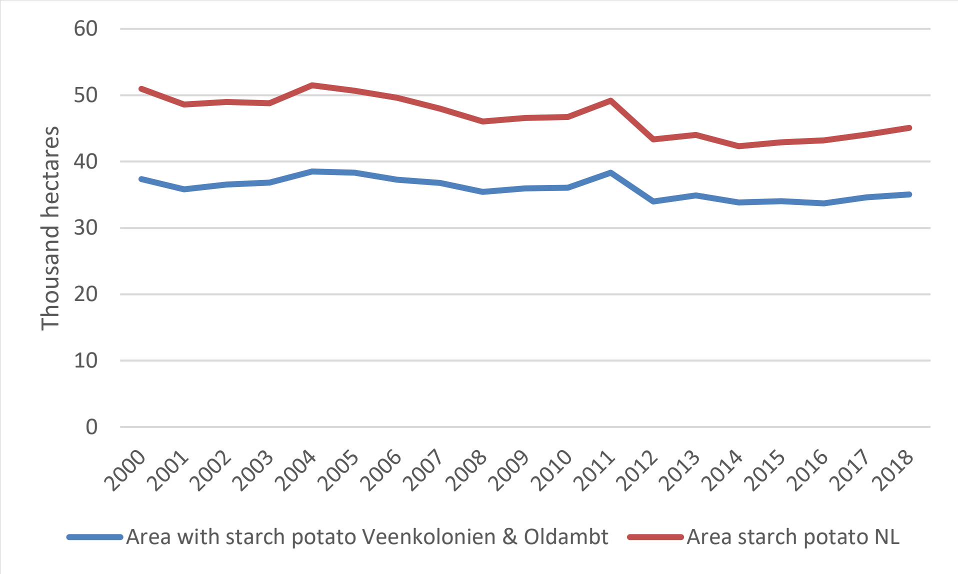


*Figure 8: Area with starch potato in the Netherlands and in Veenkolonien & Oldambt. Source:* Centraal Bureau voor de Statistiek (2019)

The reduction in area until 2011 was due to expansion of cities, industry and nature areas. At the same time, the prices for starch potatoes were not that good, especially from 2003 – 2005. In that period, banks invested money in AVEBE to make it survive, under the condition that members of the cooperation (farmers) also would contribute. That resulted in farmers paying back part of their revenue to the cooperation. Overall, the situation made it more attractive for some farmers to sell their land, or to grow less starch potatoes. However, the latter option was not used much as there were at that time not many alternative crops to grow. Nowadays, alternatives are available, though more risky and knowledge demanding (onions, carrots and flower bulbs). An explanation for the still steady supply of starch potatoes lies in the functioning of AVEBE. Farmers own shares in the cooperative and have a pre-defined volume of potatoes that they are obliged to deliver (A-volume), a pre-defined volume of potatoes that they have the right to deliver (B-volume) and a volume that they are free to deliver (C-volume; 'free potatoes'). In practice, there are hardly farmers that have the "free potatoes". Over the years, AVEBE has offered their shares for positive as well as negative prices to ensure a steady flow of starch potatoes from Veenkoloniën.

Because participants focussed most on area with potato cultivation, rather than on production, they came up with a few strategies related to the former. Also they were confused with the word 'strategy', as they interpreted it as a very conscious action of one or more actors in the farming system. One example of this is "cost reduction", which is related to increasing profit per hectare at farm level, rather than production per hectare or overall production in the region. It was mentioned in the discussion that profit optimisation is common in the area. Another example of a strategy as a result of misinterpretation is "turning agricultural land into non-agricultural land" which was associated with the challenge "reduced area of agricultural land". What still can be learnt from this, also based on audio-records, is that the reduction of agricultural land is seen as a challenge for overall production in the region. As mentioned before, the reduced area of potato cultivation was allegedly counterbalanced by an increased productivity per hectare. This is partly reflected in another strategy that was mentioned: "reducing pressure of nematodes", which increases the opportunities for potato crops to reach water- or nutrient limited production levels. Under this strategy, two topics are mentioned: 1) land exchange with dairy farmers to allow for a higher share of potatoes in the cultivation plan and 2) development of potato varieties that are more resistant to nematodes. The issuing of shares by AVEBE was not explicitly identified as a strategy. Also the increase in starch content in the potatoes was not recognized as a strategy.

## 5.2 Income of farmers

For the income of farmers, participants looked at profits from the three main crops: starch potato, sugar beet and cereals (Figure 9; Figure A4). Participants indicated that they did not have specific knowledge on high and low production years for the different crops. According to participants, profits for starch have increased from 2000 until 2011 when a plateau was reached that lasted until 2013. From 2014 to 2017 there was a decrease in profit from starch. For 2018, participants expected a further decrease of 40% due to the hot and dry summer. For sugar beets, profits have been increasingly improving from 2000 until 2011, after which a plateau was reached that continued into another increasingly improvement until 2018, in which a drop of 10% is expected due to the hot and dry summer. For cereals, profits have been relatively good, but fluctuating due to fluctuating prices on the world market. Overall the contribution of the different crops leads to a steady increase in income over the period from 2000-2011 at which a plateau is reached that lasted until 2013 (Figure 10; Figure A5). 2011-2013 is the period in which income was the highest. In the period from 2014-2016 there was a drop in income after which income recovered. 2018 will be a relatively bad year due to lower profit from sugar beets and potatoes.

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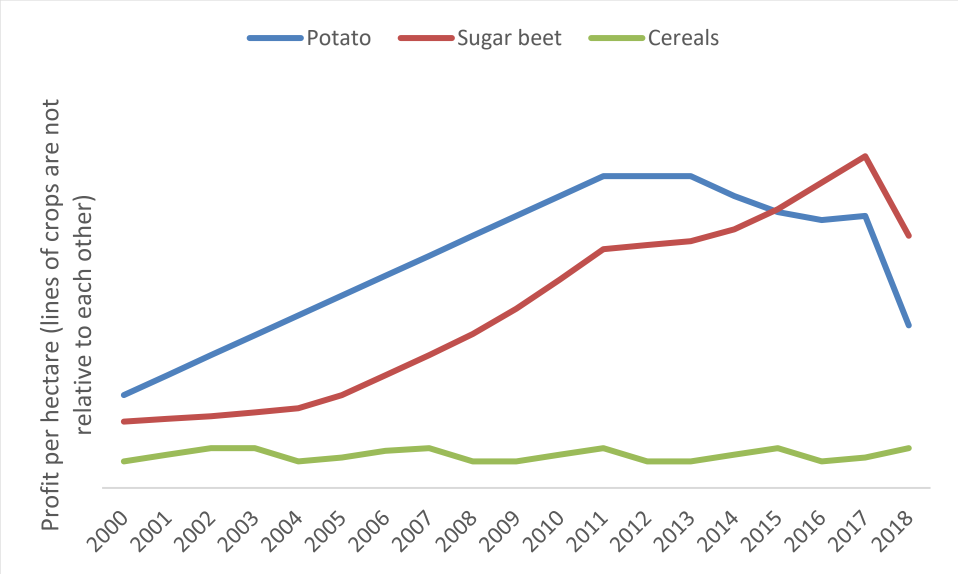


*Figure 9: Dynamics of profit per hectare for the main crops in the farming system. The indicated lines are not relative to each other and should be read as separate graphs without unit indications on the y-axis.*

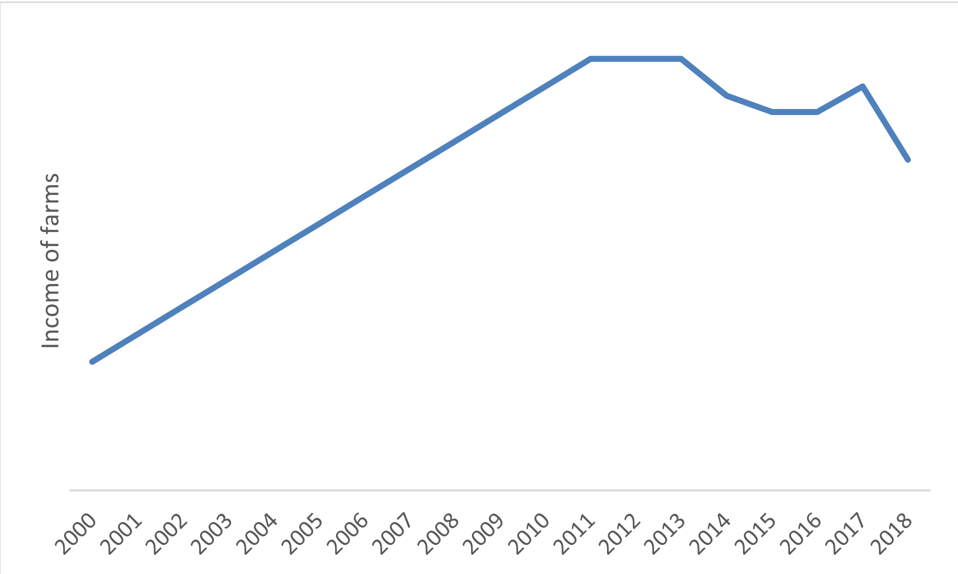


*Figure 10: Dynamics of farm income per hectare. No unit is indicated on the y-axis.*

The trend towards higher income per hectare from 2001 to 2013 is confirmed by data, however a peak in prices in 2007 was overlooked (Figure 11). Rather than a plateau from 2011 to 2013, there is a very high income per hectare in 2012. The decrease and plateau from 2014 onwards is confirmed, except for the year 2017 in which participants indicated an increase. Figure 11 shows that the impact of the drought in 2018 was on average higher than expected by participants in the workshop.

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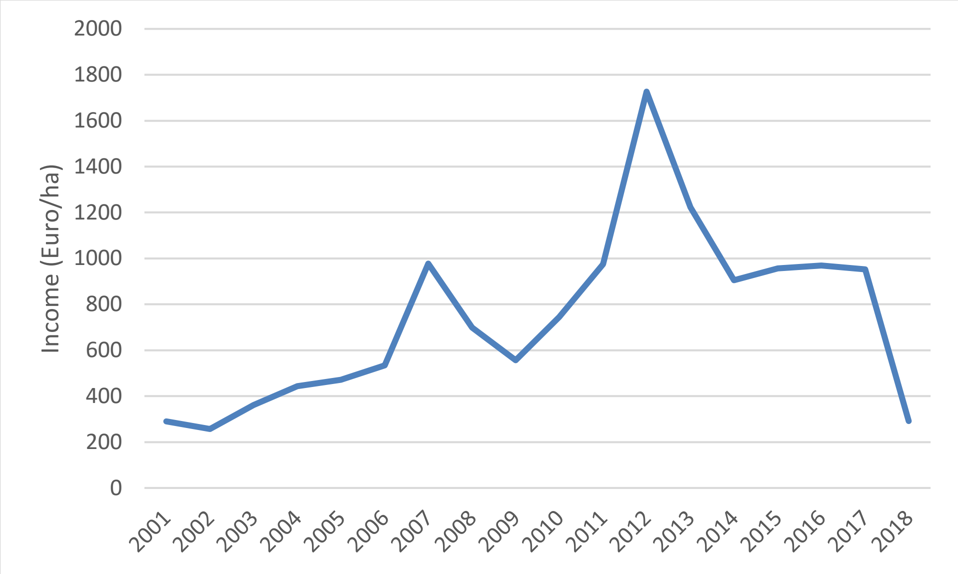


*Figure 11: Average income per hectare for starch potato farms. Source:* Wageningen Economic Research, Wageningen UR (2019)

Increasing profits for potatoes and sugar beets in the period 2000-2011 were due to good prices and improved varieties. Also scale enlargement was contributing to higher incomes. However, scale enlargement came at the cost of not being able anymore to manually adapt management to local conditions between and within fields, i.e. precision agriculture "avant la lettre" without costly and advanced electrotechnics. Consequently, the plateau for 2011-2013 was explained by the lack of implementation of new techniques for precision agriculture due to the high costs involved. The drop in income after 2013 was explained by increasing prices for production inputs for potatoes and sugar beets. The prices for inputs and outputs in cereal cultivation have stayed more or less in balance.

Strategies that enhanced income during the period 2000-2011 were scale enlargement and the development of more knowledge on soils and crop varieties. While income was increasing, there was also the reorganization of production-based subsidies into area-based subsidies. To be prepared for this, farmers and AVEBE worked out a strategy to improve the value of starch products. Where AVEBE was previously optimizing the flows of subsidies, it had to find a way to improve competitiveness on the global market. Apart from abandoning less lucrative starch markets, AVEBE increased R&D on extracting protein from potatoes. To counterbalance the increased production costs from 2014 onwards, strategies have been employed to look for better crop varieties and to increase production while lowering costs. Another strategy that would have been especially effective in 2018 would have been the opportunity of having crops that do not fall under any contract to be able to profit from high prices. Currently, with sugar beets and starch

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potatoes in the crop rotation, about 85% of the cultivation is under contract. Lastly, precision agriculture that fits with the current larger scale farms is seen as a strategy.

### 5.2.1 Soil quality

According to the participants, soil quality has in general gone down over the years due to intensive use and application of chemical fertilizer containing only a few types of nutrients. As a result, soil micro-nutrients are mined and soil life deteriorates. Participants perceive that this trend has started after the Industrial Revolution and is increased after the mechanisation of agriculture after the Second World War. Challenges of nowadays seem to have little effect looking at a time-scale of over a hundred years. A positive note was mentioned on the estimated reduction of 80% of harmful nematodes for potatoes in the soil through breeding resistant potato varieties (Figure A6). This is consistent with the decrease monitored by a Dutch organization that aims to support farmers with crop protection management strategies for starch potatoes (Stichting TBM, 2018). However, new varieties of cyst nematodes have broken through the resistance barrier of plants, resulting in an increase of nematode infection since 2010 (Stichting TBM, 2018). If this threat is not contained well, the new varieties of cyst nematodes can spread to other fields as well. Also the warm weather of 2018 is expected to lead to an increase in nematode numbers.

Participants struggled to come up with currently employed strategies that are widely used to improve soil quality. This was partly due to the level of abstractness at which the discussion was held. An example of this was a participant stating that a “Copernican” change is needed in the sense that society should get rid of anthropocentrism (Figure A7). In the end, some strategies were found: apart from breeding resistant potato varieties, they saw that raised awareness about soil quality is a first step towards increasing soil quality. Raised awareness is something that occurred in the last decade, but was perceived to be only limited to some individual actors rather than a process happening in the whole farming system. Similarly, the replenishing of soil nutrients and avoiding the use of artificial fertilizer were seen as two separate strategies at the farm level and not as strategies that were supported system wide.

# 6 Resilience attributes

## 6.1 Case-study specific strategies

Identified strategies for improving performance of selected indicators are overall moderately implemented (Figure 12; Table A7). This indicates that the implementation capacity of the farming system can be developed more. For improving profit, the strategy to increase the value of starch products is slightly implemented according to participants. However, in recent years, AVEBE has abandoned the less lucrative starch markets where they had to compete with other types of starch. Instead, AVEBE has focussed on high value starch products and farm gate prices are 14% higher in 2018 than in 2014. At the other hand, extracting protein from potatoes contributes with 2-3 euro to the total of around 80 euro per ton of the starch potato prices, while only still a small percentage of protein (<4%) is extracted for high-value protein products. “Reducing costs” is mentioned twice as a strategy and is evaluated as moderately implemented (score 2.5-3). Strategies for improving soil quality are evaluated as slightly to moderately implemented. The strategies of “better varieties” and “improved varieties against nematodes” are evaluated as moderately implemented (score 3-3.5). This can be seen as a sign that more improvement is needed and/or that there is still more potential for improvement. (Figure 12)

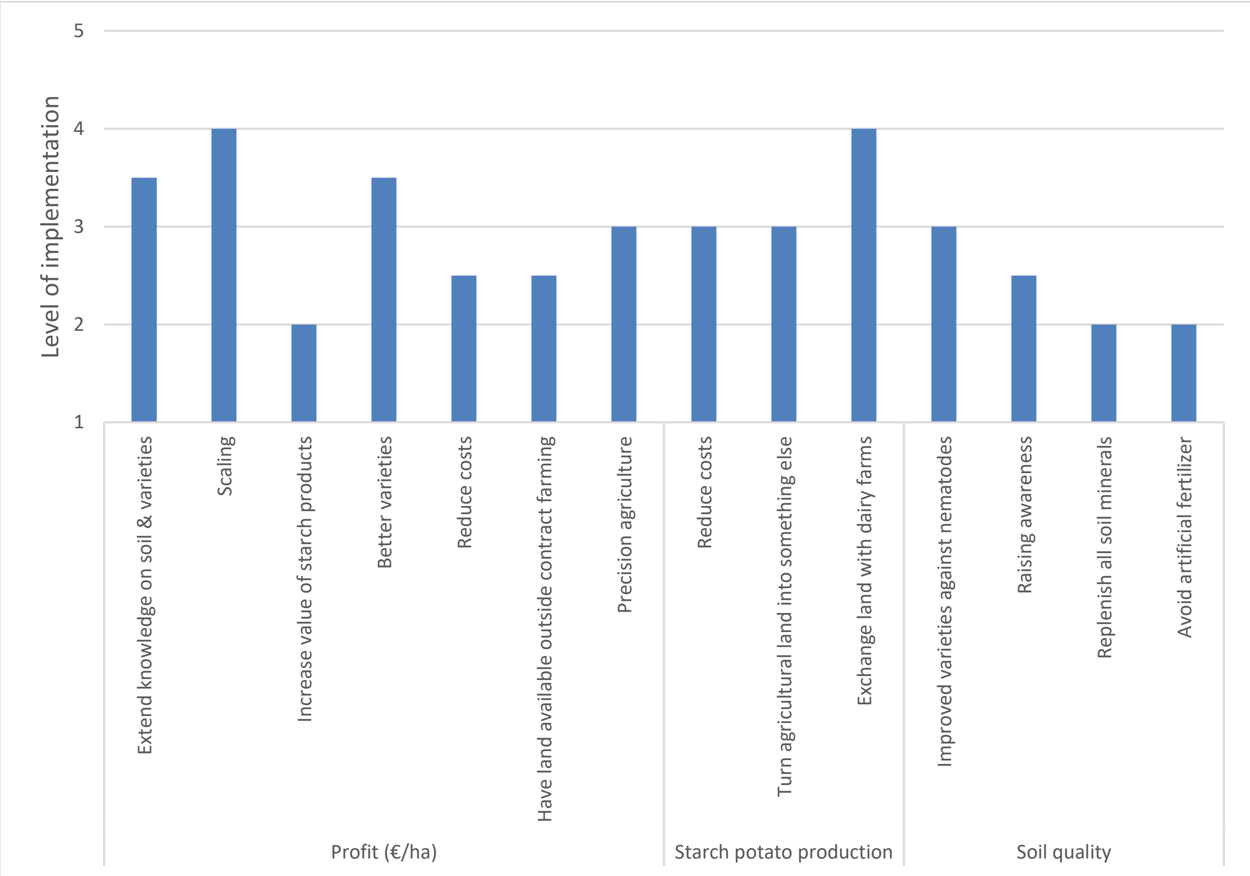


*Figure 12: Bar graph showing level of implementation of strategies to cope with challenges related to the indicators discussed. 1 = not applied, 2 = slightly applied, 3 = moderately applied, 4 = adequately applied, 5 = perfectly applied.*

Strategies are evaluated as having different effects on resilience in terms of strength, in terms of being positive or negative, and with regard to the different resilience capacities (Figure 13; Table A7). Seven identified strategies show weak to intermediate positive effects on all resilience capacities, indicating no trade-off between resilience capacities. The other seven strategies show

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a trade-off between resilience capacities, mainly between robustness and transformability. “Cost reduction”, which is mentioned twice, shows contradicting results for the effect on robustness, but effects on adaptability and transformability are evaluated as weakly positive in both cases. “Improved/better varieties”, which are mentioned twice, show contradicting results for robustness and adaptability, while a weakly positive relation for transformability is perceived in both cases. Within the group of participants that evaluated the strategy of “improved varieties”, there were also contradicting results for its effect on robustness and adaptability (Figure A8).

Of eight strategies that are evaluated to be moderately to well implemented (Figure 13; score 3-4), four strategies, “Extending knowledge on soil & varieties”, “Scaling”, “Precision agriculture” and “Exchange land with dairy farmers”, have a moderate to strong impact on robustness, the first of them also having a moderate to strong effect on adaptability and transformability. For five of the eight moderately to well implemented strategies, a trade-off occurs between resilience capacities. The other six strategies with lower level of implementation (score <3), are evaluated as having a weak to intermediate impact on resilience capacities. Two of these six strategies, “Increased value of starch products” and “Have land available outside contract farming” show a trade-off between resilience capacities.

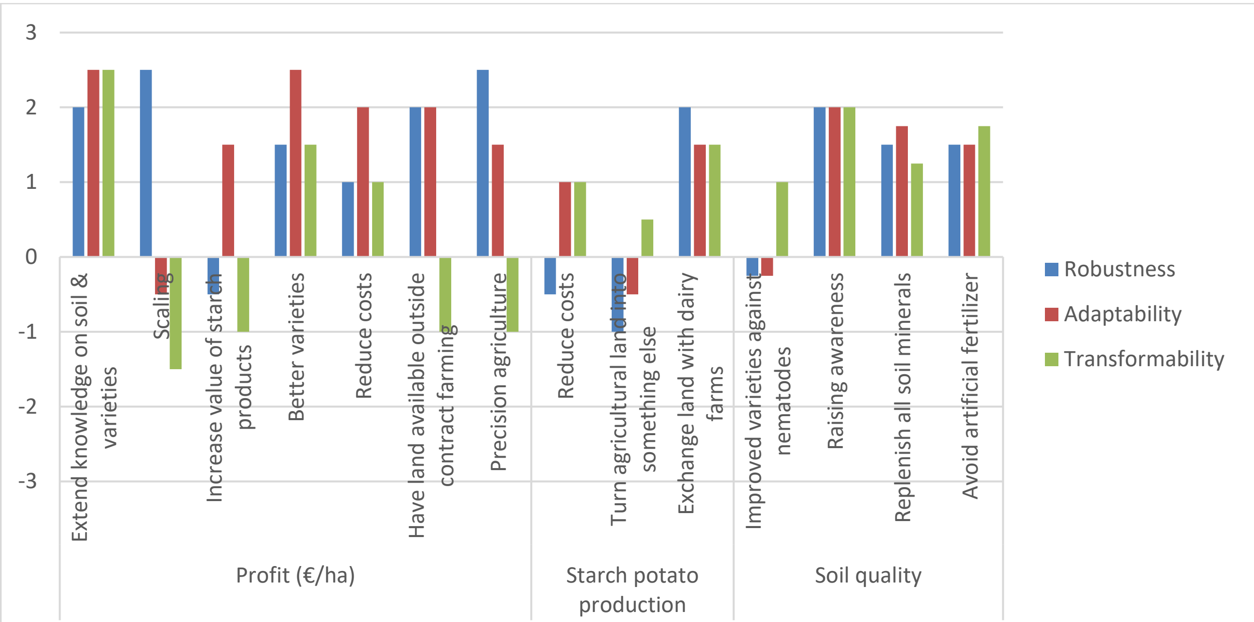


*Figure 13: Bar graph showing average scoring of effect of strategy on robustness, adaptability and transformability of the farming system. A 0 implies no relationship, a 1 or -1 a weak positive or negative relationship, a 2 or -2 a intermediate positive or negative relationship, and a 3 or -3 is a strong positive or negative relationship.*

In general, strategies identified in relation to cope with challenges related to soil quality and starch potato production, contribute equally or more to transformability and adaptability as compared

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to robustness. For strategies in relation to profit, the contribution is generally highest for robustness or adaptability, while the contribution to transformability is lower or even negative.

## 6.2 General resilience attributes

Resilience attributes are only in a small to moderate extent present in the Veenkoloniën (Figure 14, Table A8). The level of the attribute "Reasonable profitable" is lower (Figure 14) than the performance scores for the indicators that represent the system function "Economic viability". This can be explained by the fact that "Reasonable profitable" also includes explicitly the dependence on subsidies. Currently, the area-based subsidies provide a stable base income for farmers. "Functional diversity" is scoring low as inputs and outputs are not diverse. With regard to the outputs, diversity is low because many cultivated land is dedicated to contract farming. The low to moderate presence of "Response diversity" indicates that there are different ways of risk management applied, but more is possible. "Spatial and temporal heterogeneity of farm types" scores best, which can be explained by the original variety of farm sizes, the recent diversification of farms and the inflow of dairy farms into the region. The retirement of many old farmers in the next 10 years and the high thresholds for taking over or starting a new farm is reflected in the low to moderate score for "Optimally redundancy of farms". "Support by rural life" and "socially self-organized" score moderately. The moderate score of the latter attribute indicates that next to the cooperative AVEBE there is room for more forms of self-organization, e.g. collaboration between farms. "Legislation coupled with local and natural capital" scores lowest, indicating that legislation is hardly adapted to the local situation in the Veenkoloniën. Examples of this by participants are the ban on certain crop protection products that actually helped to keep weeding and tillage minimal on the wind erosion prone soils. Another example given was that current legislation constrains the creation of financial buffers at farm level during good years to survive the bad years.

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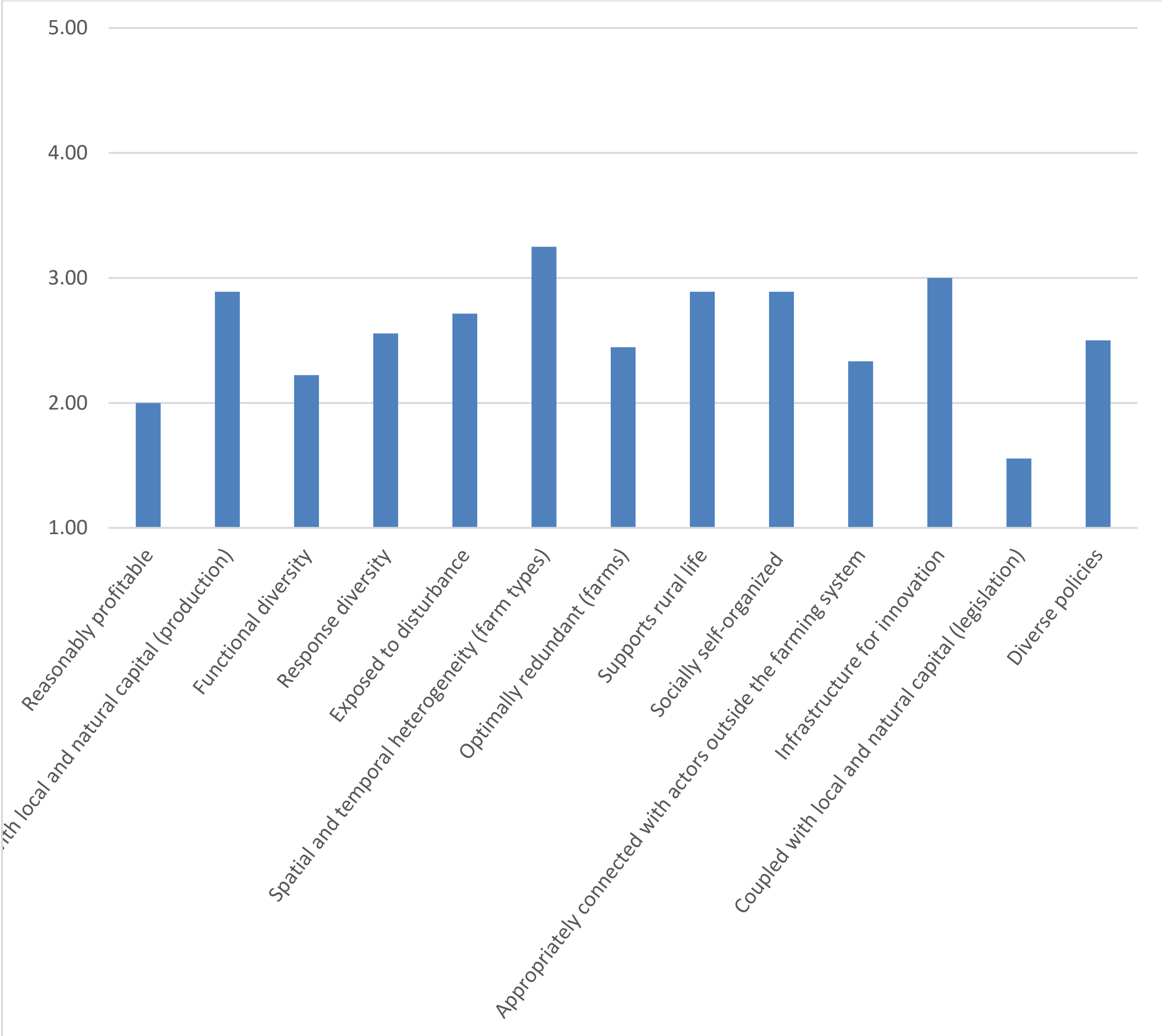


*Figure 14: Bar graph showing current performance level of resilience attributes. Performance is scored as 1 = not at all, 2 = small extent, 3 = moderate extent, 4 = big extent, 5 = very big extent. (n=9)*

Overall, diversity in the farming system is low, given the scores for “Functional diversity” and “Response diversity”. Modularity scores a bit higher than diversity, looking at “Spatial and temporal heterogeneity of farms” and “Redundancy of farms”. Combined, the scores for diversity and modularity indicate that there is a low to moderate degree of risk management in the farming system, and hence much room for improvement. The reserves of the system seem to be low with regard to “Reasonably profitable” and moderate with regard to “Production coupled with local and natural capital” and “Support rural life”. All mentioned attributes that relate to system reserves are important for agricultural production as they reflect into a certain extent the production resources capital, land and labour respectively. Farm demographics in the region are reflected by “Spatial and temporal heterogeneity of farm types”, “Optimal redundancy of farms” and “Supports rural life” and scores highest relative to the other three processes studied in SURE-Farm. Tightness of feedbacks of the system are considered low to moderate, looking respectively at “Appropriately connected” and “Social self-organization”. Both mentioned attributes are reflecting the way the system is governed, together with the attributes “Legislation coupled with local and natural capital” and “diverse policies”. Interestingly, of these four attributes, “Social self-organization” scores highest, which is also the attribute that is most influenced by the actors within the farming system, where the other three are more boundary conditions that are most of the time beyond the direct control of the farming system actors. Openness of the system is considered to be moderate, looking at the attributes “Exposed to disturbance” and “Infrastructure for innovation”.`

Except for one, all the resilience attributes are evaluated as being positive for all three resilience capacities (Figure 15). However, most of them only contribute weakly to the resilience capacities. “Reasonably profitable” and “ Coupled with local and natural capital” score highest for robustness with a moderate contribution, compared to other attributes. The mentioned attributes also score high for adaptability and transformability. However, especially for “Reasonably profitable” the performance level is low (Figure 14), indicating that its potential effect is currently not experienced by participants. “Infrastructure for innovation” and “Diverse policies” score higher for adaptability and transformability with a moderate contribution to resilience, compared to other attributes. “Response diversity” scores relatively well with a weak to moderate contribution to adaptability. Positive as well as negative scores resulted in an overall small perceived contribution of “Exposed to disturbance”, “Supports rural life” and “Legislation coupled with local and natural capital” to the resilience capacities (Figure A9, Table A9). Overall, when combining performance levels and potential contributions to resilience, the current resilience of the farming system in the Veenkoloniën seems low to moderate. Resilience is primarily robust and to a lesser extent adaptable and transformable.

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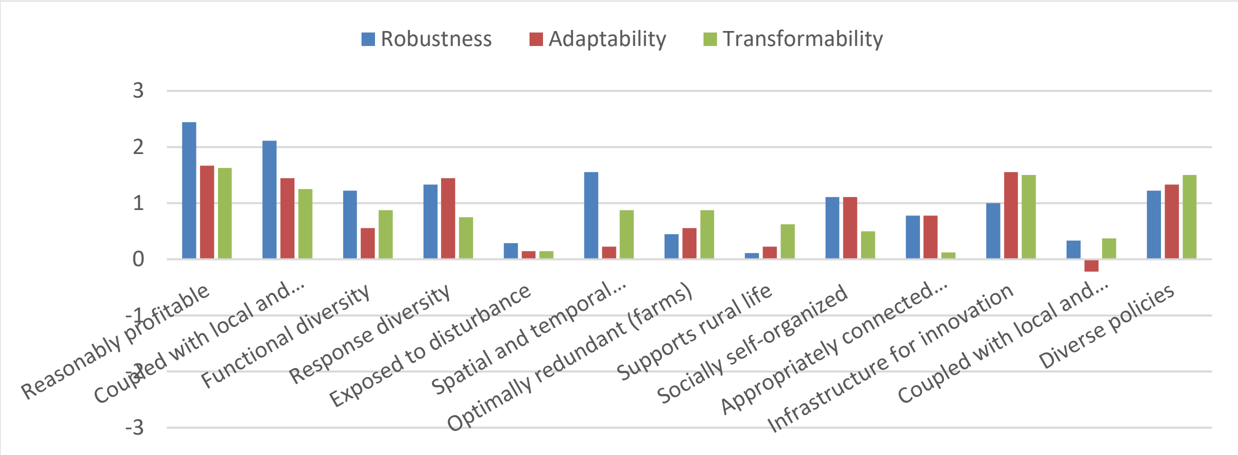


*Figure 15: Bar graph showing average scoring of perceived effect of attribute on robustness, adaptability and transformability. A 0 implies no effect,  a 1 a weak effect, a 2 a moderate effect, and a 3 is a strong effect. A '-' indicates a negative effect. (n=9)*

# 7 Discussion

## 7.1 Farming system actors

Feedback of participants mainly confirmed our social delineation of the farming system. Participants consisted of actors from within the farming system and outside the farming system. Not all actors within the farming system were participating in the workshop. This has influenced the results: presence of dairy producers could have influenced scoring on for instance the function of "Animal health" and presence of farm household members that don't take part in agricultural activities might have been able to shine more light on social dimensions of farming system functioning.

## 7.2 Essential functions of the farming system

Based on the results of this workshop, "Food production", "Economic viability" and "Maintaining natural resources" seem the most important functions of the farming system in Veenkoloniën. These functions are to a large extent being represented by harvest results of cultivated crops, profit per hectare, percentage of income from agricultural activities, soil quality and regional water availability. These mentioned indicators perform moderately to well, except for soil quality. Yields per hectare were performing highest compared to other important indicators. From a global perspective the yields are indeed very high, but compared to other regions in the Netherlands yields are a bit lower, mainly due to differences in soil conditions. Moderate scores for indicators related to economy indicate that there is room for improvement. In the area, farmers are still partly dependent on subsidies and having off-farm labor activities is seen as a concession to keep a farm business alive. One of the participants categorized farmers with off-farm jobs under the group "mailman-farmers", which was seen as deviant from the more mainstream groups of "expanders" and "diversifiers". The lower score for soil quality was influenced by low scores by *Others*, while *Farmers* evaluated it as performing it moderately well. This indicates differences in perspectives. During discussions, it became clear that participants of the *Others* group evaluated soil quality mainly from the point of (micro)nutrient status, while *Farmers* also took into account nematode pressure and workability of the soils.

## 7.3 Robustness, adaptability and transformability of the farming system

Starch potato production and profit per hectare have increased over the last two decades and seem at stable levels in the last five years. Except for 2018, where drought had a major impact on production and profit. Soil quality is considered stable as well, but at moderate performance. Overall, main indicators show signs of robustness and strategies being applied show adaptability of the farming system. Overall, implementation and contribution of strategies imply that the farming system shows signs of robustness, adaptability as well as transformability. However, there are some strategies that negatively impact some resilience capacities. For instance "scaling" and "precision agriculture", which affect transformability negatively. Overall, implementation and contribution of resilience attributes imply that the farming system shows low to moderate signs of robustness, adaptability as well as transformability. In the remainder of this sub-chapter, reflections will be made to explain the overall results of the workshop.

Farm gate prices of starch potato and hence income of farmers in the Veenkoloniën are strongly connected to the performance of AVEBE. After a crisis year in 2005/2006, AVEBE re-organized in the period 2006-2009 with aid of financial support of its members, who invested approximately 20,000 Euros per farm (de Bont *et al.*, 2007). Shortly after, in 2011, the change from production to area based subsidies, to be started in 2013, was confirmed. Among the scenarios for AVEBE, one predicted a decrease of 30% in potato supply and another a total decrease, meaning the end of AVEBE and starch potato production (de Bont *et al.*, 2007). Again, AVEBE showed capacities to avoid collapse by adapting the way of processing and marketing its products in market segments with higher added value where there is also lower competition. This resulted in higher farm gate prices, while the expectation was that prices would stay stable (Jongeneel *et al.*, 2011). Ashkenazy et al. (2018) show that being able to market a product without much competition can induce further specialisation of the system, but that a negative change in competitive advantage can have detrimental effects on a very specialized system. Hence, continuous innovation by AVEBE seems to be necessary to stay ahead of other competitors in the market in order to avoid a crisis situation.

AVEBE has shown strong engagement with its farmers. In 2018 for instance, all profit of the cooperation has been used to pay farmers the highest price possible to compensate for the lower yields due to the long hot and dry summer. Farmers on the other hand, dedicate large shares of their land to the production of starch potato, which are produced on contract. Together with the production of sugar beet on contract, this provides a steady income with reduced risk, while AVEBE and the COSUN (processor of sugar beets outside the farming system; Figure 1) are assured of a steady and high supply of starch potatoes and sugar beets respectively. Amongst others, this high and steady supply is a prerequisite for AVEBE and COSUN to experiment and ensure product differentiation with large production volumes (Verlouw, 2018).

The downside for farmers of cultivating a high share of land under contract, is that it limits diversity of crops and room for experimentation at farm level. During the workshop it was mentioned by farmers that they perceive even their smallest piece of least productive land as important for production, i.e. not available for experimentation. Participants also mentioned that they would like to have more area with 'free' crops, which was also mentioned as a strategy to improve income. The scores for the presence of resilience attributes "functional diversity" and "response diversity" is between low to moderate (Figure 11). The potential effect of these attributes is evaluated to be weakly contributing to the resilience capacities at farming system level. Hence, diversification at farm level as form of risk management does not seem the primary option for actors in the farming system to increase resilience of the whole farming system. At least, as long as it is not directly contributing to profitability. In fact, as mentioned in the introduction, at some farms in the region, diversification has been used to ensure viability of farming. During the workshop, multiple participants indicated that a fourth crop next to starch potato, sugar beets and cereals is needed. This is mainly because of the need to reduce pressure of harmful nematodes in potato crops, but also to be able to benefit from different markets and increase profit. Tulips, carrots, onions and ware potatoes might be alternative crops, but are not accessible for all farmers due to risk and technical know-how of cultivation. In addition, Jongeneel et al. (2011) mention that quality of ware potatoes and onions from Veenkoloniën cannot compete with similar commodities from areas with clayey soils in the Netherlands. Kuhlman et al. (2014) show that adding crops to the rotation can also negatively influence soil organic carbon balances, so new crops should be chosen with care. A 'free' crop is most likely also more exposed to market price volatility. Participants had contrasting views on the contribution of the resilience attribute “exposure to shocks” to farming system resilience, resulting in an overall low score. Hence, the effect of a fourth crop on farming system resilience might be ambivalent, amongst others dependent on the risk aversion of individual farmers.

The settling of dairy farms in the region in the last decades also has contributed to diversification at the farming system level. However, benefitting from co-existence of dairy and arable farms, e.g. through exchange of land is not fully exploited. According to one participant this was due to the different approach that dairy and arable farmers take. Dairy farmers have to divert their attention between livestock and land. In addition, the large availability of manure stimulates dairy farmers to spread as much as possible on their fields within legislative boundaries. In general, arable farmers on the other hand can give much more attention to their land and tend to fine-tune the nutrient supply to their land and crops. As a consequence, using land of a dairy farmer is less attractive for arable farmers. The participant saw a possibility in a production model in which the arable farmer takes care of all the land, including the grasslands and maize crops of the dairy farmer. In this model, the arable farmer applies his/her skills for fine-tuning nutrient supply and maintaining soil fertility and the dairy farmer gives his/her full attention to the livestock. This model implies that to benefit from diversity of farms at landscape level, specialization at farm level might be necessary. Another participant, an arable farmer, reflected on his experiences in working together with a dairy farmer and mentioned that the social aspect of collaboration is also very important. He initiated the collaboration with the dairy farmer, but stopped after he realized that the degree of interest and willingness in the collaboration was not at the same level for both parties.

Climate change was not explicitly mentioned as a challenge during the workshop. At the other hand, year to year yield variations were allocated to weather conditions, especially for 2018 with its long dry period during summer. Also the high value of importance allocated to the indicator “regional water availability” can be seen as an expression of the need for water when weather conditions are dry. With regard to climate change, Kuhlman et al. (2014) expected that soil management in the Veenkoloniën would not have to change much, except maybe for increasing active organic matter content. Diogo et al. (2017) show that agriculture in the Veenkoloniën will face increased financial impacts of weather extremes towards 2050, rendering agriculture non-viable. However, Diogo et al. (2017) used constant product prices dating from before 2013, while prices for starch potato have increased since then.

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The high prices of land were also not explicitly mentioned during plenary discussions. However, land prices were evaluated to have a low performance, i.e. land prices were perceived too high with regard to the function "economic viability" (Figure 4). High land prices in combination with relative low economic productivity per hectare of land put pressure on farming system actors, especially farmers, to produce as intensive and efficient as possible (Reindsen, 2018). This is especially the case for larger farms with higher degrees of foreign investment: their farm management has higher costs in order to pay yearly rents. When anticipating changes in the CAP after 2013, Jongeneel et al. (2011) expected that due to higher degrees of foreign investment, more intensive and bigger farms would experience higher income loss compared to other farms in the region. Continuous increase of average age of farmers in the region will continue and more land is expected to become available. Current profitability of crop rotations is not viable to support the purchase of extra land (Reindsen, 2018). Hence, foreign investment or hiring land by farms seems likely. This might further increase a focus on efficiency and productivity through technological innovation. This could lead to further degradation of the environment, but could also bring new methods to decrease the pressure on the environment (Ashkenazy *et al.*, 2018). An example is a digital decision support system that reduces the amount of crop protection products, thus improving efficiency and reducing environmental pressure.

## 7.4 Options to improve the resilience of the farming system

Most indicated strategies (e.g., reduce costs, scaling, increase value of products) to maintain desired levels of main indicators have contributed to keep the current system in place and are more related to the control rationale, focussing on robustness and efficiency, as explained by Hoekstra et al. (2018)."Having free crops" seems a strategy that is more according to the resilience rationale, focussing on adaptability and transformability, and contributes to the resilience attribute "input diversity". The strategy "Avoiding artificial fertilizer" seems to steer away from a situation of coerced resilience by means of anthropogenic inputs and would imply a drop in production (Rist *et al.*, 2014). Also other strategies related to coping with challenges related to soil quality ("raising awareness", "replenishing all soil minerals") are more in line with the resilience rationale, as also confirmed by stakeholder perspectives, who considered these strategies to contribute to adaptability and transformability.

None of the proposed strategies or attributes was evaluated as having a strong impact on resilience capacities. Hence, for improving resilience either a combination of strategies and attributes is used or new strategies have to be employed. The perceived current pathway to higher resilience allocates a high importance to AVEBE. Its focus on generating a stable income for farmers and its prospectus of developing more high-value products in the future is aiming at making the whole farming system more profitable and hence more resilient. This is in accordance with the fact that "Reasonably profitable" was one of the attributes with the best potential for contributing to resilience. However, farmers experience too much rigidity in this system, with regard to the share of land that they allocate to contract farming. In addition, this resilience pathway is dependent on the timely arrival of new nematode resistant varieties. At field level, increased pressure of nematodes in the future is likely to force farmers to lower the frequency of starch potato in their rotations and/or to initiate more collaborations with nearby livestock farmers. In case pressure of nematodes at field level cannot be contained, supply of starch potatoes will go down. As a result cascading effects at farm and farming system level can occur (Kinzig *et al.*, 2006). In that case, AVEBE will be challenged again to increase the value of their products to maintain the cultivation of starch potato attractive for its members.

In theory a wider crop rotation should reduce nematode pressure. This would also allow for starch potatoes with lower degrees of resistance against nematodes (Molendijk, 2018). It would be interesting to see with what the minimum share of starch potato is in the crop rotations of farmers for which AVEBE gets sufficient supply and farmers get sufficient (stability of) income. AVEBE could use that number as a guideline to assure that the soils are not pushed too much with high shares of starch potatoes. However, it should be noted that in a recent study on 350 fields, infection with virulent nematodes was detected also in fields with a crop rotation with starch potato of 1:3 (Engwerda, 2019). Hence, a wider crop rotation is no perfect warranty against increased infestation of land with virulent nematodes.

With regard to collaboration between dairy and arable farmers it seems that currently the initial stakes are too high and dependent on personal conditions. If initial investments for collaboration could be lowered, farmers could experiment more with collaboration without having much to lose.

## 7.5 Methodological challenges

Towards the end of the workshops, participants got tired, especially of filling out forms. This could imply lower reliability for the last exercises in which presence of strategies and attributes and their contribution to resilience capacities was assessed. Also participants understanding of robustness, adaptability and transformability might have deviated from the definitions as proposed in SURE-Farm. We experienced that from start to end that participants had different notions about resilience, but that they were happy to use the workshop format to discuss farming system challenges, i.e. using resilience as "boundary object" (Brand and Jax, 2007). Hence,

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conclusions on effects of strategies and resilience attributes on resilience need to be drawn with caution.

Levels, general trends and major changes of indicator performance were captured well during the workshop. However, participants indicated that they had no knowledge on year to year variation, which was confirmed by data. The lack of knowledge on year to year variation might be an explanation that identified strategies relate mostly to long-term pressures and less to yearly variations in for instance weather and market conditions.

## 8 Conclusions

Sustainability and resilience of the farming system in the Veenkoloniën can be assessed through looking at crop yield indicators, farm income indicators and indicators on the quality of natural resources. Current performance of main indicators of the farming system in the Veenkoloniën is perceived to be moderate. Participants from different stakeholder groups mainly disagreed on importance and performance of farming system functions that deliver public goods, where farmers found, for instance, soil quality less important and better performing than 'others'. Over the years, the arable farming system has shown adaptive capacity to overcome nematode pressure, years with low market prices and the change from production to area based subsidies. These adaptations have been made possible by adoption of mainly technological innovations at farm (production) level and at the processing level. Based on implementation and contribution levels of resilience attributes, we conclude with caution that 1) the general resilience of the farming system is low to moderate, 2) the farming system seems more robust than adaptable and transformable, 3) for overall resilience, the farming system depends on a combination of attributes, 4) for robustness, the farming systems depends mostly on local and natural capital and farm heterogeneity in the area, 5) for adaptability and transformability the farming system depends most on local and natural capital, infrastructure for innovation and diverse policies. The attribute "Reasonably profitable" shows high potential to contribute to all resilience capacities, but its current performance is low. Typical attributes belonging to the resilience rationale, such as diversity, redundancy and being exposed to small disturbances are not perceived to be important for farming system resilience in the Veenkoloniën. In line with this, identified strategies in general are geared towards making the farming system more efficient and robust, without purposely also strengthening adaptability and transformability. In other words it could be stated that adaptability is employed for increasing robustness. This pathway towards more robustness is dependent on the timely arrival of new nematode resistant varieties, AVEBE's continuous efforts on starch potato product innovations and the introduction of a fourth crop with a relative high economic productivity. In the meanwhile, the farms in the farming system have to stay profitable

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with limited options for adaptation and experimentation, because of low financial capital and moderate local and natural capital.

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## Appendix A. Workshop memo

The workshop was held in a spacious room with windows providing ample daylight. The room is usually location for workshops and meetings related to agriculture in the case-study area. Tables were positioned in a U-shape. Discussions in sub-groups were held in separate rooms. The provided coffee, tea and lunch was simple but adequate.

Participants critically reflected on the workshop structure and content during the workshop. Especially at the start of the workshop it took extra time to convince participants that filling out forms was useful for assessing resilience. Participants indicated that the amount of forms was too much. Towards the end of the workshop, assistance of researchers to participants was provided to explain what was asked in the forms.

Start time: 10.00

End time: 16.05

Total break time (estimation): 1 hour

*Table A1: Overview of participants.*

| Function | Organization | Stakeholder group | Comment |
|---|---|---|---|
| Owner/manager | Arable farm with starch potatoes, cerals, sugarbeets and onions | Farmer | |
| Owner/manager | Arable farm with starch potatoes, cereals, sugarbeets and carrots | Farmer | |
| Owner/manager | Arable farm Veenkolonien and farm in Eastern Europe | Farmer | |
| Manager | Experimental farm Valthermond | Farmer | |
| Owner/Manager | AB Drone | Other | |
| MSc-Student | Wageningen University | Other | |
| Owner/Manager | Carpay Advies | Other | |
| Project Manager | Municpality Westerwolde | Other | |
| Chairman | De Nieuwe Leefstijl | Other | |
| Coordinator R&D | AVEBE | Other | |
| Manager | Water board Hunze en Aa's | Other | Only morning |
| Politician | CDA AA en Hunze | Other | Only afternoon |

## Appendix B. Details on ranking and rating the functions and indicators

*Table A2: Mean and standard deviation of scores per essential function (EF) per stakeholder group and for all participants. 100 points needed to be divided to 8 EF.*

| | Farmer | | Other | | All | |
|---|---|---|---|---|---|---|
| Function | Mean | St. Dev. | Mean | St. Dev. | Mean | St. Dev. |
| Food production | 15 | 7 | 15 | 11 | 15 | 9 |
| Bio-based resources | 6 | 5 | 7 | 5 | 6 | 5 |
| Economic viability | 30 | 34 | 14 | 8 | 21 | 23 |
| Quality of life | 8 | 5 | 7 | 5 | 7 | 5 |
| Natural resources | 18 | 6 | 28 | 17 | 23 | 13 |
| Biodiversity & habitat | 10 | 8 | 13 | 6 | 11 | 7 |
| Attractiveness of the area | 8 | 5 | 11 | 6 | 9 | 6 |
| Animal health & welfare | 6 | 5 | 9 | 3 | 8 | 4 |

*Table A3: Overview of indicators associations with stakeholders made by the research team.*

| Functions (purpose) | Indicators | Stakeholder |
|---|---|---|
| *Private goods* | | |
| Deliver healthy and affordable food products | Starch potato production (t/ha) | Arable farmers, Avebe |
| | Sugar beet production (t/ha) | Arable farmers |
| | Cereal production (t/ha) | Arable farmers |
| | - | |
| Deliver other bio-based resources for the processing sector | Diversity of industrial potato products | Arable farmers, Avebe |
| | Straw production (t/ha) | Arable farmers |
| | - | |
| | - | |
| Ensure economic viability (viable farms help to strengthen the economy and contribute to balanced territorial development) | Profit (Euro/ha) | All farmers |
| | Income from agricultural activities (%) | All farmers |
| | Land prices | All farmers, land owners, government |
| | - | |
| Improve quality of life in farming areas by providing employment and offering decent working conditions. | Working hours per year per farmer | All farmers |
| | Employment related to agriculture | All farmers, government |
| | Satisfaction of being a farmer | All farmers |
| | Women working in agriculture (%) | All farmers, government |
| *Public goods* | | |

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| | | |
|---|---|---|
| Maintain natural resources in good condition (water, soil, air) | Greenhouse gas emissions | All farmers, government |
| | Soil quality | All farmers, government |
| | Regional water availability | All farmers, government, nature organizations |
| | Responsible use of nutrients | All farmers, government, nature organizations |
| Protect biodiversity of habitats, genes, and species | Responsible use of crop protection products | All farmers, government, nature organizations |
| | Number of bird species | All farmers, government, nature organizations |
| | Surface of land with nature friendly management | All farmers, government, nature organizations |
| | - | |
| Ensure that rural areas are attractive places for residence and tourism (countryside, social structures) | Unhealthy stress under farmers | All farmers, government |
| | Farms with broadened activities | All farmers, government |
| | Villages with a minimum of one school and supermarket | All farmers, government |
| | - | |
| Ensure animal health & welfare | Farms with certificates for animal welfare | All farmers, government |
| | Responsable use of antibiotics | All farmers, government |
| | - | |
| | - | |

*Table A4: Importance of indicators; original values resulting from 100 points divided over the indicators per function; transformed values including importance of the function and number of indicators per function. Transformed values allow for direct comparison between indicators*

| | Corrected values | | | | | | Original values. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Farmer | | Other | | Total | | Farmer | | Other | | Total | |
| Indicator | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev |
| Starch potato production (t/ha) | 12 | 1 | 11 | 8 | 12 | 6 | 28 | 3 | 26 | 18 | 27 | 13 |
| Sugar beet production (t/ha) | 12 | 1 | 8 | 4 | 10 | 4 | 28 | 3 | 19 | 9 | 23 | 8 |
| Cereal production (t/ha) | 12 | 4 | 9 | 5 | 10 | 5 | 28 | 9 | 20 | 12 | 23 | 11 |
| Diversity of industrial potato products | 7 | 3 | 6 | 4 | 7 | 3 | 58 | 27 | 47 | 29 | 52 | 27 |
| Straw production (t/ha) | 1 | 1 | 2 | 1 | 2 | 1 | 6 | 9 | 19 | 5 | 13 | 10 |
| Profit (Euro/ha) | 29 | 28 | 9 | 16 | 18 | 21 | 43 | 48 | 29 | 27 | 35 | 34 |
| Income from agricultural activities (%) | 32 | 29 | 11 | 19 | 20 | 22 | 47 | 49 | 33 | 30 | 39 | 36 |
| Land prices | 7 | 9 | 4 | 6 | 5 | 7 | 10 | 17 | 14 | 9 | 12 | 12 |
| Working hours per year per farmer | 8 | 6 | 6 | 5 | 7 | 5 | 28 | 21 | 22 | 18 | 24 | 18 |
| Employment related to agriculture | 6 | 4 | 6 | 4 | 6 | 4 | 20 | 14 | 22 | 15 | 21 | 14 |
| Satisfaction of being a farmer | 13 | 11 | 12 | 9 | 12 | 9 | 43 | 39 | 46 | 32 | 44 | 33 |
| Women working in agriculture (%) | 3 | 2 | 3 | 4 | 3 | 3 | 10 | 8 | 10 | 14 | 10 | 11 |
| Greenhouse gas emissions | 5 | 6 | 21 | 10 | 14 | 10 | 8 | 6 | 19 | 11 | 14 | 11 |
| Soil quality | 26 | 9 | 32 | 6 | 29 | 8 | 38 | 10 | 29 | 7 | 33 | 9 |
| Regional water availability | 22 | 6 | 32 | 11 | 27 | 9 | 31 | 6 | 29 | 12 | 30 | 9 |
| Responsible use of nutrients | 17 | 6 | 25 | 7 | 21 | 6 | 24 | 6 | 23 | 8 | 23 | 7 |
| Responsible use of crop protection products | 15 | 11 | 13 | 6 | 14 | 8 | 50 | 33 | 35 | 17 | 42 | 24 |
| Number of bird species | 4 | 5 | 10 | 9 | 7 | 8 | 14 | 14 | 26 | 28 | 21 | 22 |
| Surface of land with nature friendly management | 8 | 6 | 10 | 4 | 9 | 4 | 25 | 17 | 26 | 11 | 26 | 13 |
| Unhealthy stress under farmers | 14 | 8 | 16 | 8 | 15 | 8 | 63 | 28 | 52 | 29 | 57 | 27 |
| Farms with broadened activities | 3 | 3 | 6 | 3 | 5 | 3 | 14 | 11 | 20 | 12 | 17 | 11 |
| Villages with a minimum of one school and supermarket | 5 | 5 | 9 | 5 | 7 | 5 | 21 | 17 | 28 | 18 | 25 | 17 |
| Farms with certificates for animal welfare | 3 | 4 | 4 | 3 | 3 | 3 | 25 | 29 | 22 | 20 | 23 | 23 |
| Responsible use of antibiotics | 9 | 4 | 6 | 5 | 8 | 5 | 75 | 29 | 38 | 35 | 54 | 36 |

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*Table A5: 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.*

| | Corrected values | | | | | |
|---|---|---|---|---|---|---|
| | Farmer | | Other | | Total | |
| Indicator | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev |
| Starch potato production (t/ha) | 3.000 | 1.414 | 3.600 | 0.548 | 3.333 | 1.000 |
| Sugar beet production (t/ha) | 3.750 | 1.258 | 3.600 | 0.894 | 3.667 | 1.000 |
| Cereal production (t/ha) | 3.250 | 1.258 | 3.800 | 0.447 | 3.556 | 0.882 |
| Diversity of industrial potato products | 3.000 | 0.000 | 3.600 | 1.140 | 3.375 | 0.916 |
| Straw production (t/ha) | 5.000 | #DIV/0! | 2.800 | 0.447 | 3.167 | 0.983 |
| Profit (Euro/ha) | 3.000 | 0.816 | 3.000 | 0.707 | 3.000 | 0.707 |
| Income from agricultural activities (%) | 3.250 | 0.500 | 2.600 | 0.894 | 2.889 | 0.782 |
| Land prices | 2.250 | 0.957 | 2.600 | 1.140 | 2.444 | 1.014 |
| Working hours per year per farmer | 2.750 | 1.258 | 2.750 | 0.500 | 2.750 | 0.886 |
| Employment related to agriculture | 4.250 | 0.500 | 3.250 | 0.500 | 3.750 | 0.707 |
| Satisfaction of being a farmer | 3.125 | 1.031 | 2.750 | 0.957 | 2.938 | 0.943 |
| Women working in agriculture (%) | 2.000 | 1.155 | 3.250 | 1.258 | 2.625 | 1.302 |
| Greenhouse gas emissions | 3.250 | 1.708 | 1.800 | 0.447 | 2.444 | 1.333 |
| Soil quality | 3.250 | 0.500 | 1.800 | 0.447 | 2.444 | 0.882 |
| Regional water availability | 3.500 | 0.577 | 2.600 | 1.140 | 3.000 | 1.000 |
| Responsable use of nutrients | 3.750 | 0.500 | 2.800 | 1.304 | 3.222 | 1.093 |
| Responsable use of crop protection products | 4.000 | 0.000 | 2.800 | 1.095 | 3.333 | 1.000 |
| Number of bird species | 2.750 | 1.258 | 1.600 | 0.894 | 2.111 | 1.167 |
| Surface of land with nature friendly management | 2.500 | 0.577 | 2.200 | 1.304 | 2.333 | 1.000 |
| Unhealthy stress under farmers | 2.500 | 1.000 | 2.200 | 0.447 | 2.333 | 0.707 |
| Farms with broadened activities | 2.500 | 0.577 | 2.800 | 0.447 | 2.667 | 0.500 |
| Villages with a minimum of one school and supermarket | 2.000 | 0.816 | 2.200 | 0.837 | 2.111 | 0.782 |
| Farms with certificates for animal welfare | 4.000 | 0.816 | 3.250 | 0.500 | 3.625 | 0.744 |
| Responsable use of antibiotics | 4.000 | 0.816 | 3.500 | 0.577 | 3.750 | 0.707 |

*Table A6: Mean and standard deviation of scoring on performance of essential functions per stakeholder group and for all participants. Derived from scoring of importance and performance of indicators.*

| | Corrected values | | | | | |
|---|---|---|---|---|---|---|
| | Farmer | | Other | | Total | |
| Indicator | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev |
| Food production | 3.3 | 1.3 | 3.7 | 0.5 | 3.5 | 0.9 |
| Bio-based resources | 2.9 | 0.7 | 3.4 | 0.9 | 3.3 | 0.8 |
| Economic viability | 3.0 | 0.6 | 2.8 | 0.6 | 2.9 | 0.6 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Quality of life | 3.2 | 0.6 | 2.9 | 0.6 | 3.0 | 0.6 |
| Natural resources | 3.4 | 0.3 | 2.3 | 0.7 | 2.8 | 0.8 |
| Biodiversity & habitat | 3.3 | 0.4 | 2.3 | 1.0 | 2.8 | 0.9 |
| Attractiveness of the area | 2.4 | 0.6 | 2.3 | 0.3 | 2.3 | 0.4 |
| Animal health & welfare | 4.0 | 0.8 | 2.7 | 1.6 | 3.3 | 1.4 |

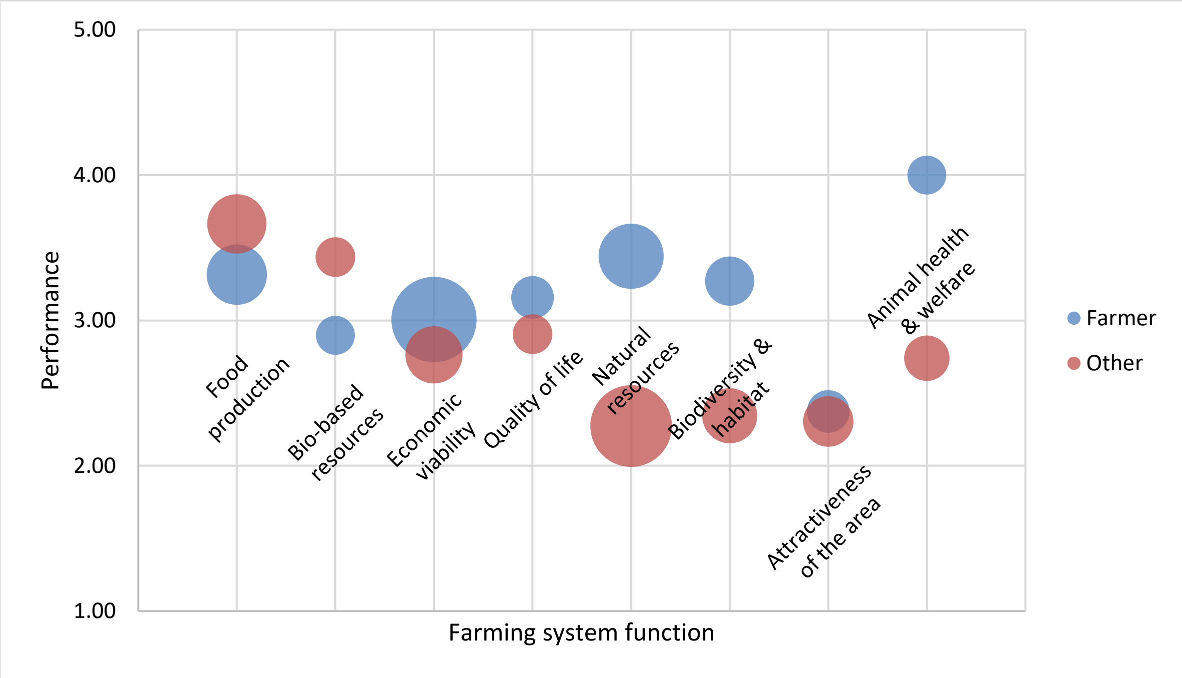


*Figure A1: Bubble graph presenting averaged scores on performance of essential functions (from 1 to 5), aggregated by stakeholder group, while also indicating their importance (size of the bubbles), relative to each other.*

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## Appendix C: Dynamics of main indicators

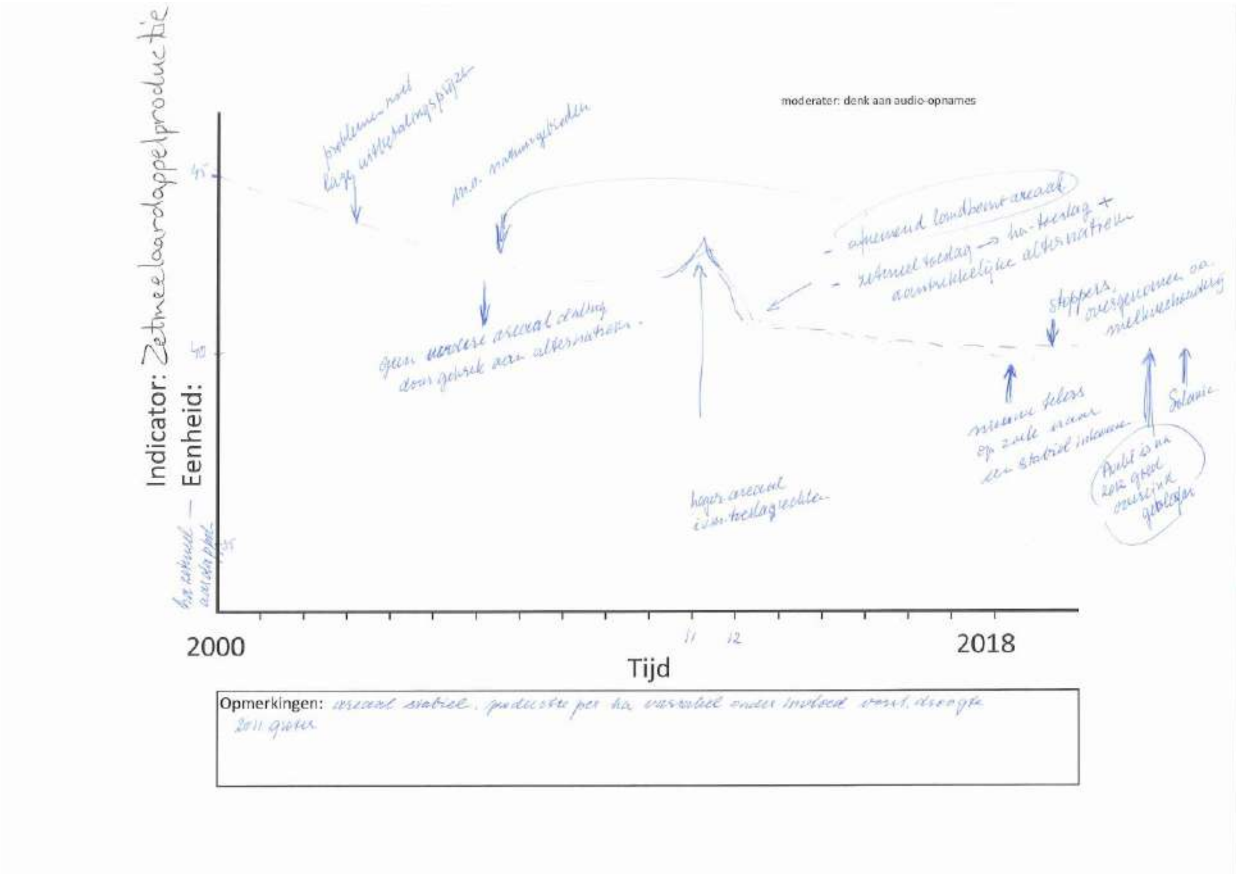


*Figure A2: Original sketch of starch potato area drawn by a researcher based on contents of the discussion.*

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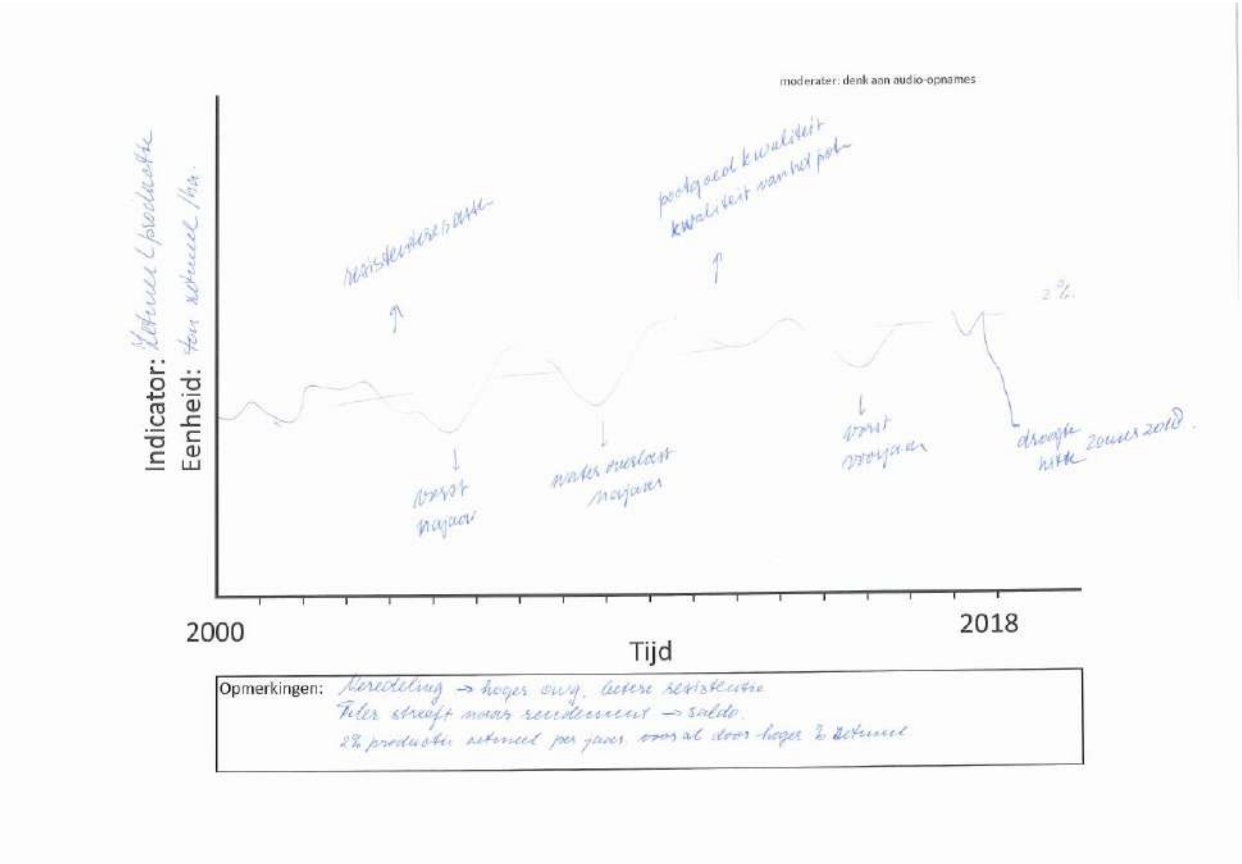


*Figure A3: Original sketch of starch potato production per hectare drawn by a researcher based on contents of the discussion.*

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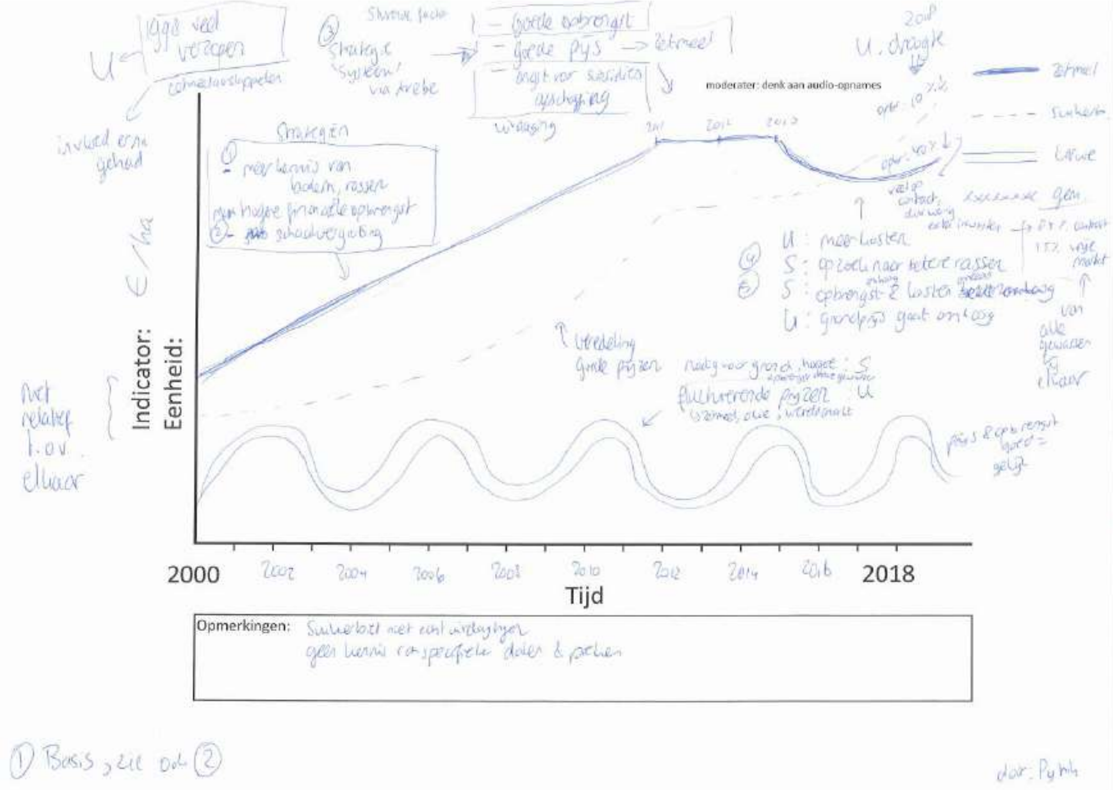


*Figure A4: Original sketch of income from crops per hectare drawn by a researcher based on contents of the discussion.*

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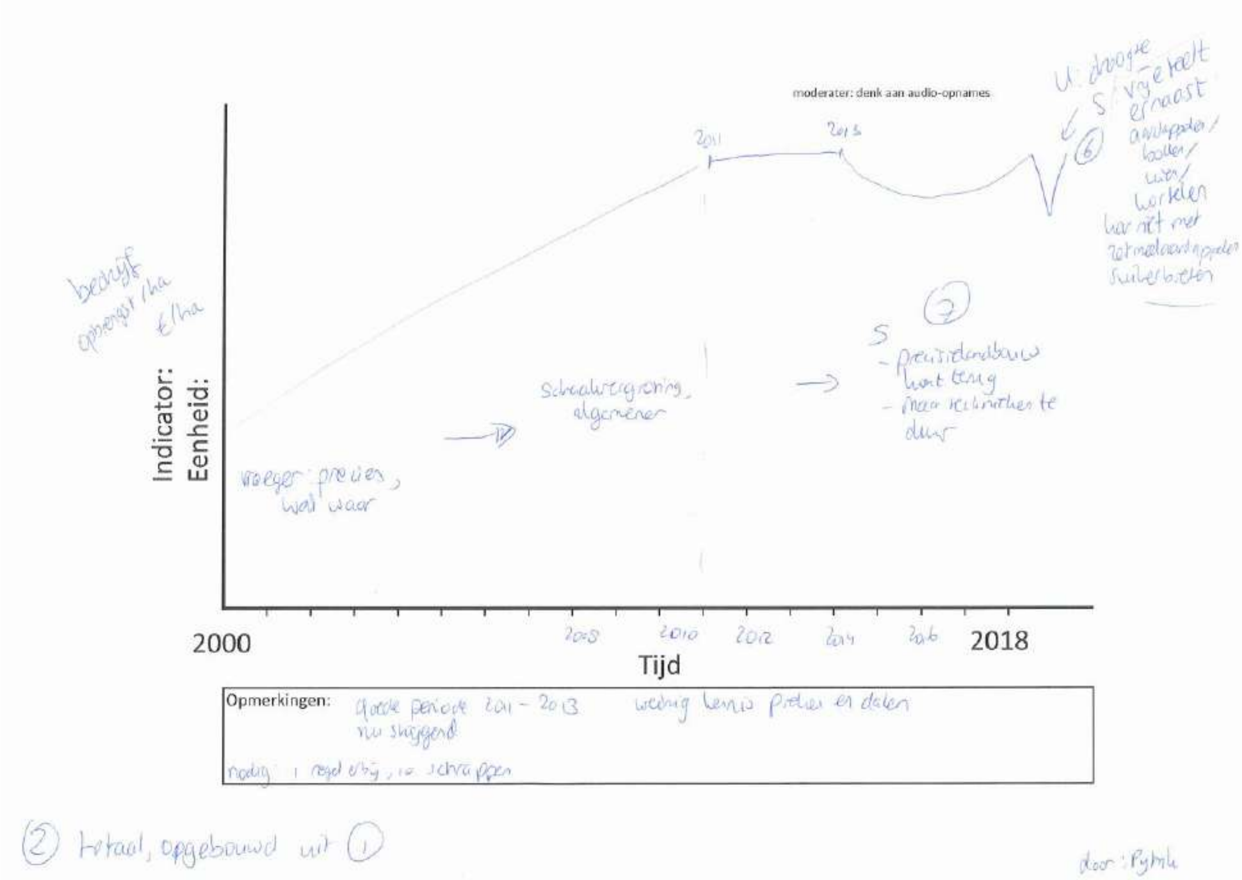


*Figure A5: Original sketch of income per hectare drawn by a researcher based on contents of the discussion.*

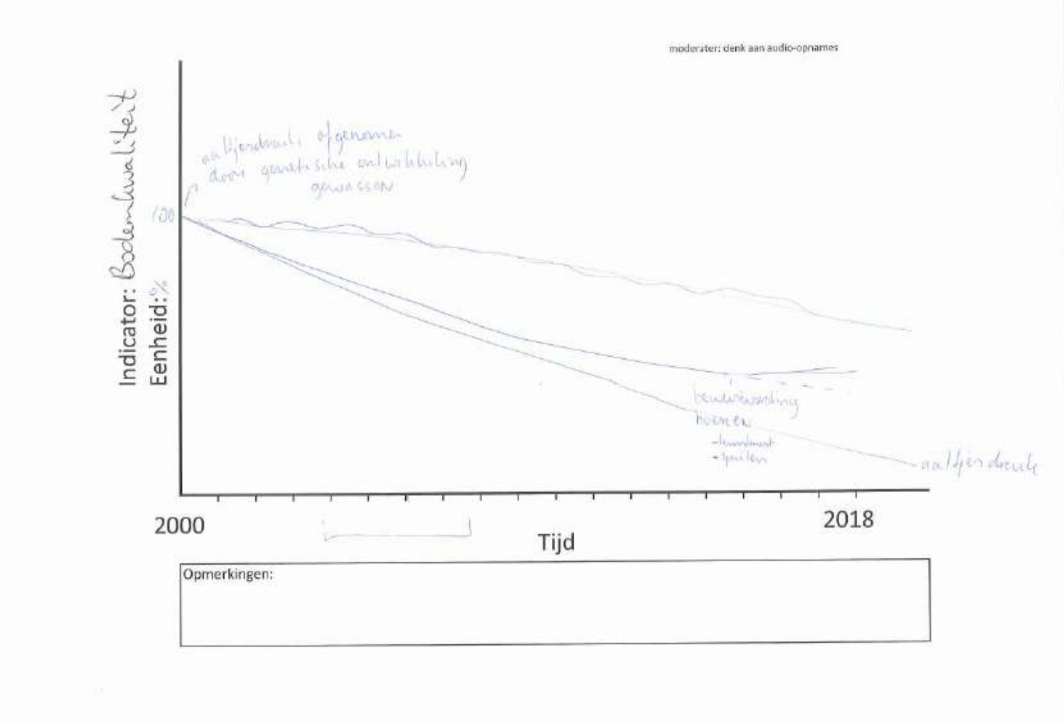


*Figure A6: Original sketch for soil quality drawn by researchers based on the content of the discussion. Participants did not agree on the sketch, which is why this figure is not presented in the main report.*

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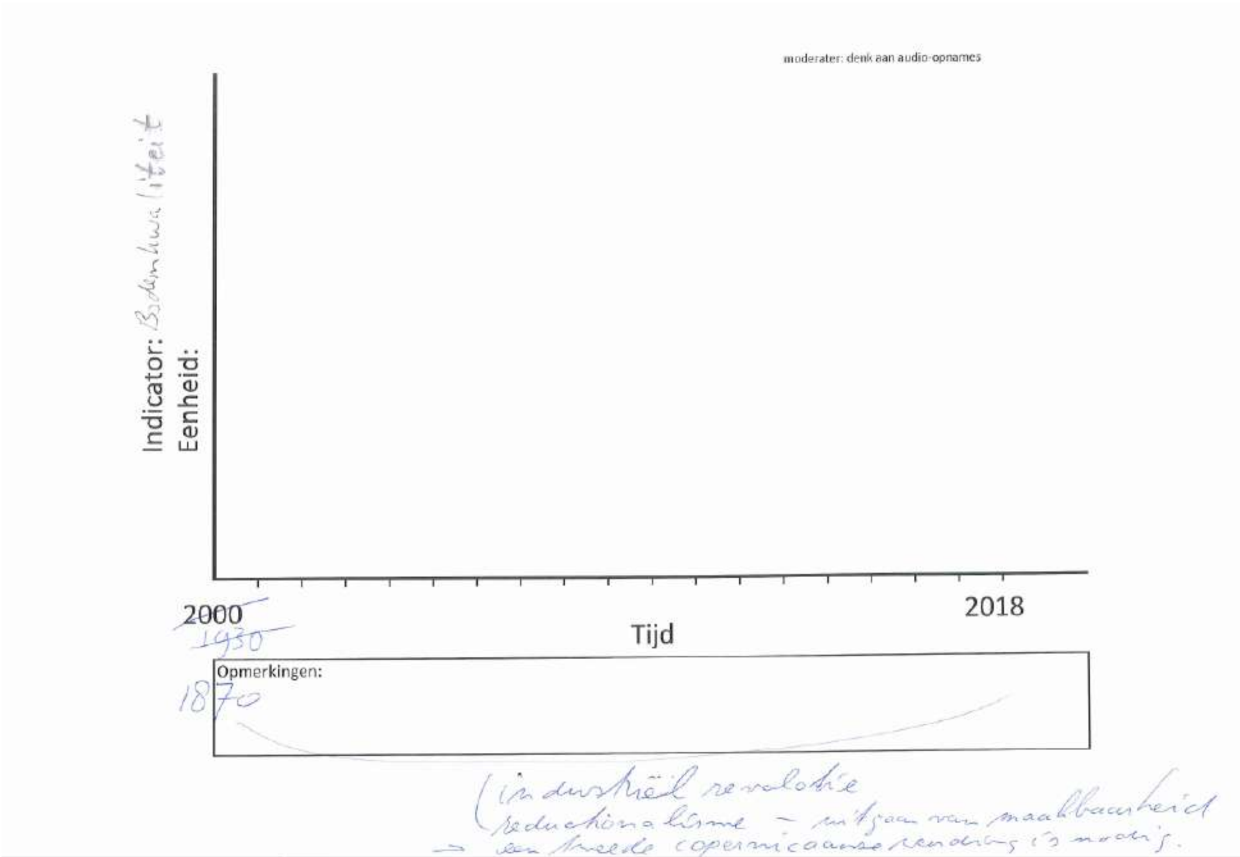


*Figure A7: Sketch paper for soil quality containing only comments on the start of the perceived decline in soil quality and the need for a "Copernican" change.*

## Appendix D: Details on scoring strategies and resilience attributes

*Table A7: Extent of implementation of strategies and their potential contribution to the resilience capacities of the farming system.*

| | | | | Potential contribution to resilience capacities | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Implementation score | | Robustness | | Adaptability | | Transformability | |
| Selected indicator | Strategy | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev |
| Profit | Extend knowledge on soil & varieties | 3.5 | 0.7 | 2.0 | 1.4 | 2.5 | 0.7 | 2.5 | 0.7 |
| | Scaling | 4.0 | 1.4 | 2.5 | 0.7 | -0.5 | 3.5 | -1.5 | 2.1 |
| | Increase value of starch products | 2.0 | NA | -0.5 | 0.7 | 1.5 | 2.1 | -1.0 | 1.4 |
| | Better varieties | 3.5 | 0.7 | 1.5 | 0.7 | 2.5 | 0.7 | 1.5 | 0.7 |
| | Reduce costs | 2.5 | 0.7 | 1.0 | 0.0 | 2.0 | 1.4 | 1.0 | 0.0 |
| | Have land available outside contract farming | 2.5 | 2.1 | 2.0 | 1.4 | 2.0 | 1.4 | -1.0 | 1.4 |
| | Precision agriculture | 3.0 | 1.4 | 2.5 | 0.7 | 1.5 | 2.1 | -1.0 | 1.4 |
| | Starch potato production | 3.3 | 0.8 | 0.2 | 1.7 | 0.7 | 1.2 | 1.0 | 0.9 |
| Starch potato production | Reduce costs | 3.0 | 0.0 | -1.0 | 1.4 | -0.5 | 0.7 | 0.5 | 0.7 |
| | Turn agricultural land into something else | 4.0 | 1.4 | 2.0 | 1.4 | 1.5 | 0.7 | 1.5 | 0.7 |
| | Exchange land with dairy farms | 2.3 | 1.1 | 1.2 | 1.6 | 1.3 | 1.4 | 1.5 | 1.4 |
| Soil quality | Improved varieties against nematodes | 2.5 | 0.5 | 2.0 | 1.2 | 2.0 | 1.2 | 2.0 | 1.2 |
| | Raising awareness | 2.0 | 0.8 | 1.5 | 1.3 | 1.8 | 1.0 | 1.3 | 2.1 |
| | Replenish all soil minerals | 2.0 | 1.4 | 1.5 | 0.6 | 1.5 | 1.3 | 1.8 | 1.5 |
| | Avoid artificial fertilizer | 2.8 | 1.1 | 1.2 | 1.5 | 1.3 | 1.5 | 0.9 | 1.6 |

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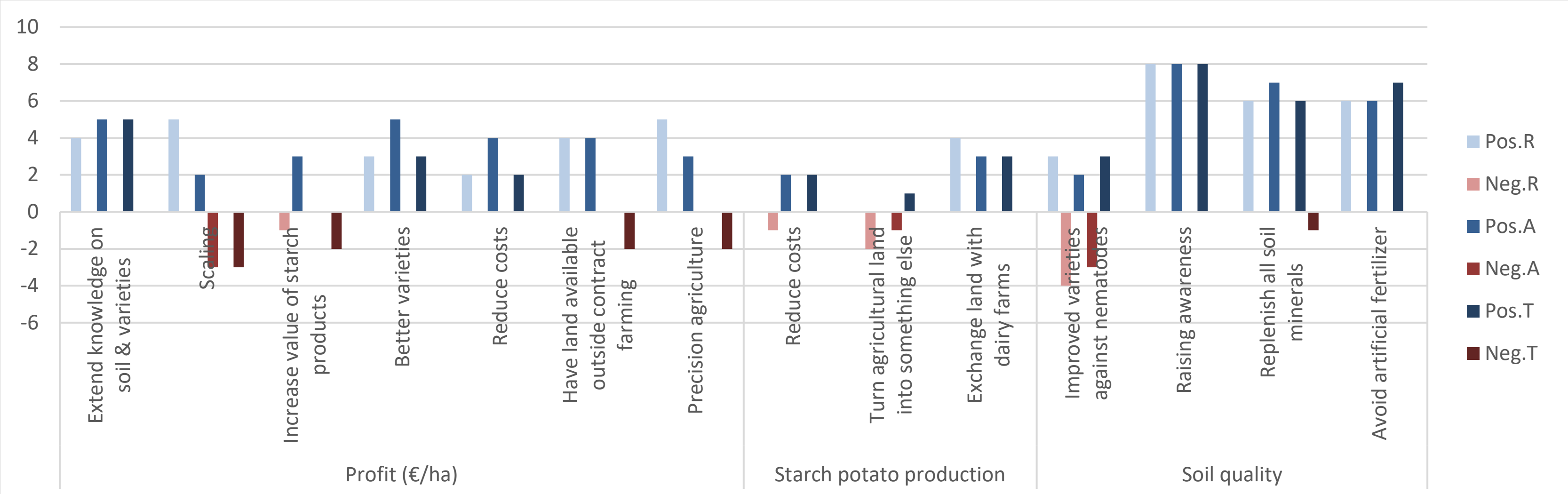


*Figure A8: Bar graph presenting total positive and negative points allocated to a strategy's contribution to robustness, adaptability and transformability.*

*Table A8: Mean and standard deviation of performance scores of resilience attributes. Per stakeholder group and for all participants.*

| | Extent into which attribute applies in FS | | | | | |
|---|---|---|---|---|---|---|
| | Farmer | | Other | | Total | |
| Resilience attribute | Mean | St. Dev | Mean | St. Dev | Mean | St. Dev |
| Reasonably profitable | 2.0 | 1.4 | 2.0 | 0.0 | 2.0 | 0.9 |
| Coupled with local and natural capital (production) | 2.8 | 1.0 | 3.0 | 0.7 | 2.9 | 0.8 |
| Functional diversity | 2.3 | 0.5 | 2.2 | 0.8 | 2.2 | 0.7 |
| Response diversity | 2.8 | 1.0 | 2.4 | 0.5 | 2.6 | 0.7 |
| Exposed to disturbance | 4.0 | 1.0 | 1.8 | 0.5 | 2.7 | 1.4 |
| Spatial and temporal heterogeneity (farm types) | 3.8 | 1.0 | 2.8 | 1.0 | 3.3 | 1.0 |
| Optimally redundant (farms) | 2.8 | 1.3 | 2.2 | 0.8 | 2.4 | 1.0 |
| Supports rural life | 3.0 | 1.6 | 2.8 | 0.8 | 2.9 | 1.2 |
| Socially self-organized | 3.0 | 1.8 | 2.8 | 1.3 | 2.9 | 1.5 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Appropriately connected with actors outside the farming system | 1.5 | 0.6 | 3.0 | 1.0 | 2.3 | 1.1 |
| Infrastructure for innovation | 3.0 | 0.8 | 3.0 | 1.0 | 3.0 | 0.9 |
| Coupled with local and natural capital (legislation) | 1.3 | 0.5 | 1.8 | 0.8 | 1.6 | 0.7 |

*Table A9: 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 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Farmer | | | | | | Other | | | | | | Total | | | | | |
| | Robustness | | Adaptability | | Transformability | | 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. | Mean | St. Dev. | Mean | St. Dev. | Mean | St. Dev. |
| Reasonably profitable | 2.5 | 0.6 | 1.5 | 1.3 | 2.0 | 1.0 | 2.4 | 1.3 | 1.8 | 1.6 | 1.4 | 2.2 | 2.4 | 1.0 | 1.7 | 1.4 | 1.6 | 1.8 |
| Coupled with local and natural capital (production) | 2.0 | 1.2 | 1.0 | 1.4 | 0.3 | 3.1 | 2.2 | 1.8 | 1.8 | 1.3 | 1.8 | 1.3 | 2.1 | 1.5 | 1.4 | 1.3 | 1.3 | 2.1 |
| Functional diversity | 2.0 | 1.2 | 1.0 | 1.4 | 1.0 | 2.0 | 0.6 | 1.9 | 0.2 | 1.5 | 0.8 | 0.8 | 1.2 | 1.7 | 0.6 | 1.4 | 0.9 | 1.2 |
| Response diversity | 1.8 | 1.0 | 1.8 | 1.0 | 1.3 | 0.6 | 1.0 | 1.9 | 1.2 | 1.3 | 0.4 | 1.5 | 1.3 | 1.5 | 1.4 | 1.1 | 0.8 | 1.3 |
| Exposed to disturbance | 0.7 | 0.6 | -0.3 | 1.5 | -0.3 | 1.5 | 0.0 | 2.2 | 0.5 | 2.1 | 0.5 | 1.9 | 0.3 | 1.6 | 0.1 | 1.8 | 0.1 | 1.7 |
| Spatial and temporal heterogeneity (farm types) | 2.0 | 0.8 | 0.3 | 2.2 | 0.3 | 2.1 | 1.2 | 1.3 | 0.2 | 1.3 | 1.2 | 1.6 | 1.6 | 1.1 | 0.2 | 1.6 | 0.9 | 1.7 |
| Optimally redundant (farms) | 0.3 | 2.4 | 0.0 | 2.0 | 1.0 | 2.0 | 0.6 | 1.8 | 1.0 | 1.0 | 0.8 | 1.3 | 0.4 | 1.9 | 0.6 | 1.5 | 0.9 | 1.5 |
| Supports rural life | 0.3 | 2.6 | 0.3 | 2.2 | 1.7 | 1.2 | 0.0 | 2.2 | 0.2 | 2.0 | 0.0 | 2.1 | 0.1 | 2.3 | 0.2 | 2.0 | 0.6 | 1.9 |
| Socially self-organized | 1.3 | 1.7 | 1.0 | 1.6 | 0.0 | 2.6 | 1.0 | 2.1 | 1.2 | 1.1 | 0.8 | 0.8 | 1.1 | 1.8 | 1.1 | 1.3 | 0.5 | 1.6 |
| Appropriately connected with actors outside the farming system | 0.5 | 2.1 | 0.8 | 2.1 | -1.7 | 2.3 | 1.0 | 1.2 | 0.8 | 1.3 | 1.2 | 1.3 | 0.8 | 1.6 | 0.8 | 1.6 | 0.1 | 2.2 |
| Infrastructure for innovation | 0.8 | 1.9 | 1.3 | 1.7 | 1.0 | 0.0 | 1.2 | 1.1 | 1.8 | 1.3 | 1.8 | 1.3 | 1.0 | 1.4 | 1.6 | 1.4 | 1.5 | 1.1 |
| Coupled with local and natural capital (legislation) | -0.8 | 2.2 | -2.0 | 1.4 | -0.3 | 2.5 | 1.2 | 1.6 | 1.2 | 1.3 | 0.8 | 1.6 | 0.3 | 2.1 | -0.2 | 2.1 | 0.4 | 1.9 |

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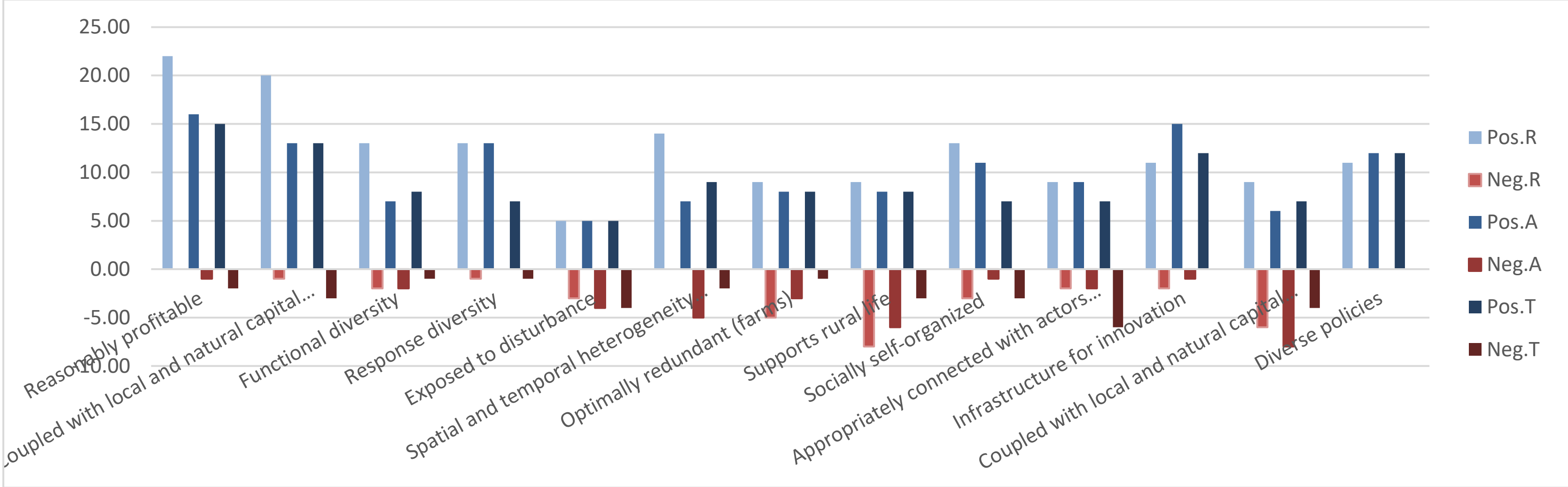


*Figure A9: Bar graph presenting total positive and negative points allocated to a resilience attributes' contribution to robustness, adaptability and transformabilty.*

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