Chapter 5

Case study: AVEBE

5.1 Position in research

The AVEBE case study concentrates on the development of knowledge of sustainability of the starch potato farmer population of AVEBE. In this study, this farmer population is the unit of adoption. Knowledge of sustainability of starch potato growth has been developed in the Agrobiokon research programme, in recent years. This research programme has focussed on optimising crop growth and farmer earnings. Additionally, various channels of communication, among which several decision support systems, have been implemented to realise sustainability of knowledge in starch potato growth, focusing on knowledge integration. However, because these channels of communication were developed from a top-down orientation by researchers (unit of execution) who developed the knowledge of sustainability regarding starch potato growth in the first place, solely focusing on the knowledge of starch potato growth, and not considering the farmers who eventually use this knowledge of sustainability, the effect of these channels on AVEBE's starch potato farmer population has been insignificant. Here, we focus on the decision support systems that are used to communicate with farmers.

In this study, knowledge of farmers is developed to complement the knowledge of starch potato growth. Building on the theoretical discussion in chapter 3, this knowledge of farmers is required to shape the interaction between farmer and decision support system. Chapter 3 indicates that communication from a decision support system to an individual requires the decision support system to shape its information such that the individual is able to transform it into knowledge. Implementing the knowledge of farmers in the decision support system in the component 'model of user', should smooth farmer-decision support system interaction (see also section 3.3). The assumption is that a properly designed decision support system, tailoring its communication with its user, i.e. the farmer, initiates learning at the side of the farmer and thus realises sustainability of knowledge.

AVEBE's current decision support systems have been constructed based on the assumption that three types of farmers exist (i.e. low-, mid-, and high-yielding farmers), each type of farmer requiring support regarding different aspects of starch potato growth. For instance, low and mid-yielding farmers were offered decision
support regarding cultivar selection and raise damage. Advanced crop management support targeted high-yielding farmers. Concerning the used typology, implicitly the assumption was made that all farmers process information in a similar manner. This led to the perspective that no additional measures are required to trim the interaction between decision support system and farmers. The result is that each decision support system that has been developed communicates with farmers, using one vocabulary: the vocabulary of the researchers who developed the knowledge of sustainability of starch potato growth.

In this research, these assumptions regarding AVEBE farmers are tested, hypothesising that variations in yield in quantitative and qualitative sense, demonstrate similar, stable variations regarding farmers' information processing behaviours, their task environment, and prior related knowledge regarding starch potato growth. The methodological approach that is used, is the empirical cycle (see chapter 4). The result of the AVEBE study is increased and more useful knowledge of sustainability with regards to farmers and the ways they can be communicated with. This knowledge of sustainability of farmers extends theory on AVEBE's starch potato growth. Consequently, this knowledge of sustainability of farmers extends the normative framework that is used in designing next versions of current and new decision support systems at a later stage.
5.2 Introduction

The remainder of this chapter is based on:

5.2 Introduction

This chapter discusses the transformation of knowledge into economic and ecological value, to improve the sustainability of the starch potato value chain, which challenges both starch potato growers and the starch potato industry in the Northwest of Europe. The study that is addressed, particularly targets types of concentrated knowledge: decision support systems regarding starch potato growth. As participant of the Agrobicton research programme, AVEBE developed such systems, enabling its farmers to increase the yield of their farms. However, so far the developed decision support systems did not have the intended effect. Improving sustainability requires the use and reuse of knowledge of sustainability. Therefore, it is imperative that both farmers and the sector increase their yield using fewer resources, in order to survive the changes that globalisation of agriculture imposes on them. Apparently, some barriers stand in the way of the intended transfer of knowledge through decision support systems, and thus in the way of sustainability of knowledge. Therefore, this study explores what factors might explain the lack of knowledge transfer through developed decision support systems.

The starch potato growth of the northeast of The Netherlands and the northwest of Germany (referred to as the Ems-Dollard Eurregion (EDR)) forms the base of a sustainable agricultural production chain for food and non-food applications. This growth concentrates in the provinces of Groningen and Drenthe in The Netherlands, and Emsland in Germany. Approximately 70,000 hectares of starch potatoes are grown at about 5,000 farms. In the last ten years, both area and total number of farms reduced, while average farm size increased. The average production approximates 30 tons per hectare (field weight). The 70,000 hectares of starch potatoes represent a total value of about 170 million euros. The added value of the potato starch industry is estimated at 700 million euros, and causes the direct and indirect employment of 8,000 in the region. Summarising, the value chain of potato starch is an important factor of the Ems-Dollard Eurregion economy and agriculture. In this chapter, only the Dutch starch potato farmers are considered. These Dutch farmers concern about 45,000 hectares, divided among 2,100 farms.

Societal, technological, and climatologic changes are recognised to undermine the current situation of the starch potato value chain. Societal changes follow upon the Kyoto agreement, and a change of the European Union’s (EU) Common Agricultural Policy (CAP). The breakdown of the Common Agricultural Policy, in line with World Trade Organisation (WTO) agreements, eventually stops current subsidies for potato starch production, and opens the European Union’s borders for cheaper sources of starch.

Technical trends influencing the value chain of potato starch are the intensified use of information, utilisation of green and white biotechnology, and a further in-
crease of scale. Adequate information, correctly applied, and delivered through appropriate advice systems is assumed to increase yields by 20-30%. Green biotechnology (i.e. changing a plant’s genetic make-up), and white biotechnology (i.e. the industrial application of genetically modified enzymes and bacteria for enzymatic and fermentation processes) influence the configuration of farmers’ and processors’ production processes. Green biotechnology enables the design of new potato cultivars, producing a 20-30% yield increase. Combining green and white biotechnology enables the production of additional valuable components, such as for instance aromas, medical ingredients, or industrial chemicals. A further increase of scale results in either large-scale, capital-intensive farms, producing several agricultural raw materials, or small multifunctional farms, profiting from a multitude of economic activities that are linked to plant, animal, and land. The agri-industrial value chain benefits mostly from large-scale farms.

Climatologic changes already influence the starch potato growth. Especially changing patterns of precipitation, more frequent forms of extreme weather (seasonal night frost, hail, prolonged periods of precipitation, and drought), and an increase of average temperatures causes an increasing fluctuation of farmers’ income. These changes especially affect risk-prone capital-intensive farms.

Being one of few European large-scale value chains of potato starch, starch potato growth in the EDR-Regions is considered to possess the innovation capacity to utilise the changing circumstances for improving the value chain of potato starch in market and society. The Dutch knowledge position regarding agriculture and food-industry, and the professional knowledge of Dutch farmers is used. Eight years ago the Agrobiokon-platform was established (Agrobiokon: Agro-Biotechnological Carbo-hydrate Research Netherlands), targeting innovation of carbo-hydrate value chains. Agrobiokon consists of knowledge institutions, growers, national and regional authorities, and potato starch processing industry.

By participating in Agrobiokon, AVEBE expressed its intention to change in order to meet the new demands of the future. Such change implies the adaptation of every farm and farmer that is part of the AVEBE co-operative, hence realising sustainability of knowledge in the AVEBE farmer population. Knowledge of sustainability generated by the Agrobiokon programme has to be transferred to individual farmers and applied within their daily activities. In other words, knowledge integration has to be realised. To achieve this knowledge transfer, the Agrobiokon programme developed and applied different channels of knowledge transfer. For an average-sized farm to withstand the above-mentioned challenges, AVEBE estimates them having to realise a yield improvement of 25%. The effect of the intended knowledge transfer on farmer and farm performance has been moderate up to now.

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Footnote: Processors are AVEBE factories that transform starch potatoes into starch.
5.3 Organisation

5.3.1 In general
AVEBE is a world leader concerning sales, marketing, development, and production of potato starch and potato starch specialities that are used in Food, Paper, and Industrial Specialties such as textile and concrete. AVEBE targets to strengthen its market position and actively participates in the increasing liberalisation of global trade. Internally, the organisation implements its strategy of becoming the world leader in potato starch, and the supplier of solutions to its customers from Food, Paper, and Industrial Specialties, by increasing its knowledge on functional applications. Additionally, AVEBE strives for a sustainable development. The organisation's divisions control the total value chain of potato starch production, including services and product and process development with and in favour of its customers.

5.3.2 History
AVEBE is strongly connected with the history of the three Northern provinces of The Netherlands. After the ice age, the Bourtanger Moor marshlands developed between the river Eems and the Hondsreg. From these marshlands, peat moor grew in ten metres thick packages. Already in Roman times, lumps of peat were extracted and used as fuel. However, the systematic extraction of peat in the former fen communities only started in the seventeenth century. The cut peat district was transformed into farming land. Somewhere in the eighteenth century, the potato was introduced into the former fen communities (van Houten, 1994). The remaining soil was suitable for potato growth, and used for consumption potatoes for a long time. In the nineteenth century, the potato was industrially processed, in the beginning in alcohol and syrup production.

Around 1840, the first potato starch factories appeared in the area, running on horsepower at a small scale. These factories innovated and quickly switched to steam power. This increase of capacity stimulated further growth of potato production. The involved farmers also introduced another innovation: fertiliser.

Fertiliser is the first innovation that was established, and while the potato starch industry grew, farmers united in agricultural unions, and cooperated regarding purchasing of sowing seed, fertilisers, and tools. At the end of the nineteenth and the beginning of the twentieth century, the starch industry produced surpluses of potatoes. Potato starch industrialists organised themselves in purchasing cartels, making price agreements. Farmers responded by building their own factories in order to put 'our' product on the market: the co-operative was formed. These factories became an extension of their farms. This also preludes the second innovation at the farms: mechanisation and the introduction of new, improved starch potato varieties. Mechanisation was typified by ploughs, planting machines, and fertilising machines. Since 1875, the visionary 'Veenkoloniale Boerenbond' (a former fen communities farmer union) offered rewards for the development of a harvester. After many prototypes, a suitable harvester was developed just after World War II.
Another stimulus for production was the introduction of new varieties with a high amount of starch. The 'eigenheimer' is a well-known variety that was introduced to the market in 1893 (Dendermonde & Sierman, 1979). The cooperating potato starch factories united into the organisation A.V.B. (Aardappelzetmeel Verkoop Bureau - Potato starch Sales Agency). AVB produced one product: potato starch. Herewith, AVB largely depended on the potato starch industrials that next to native starch, also sold chemically modified products such as dextrins. After World War II, AVB had changed its name into AVEBE and started producing chemically modified products as well. At the end of the 1970’s, AVEBE is the only remaining manufacturer of potato starch products and derivatives in The Netherlands.

After World War II, the agricultural sector experienced an increase of scale, land consolidation, and crop protecting substances increasing its production even more. However, the potato cyst nematode (PCN) penetrated the former few communities, and proved impossible to extinguish. In 1949, farmers were forced to switch from two-year, into three-year rotations concerning their potato growth. This changed in 1967, due to the introduction of new resistant varieties and PCN pesticides. PCN remains one of a farmer's largest problems. Optimising the variety choice regarding PCN control is discussed later in this chapter. At this moment, farmers and the potato starch industry are challenged to transform current demands into a future strategy. Later in this chapter, we discuss the role of knowledge management within innovation and the transformation of the value chain of potato starch.

5.3.3 AVEBE’s vision on sustainability

The credo ‘achieving more with less’ typifies AVEBE’s relationship with sustainable development. Sustainable development is one of its core values. AVEBE performs a balancing act between its economic, social, and environmental responsibilities. These core values are also communicated to its suppliers, among which the starch potato growers. Improving quality and decreasing the usage of resources per unit of production is the objective. AVEBE attempts to reach this objective by increasing the yield per hectare on the one hand, and decreasing the use of resources through the implementation of knowledge on the other.

Genetically modified organisms (GMO) fit AVEBE’s strategy. AVEBE develops genetically modified organisms exclusively for technical, non-food applications. Genetically modified organisms potency is high: improved product quality and a reduction of chemicals and the use of energy. Genetically modified organisms can replace synthetic (oil-based) products by renewable resources, reducing CO₂ emissions, decreasing greenhouse effects, and driving back climate changes.

5.3.4 Agrobiokon

The Agrobiokon research programme coordinates research conducted by different knowledge and information agencies. Accessibility of existing knowledge prevails in the Agrobiokon and HPA (Hoofdproductschap Akkerbouw; Main Agriculture Agency) research programmes, thus contributing to sustainability of knowledge.
5.3. Organisation

Together, they built the knowledge portal Kennisakker (Knowledge Field) which provides access to all research collectively financed by the farmers. In order to communicate one clear message to farmers, results from research are offered through this website to all parties involved, including extension services. Agrobioncon’s research programme objectives are:

1. Reducing production costs and crop losses,
2. Increasing yields through the increase of production per hectare, whereby conditions of use of environmental, natural, and societal resources are met,
3. Developing new starch products and processes with high added value.

Together, AVEBE and Agrobioncon offer a variety of solutions to overcome the bottlenecks that have been identified within starch potato growth. The portfolio of knowledge transfer consists of individual growth advice, study groups, demonstrations, Optimedit study days, readings, the Kennisakker knowledge portal, growth manuals, magazines, and particularly decision support systems. As part of the Agrobioncon strategy, these solutions intend to address different farmers of the AVEBE population. In this fashion, the support that is offered can be tailored to the needs of the individual farmer. The underlying assumption is that various types of farmers are identifiable in terms of economic performance. Different means of communication are required in order to address the individual attitudes of farmers. Decision support systems are considered here in more detail, because they are regarded as condensed, interactive channels for knowledge transfer, which can be tailored by the farmer himself, and in this fashion contribute to sustainability of knowledge.

Two decision support systems are discussed briefly, each targeting a different segment of the AVEBE farmer population. The first system TIPSTAR™ interactively advises farmers regarding irrigation, fertilisation, quality improvement, control of losses, and optimisation of costs. TIPSTAR™ was designed to support high-yielding farmers. The TIPSTAR™ prototype generates area-specific advice, targeting the optimisation of starch and protein production per hectare, bounded by predetermined natural and environmental conditions. TIPSTAR™ supports tactical and operational decisions.

TIPSTAR™

TIPSTAR™ is a decision support system, based on the paradigms and concepts of system theory (see section 1.2.1). The crop, soil, and climate are identified as the subsystems to be studied and understood, and that can be described using mathematical functions. Knowledge from the domains of soil-physics, soil-chemistry, crop ecology, eco-physiology, and meteorology are used. If this knowledge is used, an improvement of the sustainability of starch potato growth can be realised. A simulation model formalises this knowledge, in which crop management, daily weather, physical, and chemical soil data are inputs to the system.

Solar energy, temperature, water, fertilisation, and diseases and plagues determine growth and development of starch potatoes. The crop growth model assumes

\footnote{Optimedit is a management information system that allows individual benchmarking of farm performance.}
that solar energy transforms into assimilates (sugars), and subsequently divides among the processes of growth, maintenance, and reproduction. These processes function well if enough nitrogen and water are present to produce protein and other structure and stock components. The plant absorbs nitrogen through its roots, after which nitrogen is transported towards the different organs for processes of bio-synthesis. Water is required for uptake of nitrogen, for breathing and cooling of the plant. The mentioned processes describe growth and development of the different organs of the plant: leaves, stems, roots, and tubers. Technically, this is called a 'multi-compartment stochastic dynamic crop growth model'.

The soil-water system simulates the crop’s daily availability of water. The farmer’s irrigation data is used together with precipitation data from weather stations and groundwater data from the 1:30,000 territorial map of The Netherlands. The soil is divided into 1 centimetre thick layers. The functional description of these layers is aggregated into soil profiles of 1.20 depths. In this manner, water retention can be determined per layer of the soil profile. The simulation calculates the available water per 1 cm layer, using the difference between the soil’s drainage and its capillarity. The crop growth model calculates total root depth and root density per 1 centimetre layer; summing up to the total water usage of the crop.

The Soil-Organic Substance and Nitrogen system simulates the crop’s daily availability of nutrients (nitrogen) for each separate layer of the soil. In this, the farmer’s fertilising data are used. The soil is schematised similar to the soil-water model. The crop’s daily available amount of nitrogen per layer results from the processes of mineralisation, nitrification, de-nitrification, and drainage and uptake by the crop. Mineralisation is the process that transforms organic substance (such as green fertiliser, compost, or crop residue) into carbon dioxide and nitrogen (ammonium / nitrate). Herewith, mineralisation is one of the most important processes determining the soil’s sustainability. The amount of organic substance of the soil determines its water retention, and is the source of the saprophytic soil life.

OPTiras™

The second decision support system OPTiras™ is a decision support system for cultivar selection that supports a farmer in selecting cultivars relative to cultivar characteristics. A screen dump of OPTiras™ is provided in figure 5.1. It is intended for low-yielding farmers. A variety of properties, relating to yield, resistance against pests and diseases, and storage, characterises a potato cultivar. The farmer’s personal preferences, diseases present in the field, and cultivar properties determine his choice. OPTiras™ assists the farmer in choosing the cultivar properties and sorting the cultivars based on priorities.

Despite its long history and massive available knowledge, potato cyst nematodes (PCN) still cause an average €150 per hectare per year of costs, in the starch potato area. This is about ten to fifteen percent of farmers’ net-income. Reducing the infestation to economic acceptable levels requires the right combination of cultivar, growth frequency, field choice, and nematicide usage. Cultivars differ greatly regarding resistance (the ability to reduce the infestation), and tolerance (the ability to resist the infestation). The factors PCN resistance and PCN tolerance are uncorrelated. A non-resistant and highly tolerant cultivar can multiply the existing PCN population by 30. In contrast, a highly resistant and intolerant
cultivar reduces the PCN population by two to three, whereby a large portion of the yield is lost.

OPTiRas™ combines the PCN population level of the field and the available information of the cultivars with population dynamics of the potato cyst nematode, also considering the use of pesticides. The decision support system ensures that the farmer gains insight into PCN damage levels and the financial consequences of an (un)justified selection cultivar and the (un)justified application of pesticides. OPTiRas™ attributes to the sustainable management of the soil system, providing support in relation to knowledge of sustainability of cultivar selection.

5.3.5 Short-term challenges

As indicated before, farmers are required to increase their yields with at least 25% per hectare in order to survive the current and prospected changes of the industry's environment. However, on the short-term farmers need to overcome several serious bottlenecks regarding their starch potato growth that stand in the way of the required changes. Research shows that a limited number of factors determine yield and efficiency of their growth. Figure 5.2 provides an overview of the identified bottlenecks. As shown, the top five bottlenecks are PCN contamination, storage losses due to harvest damage, viruses, storage losses due to rot, and storage losses
due to inappropriate storing techniques. The knowledge required to remove these bottlenecks is available in The Netherlands. Eighty percent of AVEBE’s farms will sustain, if the five most costly bottlenecks are resolved, increasing economic revenues by 500 euros per hectare per year.

Figure 5.2: Possibilities for yield improvements (Van Haren, 2005)

5.3.6 Target groups of innovation

Approximately 2,100 Dutch starch potato farms started the 2004 growing season, all different in size and productivity. Different types of farms and farmers are assumed to exist within this population. The underlying rationale to assume different types of farmers exist is that farmers focus on different aspects of their yield, depending on their farming skills. We expected to find farmers who produce either above or below average concerning their yields in ton per hectare, and above or below average potato quality, resulting in four different groups of farmers.

Based on a cluster analysis, these four different types of farmers have been distinguished. The found clusters have been labelled respectively normal farmers, quality farmers, quantity farmers, and top farmers. Table 5.1 shows the differences between clusters regarding yield in tons per hectare (base weight) and potato quality in premium points. Figure 5.3 displays the same clusters graphically. The size of the circles refers to the contribution of the respective clusters.

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3 A brief explanation of less common terms of figure 5.2 is provided. The Nematode Pratylenchus is a root lesion nematode; an organism that feeds on the roots of potatoes. Micronutrients are elements in the soil; they are essential for plant growth. Aplids are pests, animals that eat plants and destroy crops. Nematode Trichodorus is a stubby-root nematode. The root system of plants appears to be not full-grown in case of Trichodorus eating the roots. N-fertilisation concerns fertilisation using nitrogen (N₂). Seed potato Rhizoctonia refers to the disease that is caused by the fungus Rhizoctonia solani, which affects plants. Phytophthora infestans is the fungus that causes potato late blight, one of the most damaging diseases for plants. Lastly, PCN stands for Potato Cyst Nematode.
5.3. Organisation

to the total production of starch of AVEBE (also indicated with the mentioned percentages). Table 5.2 displays cluster profiles, based on farm and farmer characteristics of the individual clusters. Types of farmers differ significantly concerning their farm area ($F(3, 603) = 5.4, p = .001$), and area used for starch potatoes ($F(3, 603) = 6.7, p = .000$). Quantity growers participate more in sugar beet growth ($Pearson \chi^2(3, N = 610) = 19.6, p = .000$), whereas other farmers report to grow other types of crops more ($Pearson \chi^2(3, N = 610) = 13.4, p = .004$). Types of farmers also differ regarding their age ($F(3, 597) = 2.908, p = .034$). Lastly, top farmers more often receive extra education ($Pearson \chi^2(3, N = 586) = 33.58, p = .000$), and more often collect information regarding starch potato growth ($Pearson \chi^2(3, N = 588) = 13.86, p = .003$). In relation to the sketched problems, top farmers are considered the only group able to sustain without additional measures.

Table 5.1: Clusters of farmers

<table>
<thead>
<tr>
<th>Cluster</th>
<th>$N$</th>
<th>Base weight (ton / ha)</th>
<th>Premium points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\mu$</td>
<td>$\sigma$</td>
<td>$\mu$</td>
</tr>
<tr>
<td>Top farmers</td>
<td>512</td>
<td>54.78</td>
<td>4.46</td>
</tr>
<tr>
<td>Quantity farmers</td>
<td>585</td>
<td>45.41</td>
<td>3.21</td>
</tr>
<tr>
<td>Quality farmers</td>
<td>391</td>
<td>41.26</td>
<td>3.65</td>
</tr>
<tr>
<td>Normal farmers</td>
<td>412</td>
<td>32.84</td>
<td>4.44</td>
</tr>
</tbody>
</table>

Figure 5.3: Farmer clusters

Quantity and quality of a farmer’s yield are the used dimensions for cluster analysis, both averaged over the last three years. The quantity of a farmer’s yield is measured in tons per hectare and corrected for its starch content (base weight).
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Table 5.2: Cluster profiles

<table>
<thead>
<tr>
<th>Population characteristics</th>
<th>Cluster</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers in population</td>
<td>top</td>
<td>526</td>
<td>605</td>
<td>379</td>
</tr>
<tr>
<td>% of population(^a)</td>
<td>quantity</td>
<td>27.76%</td>
<td>38.40%</td>
<td>19.90%</td>
</tr>
<tr>
<td>% of total production</td>
<td>quality</td>
<td>36.30%</td>
<td>36.30%</td>
<td>14.00%</td>
</tr>
</tbody>
</table>

Farm characteristics

<table>
<thead>
<tr>
<th>Average farm area(^b)</th>
<th>88.3</th>
<th>78.2</th>
<th>67.8</th>
<th>65.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD farm area(^b)</td>
<td>60.4</td>
<td>48.2</td>
<td>43.6</td>
<td>43.2</td>
</tr>
<tr>
<td>Average starch area(^b)</td>
<td>34.1</td>
<td>32.1</td>
<td>23.6</td>
<td>23.6</td>
</tr>
<tr>
<td>SD starch area(^b)</td>
<td>29.2</td>
<td>22.1</td>
<td>23.5</td>
<td>23.3</td>
</tr>
<tr>
<td>High participation in</td>
<td>other crops</td>
<td>sugar beets</td>
<td>other crops</td>
<td>other crops</td>
</tr>
<tr>
<td>growth of</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Farmer characteristics

<table>
<thead>
<tr>
<th>Average age</th>
<th>48.4</th>
<th>46.5</th>
<th>47.9</th>
<th>50.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD age</td>
<td>10.9</td>
<td>10.7</td>
<td>11.3</td>
<td>12.1</td>
</tr>
<tr>
<td>Freq. of extra education</td>
<td>every 6 months</td>
<td>once a year</td>
<td>once a year</td>
<td>once a year</td>
</tr>
<tr>
<td>Freq. of information</td>
<td>every 6 months</td>
<td>once a year</td>
<td>once a year</td>
<td>once a year</td>
</tr>
</tbody>
</table>

Note: \(^a\) N = 1,900  \(^b\) area in hectare

The quality of a farmer’s yield equals the premium points AVEBE ascribes to the yield. These premium points are a quality measurement of potatoes a farmer delivers at factory gates. A sample of a farmer’s potato delivery is valued regarding ten different dimensions, each graded between zero and ten. These include contamination (tare weight), amount of rot, heating and frost damage, and diseases. Additionally, defects due to dirt enclosure are judged. These defects include damage, growth cracks, the presence of diseases, and rust. A farmer’s premium points equal the sum of the ten grades. Subsequently, the premium points are used to determine the percentage of the premium the farmer will receive as bonus, on top of the weight-based fee of his yield.

In our cluster analysis, we used multiple clustering methods\(^4\), to determine which clusters could be recognised based on farmers’ yields and premium points. The different clustering methods were all initialised to find two to six clusters in the complete dataset of yields and premium points of the entire population of Dutch AVEBE farmers. The different methods converge at four clusters in the set. The clustering is insensitive to location and soil type. Table 5.3 presents the functions that linearly describe the different clusters found, which were determined using a discriminant function analysis using the two clustering variables (yield and premium points) and the found clusters as inputs.

\(^4\)Hierarchical cluster analysis based on Ward’s method, k-means cluster analysis, and a two-step cluster analysis were used to recognise the different farmer clusters within the Dutch AVEBE farmer population.
5.4 The business project: achieving more with less

<table>
<thead>
<tr>
<th>Cluster</th>
<th>constant</th>
<th>Base Weight (ton / ha)</th>
<th>Premium points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top farmers</td>
<td>-443.7</td>
<td>3.82</td>
<td>7.74</td>
</tr>
<tr>
<td>Quantity farmers</td>
<td>-372.9</td>
<td>3.20</td>
<td>7.27</td>
</tr>
<tr>
<td>Quality farmers</td>
<td>-403.2</td>
<td>2.80</td>
<td>7.78</td>
</tr>
<tr>
<td>Normal farmers</td>
<td>-327.2</td>
<td>2.34</td>
<td>7.12</td>
</tr>
</tbody>
</table>

5.4 The business project: achieving more with less

The Agrobioeken research programme has almost finished and, as mentioned earlier, solutions for knowledge transfer have been implemented but have not realised the intended results so far. The objective of realising sustainability of knowledge has only partially been reached; new knowledge of sustainability has been produced, but knowledge integration of this knowledge has not taken place so far. Especially the developed decision support systems often remain unused. In the period between December 2004 and April 2005 approximately 1,400 initial visitors (i.e. unique IP-addresses) of the OPTiras™ website have been recorded, eventually resulting in only 22 actual users. Originally, the OPTiras™ system was designed to target low-yielding farmers, i.e. normal and quality farmers of the AVEBE farmer population, providing them with knowledge of sustainability of cultivar selection, and so attempting to cause an increase in the yields of these farmers. As stated earlier, the OPTiras™ decision support system aids farmers in their cultivar selection, which is used in the upcoming cropping season. The selection of cultivars is one of the decisions a farmer needs to make regarding his starch potato growth.

This study explores what factors stand in the way of knowledge transfer using decision support systems within the value chain of AVEBE’s starch potato growth? Based on Waern (1989), we distinguish two sides to this question. First, the user side refers to the motives of a user to use a decision support system. Focusing on this side provides answers to the question why a certain user is willing or unwilling to use a decision support system regarding a certain task. Additionally, the focus on the user side provides footholds for intervention at the level of the user. Second, the decision support system side refers to the design decisions that are made during its build. A focus on this side provides an answer to the question whether the decision support system connects to the farmers’ manner of decision-making and his perceived effectiveness of using a decision support system as tool. It also provides footholds to alter the design to improve this connection (Waern, 1989, p.124). In this study, we focus on the decision support system side. For a more detailed view on the interaction between decision support system and user, we refer to section 3.3.1.

Figure 5.4 displays a reflective model that is used in this research. In this chapter, the concepts of information sources use, decision-making, and decision result are reported. The elements of personality, skill, motivation, and attitude are reported by Pieters (2005). The issues of farming style and innovation style
remain to be investigated still.

Studies conducted in the Agrobiokon programme focusing on the different bottlenecks of the starch potato growth, and developing knowledge of sustainability of starch potato growth, form the basis of the developed decision support systems. Mostly, the outcomes of these studies are mathematical models of for instance PCN population dynamics, weather dynamics, or soil dynamics. Using a fixed set of variables, these models compute how certain processes influencing starch potato growth behave over time, and calculate the implications for the growth itself. These mathematical models form the basis of the decision support systems that have been developed in the Agrobiokon programme. However, whereas Agrobiokon researchers concentrated on building mathematical models, accurately describing the different aspects of the starch potato growth, farmers presumably use a different rationale concerning their growth; experience and rules of thumb are assumed to dictate the outcomes of their growth-related decisions. Therefore, trying to support farmers with decision support systems based on scientifically constructed mathematical models might distance farmers and decision support systems, already from the start.

As indicated, Agrobiokon’s decision support systems intend to provide decision support for different segments of the AVEBE farmer population. The subdivision of the AVEBE farmer population into normal, quality, quantity, and top farmers is used. The TIPSTAR™ system targets the top farmers, whereas the OPTIrast™ system is intended for normal and quality farmers. However useful, the subdivision into normal, quality, quantity, and top farmers is arbitrary, for it was based entirely on quantitative and qualitative measures related to a farmer’s yield. Additionally, these measures provide no footholds concerning the design of decision support systems. Instead, the subdivision of the AVEBE farmer population needs to be related to farmer characteristics that can be used as input parameters for the decision support system design trajectory.

In this study, a decision-making perspective is chosen, perceiving farmers as human decision makers, which in their turn are postulated as information processing systems (Newell & Simon, 1972). Human decision-making involves two components (see also section 3.2.1). First, the farmer with his personal characteristics
5.4. The business project: achieving more with less

and his personal decision-making behaviour regarding his starch potato growth is of importance. The second factor of importance concerns the task environment in which the farmer makes his decisions, i.e. the farm. Before we can discuss design factors of decision support systems, a clear view of both the farmer’s decision-making and the farmer’s task environment is needed. Therefore, we discuss both farmer decision-making and a farmer’s task environment first.

5.4.1 Human decision-making

In decision theoretical terms, a farmer involved in decision-making relating his starch potato growth equals a human decision-maker or human problem solver (see section 3.2.1). The farmer is perceived as a human information processor (Card et al., 1983; Newell & Simon, 1972). As a human information processor, the farmer exchanges information with his task environment. Through information exchange with his task environment, the human problem solver creates representations of the task environment within his mind. These representations comprise a farmer’s knowledge about the task environment that helps him to accomplish a certain objective within the task environment.

Regarding a farmer’s current knowledge, the factors of importance that are identified are the number of years of his experience within a certain domain and his level of education. To acquire lacking knowledge, the farmer is assumed to use multiple information sources. Different types of information sources are distinguished based on the used medium. Tables 5.4 and 5.5 show various information sources we identified. A distinction is made between paper-based, social, and electronic sources of information.

<table>
<thead>
<tr>
<th>Table 5.4: Paper-based information sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>general agricultural starch potato growth</td>
</tr>
<tr>
<td>De Boerderij Informa</td>
</tr>
<tr>
<td>Oogst Aardappelwereld magazine</td>
</tr>
<tr>
<td>Het Landbouwblad Optimeel annual report</td>
</tr>
<tr>
<td>Agrarisch Dagblad</td>
</tr>
<tr>
<td>Veldpost</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 5.5: Social and electronic information sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>social</td>
</tr>
<tr>
<td>Starchpotato study groups</td>
</tr>
<tr>
<td>Field gatherings electronic potato</td>
</tr>
<tr>
<td>Harvest damage study groups</td>
</tr>
<tr>
<td>Experimental farm demo days</td>
</tr>
<tr>
<td>AVEBE extension workers</td>
</tr>
<tr>
<td>electronic</td>
</tr>
<tr>
<td>Kennisakker knowledge portal</td>
</tr>
<tr>
<td>Optimeel crop registration</td>
</tr>
<tr>
<td>OPTIras™</td>
</tr>
<tr>
<td>OPTIrob™</td>
</tr>
</tbody>
</table>

Concerning paper-based information sources, a distinction is made between magazines and newspapers that target the agricultural sector in general, and those that specifically target potato growth. General magazines and newspapers about
agriculture are “De Boerderij” (the Farm), “Oogst” (Harvest), “Het Landbouw- 
blad” (The Agricultural Gazette), “Agrarisch Dagblad” (Agriculture Daily), and “
Veldpost” (Field Post). Magazines specifically targeting potato growth are In-
forma (AVEBE's monthly magazine), “Aardappelwereld magazine” (Potato world 
magazine), and the Optimeel annual report. The Optimeel system is an electronic 
crop and paper based registration system. Recorded data are stored and analysed 
in a central database. Annually, a report of the analysed results is issued to farm-
ers having a subscription, enabling the benchmarking of own farm performance 
comparing this with average performance of similar farms and crops. 

Social sources of information concern a variety of study groups, focusing on 
starch potato growth in general, or specifically on harvest damage. At field gather-
ings with the electronic potato, farmers' harvesters are assessed using an electronic, 
potato-like device (the 'electronic potato'; in Dutch: 'electronische knol'). This 
device measures all the harvester's factors that are known to cause damage to 
potatoes during harvesting. In figure 5.2, harvest damage is coded as 'storage loss 
tuber damage'. At demo days at experimental farms, farmers are informed about 
new potato cultivars and crop management methods. AVEBE extension workers 
are advisors that provide personal advice to farmers.

Electronic information sources that are currently available to farmers are the 
Kennisakker knowledge portal, Optimeel crop registration, OPTiras™ (AVEBE, 
2005b), and OPTirob™ (AVEBE, 2005a). The Kennisakker portal provides in-
formation about various topics related to starch potato growth. In principle, the 
Kennisakker portal displays results from farmer-funded fundamental, strategic, 
and applied agronomic research. Optimeel crop registration concerns an electronic 
channel farmers can use to record crop management data they need to provide to 
different authorities. OPTirob™ is a decision support system that calculates a 
farmer's losses due to (bad) storage of his potatoes.

Additional to different sources of information, the frequency of receiving extra 
training and the frequency in which the decision-maker informs himself about a 
specific topic are recognised as important factors. Both factors provide an in-
dication about the frequency with which a farmer renews his knowledge about his 
field of expertise.

5.4.2 The task environment

Decisions concerning the starch potato growth centre on the three elements of 
field, cultivar, and farmer. A field is a part of a farmer’s farmland that is used 
to realise growths. The farmer either owns or leases farmland. Regarding the 
field, important factors are its nutrient status, water status, and presence of pests 
and diseases. The term cultivar refers to the potato cultivar the farmer uses 
to realise his growth. From a scientific point of view, a cultivar’s most critical 
factors relating to cultivar selection are its PCN resistance, and PCN tolerance. 
For farmers, important factors are the period potatoes can be stored, the delivery 
moment, and the probability for pests and diseases to infect their crop. These 
factors determine a farmer's expected yields and costs.

A farmer's decision is a specific field-cultivar-objective combination per field, 
balancing individual factors relating to field, cultivar, and economic objective.
5.4. The business project: achieving more with less

Farmers are used to make these decisions. Their speciality is to deal with numerous uncertainties, these decisions contain. Uncertainties that confront a farmer are for instance changing weather conditions, existing field variations, cultivars’ biological variations, and the occurrence of diseases and plagues.

A farmer’s decisions take place at four different levels of aggregation, being current growth, crop rotation, farm, and society. Operational decisions concern the current cropping season. Tactical decisions relate to crop rotation, spanning two to three years. Decisions concerning crop rotation, determine what crops are grown on what fields, and how these crop-field combinations alternate in the next years. For instance, a farmer might choose to grow potatoes in one year and sugar beets in the next. At farm level, a farmer makes strategic decisions with a time horizon of four to ten years. Farm continuity and societal developments drive his strategic decisions. Factors influencing farm continuity are a farmer’s economic circumstances, and the farm’s succession. Societal developments, often spanning more than ten years, concern an increasing critique on farming by the public, tightening up of legislation, and rising land prices.

AVEBE actively gives advice and financial support in relation to farmers’ decisions, at the four levels of aggregation. At growth and crop rotation level, AVEBE provides information on paper and through software systems. At farm and society level, AVEBE has the role of contact person.

The complexity of decisions at operational level becomes apparent when considering one growth in more detail. Potato growth is seasonal, implying that there is a small time frame to realise the growth. The season starts in the spring when potatoes are planted, and lasts until harvesting in the fall. Outside this time frame, potatoes either are kept in storage, or are delivered to the factory. In contrast to the limited time frame related to a singular season of potato growth, decisions concerning one cropping season span almost three years in total, assuming a farmer organizes his own potato seed multiplication. If a farmer buys his seed potatoes, the time frame reduces to one and a half year.

The distinction between farmers multiplying their own potato seed and those that do not, divides growth decisions into two phases. Preceding both phases, a farmer selects cultivars he plans to use in next growth. Then, the first phase concerns seed potatoes increase, in which a farmer uses one of his fields to increase his stock of seed potatoes. The second phase denotes the actual growth phase, in which seed potatoes are planted on several fields. When the potato plants have matured, they are harvested, either be kept in storage for later delivery, or delivered directly to the factory.

To complicate matters, a farmer usually grows more than just starch potatoes on his land (limited by the total farm area), forcing the farmer to divide his farm land and his attention among different types of crops and different types of growth. Most Dutch starch potato farmers combine their starch potato growth with sugar beets, grain, or other crops (see table 5.2). Essentially, crop growth involves crop-related and crop-independent risks. Growing multiple crops enables the farmer to reduce risks that relate to a specific crop, and allows him to spread involved costs among different crops he grows.
5.4.3 Decision support systems

In section 5.3.4, various decision support systems systems have been discussed, which AVEBE uses to increase the sustainability of its farmers. These decision support systems intend to support the farmers regarding various aspects of starch potato growth. Scientific research has been used to construct the mentioned systems. However, during the development of various decision support systems, none of the AVEBE farmers have been consulted regarding their demands. Essentially, the decision support systems were constructed without an understanding of their users, withholding these systems to tailor their interaction with farmers; the 'model of user' is missing from the developed decision support systems (see also section 3.3.1).

The missing representation of a user in the Agrobicken programme is identified as main cause for the lack of knowledge transfer using decision support system in the AVEBE context, a statement that is aligned with our discussion of section 3.3.3. This missing representation disrupts Agrobicken’s strategy for tailored knowledge transfers for different types of farmers, and hampers the realisation of sustainability of knowledge in starch potato growth. Attempting to develop knowledge of sustainability about farmers, by constructing a model of farmers that can be incorporated in decision support systems, this study hypothesises that the different types of farmers that are identified based on economic criteria can also be described in terms of their individual decision-making and learning behaviours.

5.4.4 Method

Two measurements have taken place, at two distinct moments in time. The first measurement concerns a questionnaire that was sent to AVEBE's entire Dutch farmer population in December 2004 (N ≈ 2,100). The first measurement concerned an enquiry into farmers' use of information sources and their individual perspectives on the cultivar selection decision. Regarding information sources, farmers needed to specify whether they were familiar with the information source. In case of familiarity, farmers were asked to specify how applicable they deemed the information source in relation to their starch potato growth. Regarding computers, Optimel crop registration, and decision support systems, farmers were asked to specify whether they use these at their farms. Concerning the farmers' perspectives on the cultivar selection decision, farmers were asked to specify whether they considered certain potato-related variables in their own decision, and how much they valued these variables during the decision-making process.

Before send out, questions in the questionnaire were pilot tested for answerability and clarity twice. In the first pilot test, 8 extension workers of AVEBE were asked to fill-in the questionnaire. In the second pilot test, the test panel consisted of 21 AVEBE farmers from a study group. Questions have been modified after each pilot test, using the suggestions from the test panels.

720 farmers responded to the questionnaire, a response rate of more than 34%; 608 farmers could be ascribed to their appropriate clusters. Of these 608, 181 are top farmers (29.8% of 608), 218 quantity farmers (35.9% of 608), 122 quality farmers (20.0% of 608), and 87 normal farmers (14.3% of 608).
5.5. Results

The second measurement took place at the 2005 PCN-day, during which farmers received advice concerning PCN, such as risks for their crops and countermeasures they can take. Regarding our measurement, visitors were asked to use OPTiras™, and instructed to fulfill a complete session through the system from the initial page until they receive an advice. These sessions were observed, and notes of remarkable actions were made. Session start and stop times were recorded. At the end of OPTiras™ sessions, participants were asked to fill out a questionnaire, consisting of three constructs from the Software Usability Measurement Inventory (SUMI) (Kirákoski, 1994), an instrument for measuring the usability of software. The used constructs are helpfulness, control, and learnability, each composed of 10 indicators. Helpfulness refers to the extent to which the software is self-explanatory. The dimension of control denotes the degree to which the user deems himself in control of the software. Finally, learnability is the extent to which a user understands the system and is able to learn the system’s new features. Additionally, participants were asked to specify whether they experienced problems using OPTiras™. In total 22 individuals participated in OPTiras™ sessions: 17 farmers and 4 other participants. We were able to ascribe appropriate clusters to 11 of the farmers (5 top farmers; 4 quantity farmers; 1 quality farmer; 1 normal farmer).

5.5 Results

5.5.1 Measurement 1

Regarding the use of information sources, no significant differences exist between types of farmers regarding the familiarity of paper-based information sources, nor the value farmers ascribed to these sources ($p < .05$). Significant differences exist between clusters in relation to use of social and electronic sources of information. Table 5.6 shows the Pearson $\chi^2$ values for variables representing familiarity with social information, and indicates whether differences exist between the four types of farmers. Table 5.7 displays Pearson $\chi^2$ values regarding differences between different types of farmers and their familiarity with electronic information sources. Tables 5.6 and 5.7 indicate that farmers from high-yielding clusters are more aware of different social and electronic sources of information. Additionally, top farmers are more familiar with study groups on starch potato growth in general, whereas quantity farmers are more acquainted with field gatherings focusing on the electronic potato. Quality and normal farmers are largely unaware of the social and electronic sources of information. No differences are found in the appreciation of the different social and electronic sources of information. Additionally, types of farmers do not differ concerning their familiarity with OPTiras™ ($Pearson \chi^2(6, N = 594) = 7.629, p = .267$) and OPTirob™ ($Pearson \chi^2(6, N = 587) = 5.496, p = .482$).

Table 5.8 shows Pearson $\chi^2$ values for variables denoting use of different information sources by the farmer for his farming activities. Computer use and use of Optimeel crop registration during their last growth are significantly higher among top-farmers. Additionally, use of decision support systems is higher among top
and quantity farmers.

Table 5.6: Familiarity with social information sources

<table>
<thead>
<tr>
<th>Familiar with</th>
<th>Pearson $\chi^2$</th>
<th>df</th>
<th>N</th>
<th>highest cluster(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch potato study groups</td>
<td>27.4***</td>
<td>6</td>
<td>596</td>
<td>1</td>
</tr>
<tr>
<td>Field gatherings electronic potato</td>
<td>24.9***</td>
<td>6</td>
<td>595</td>
<td>2</td>
</tr>
<tr>
<td>Harvest damage study groups</td>
<td>8.1</td>
<td>6</td>
<td>597</td>
<td>-</td>
</tr>
<tr>
<td>Experimental farm demo days</td>
<td>41.5***</td>
<td>6</td>
<td>596</td>
<td>1 and 2</td>
</tr>
<tr>
<td>AVEBE extension workers</td>
<td>27.0***</td>
<td>6</td>
<td>595</td>
<td>1 and 2</td>
</tr>
</tbody>
</table>

Note: *$p < .10$  **$p < .05$  ***$p < .01$  

Table 5.7: Familiarity with electronic information sources

<table>
<thead>
<tr>
<th>Familiar with</th>
<th>Pearson $\chi^2$</th>
<th>df</th>
<th>N</th>
<th>highest cluster(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kennisukker portal</td>
<td>24.9***</td>
<td>6</td>
<td>594</td>
<td>1 and 2</td>
</tr>
<tr>
<td>Optimized crop registration</td>
<td>27.1***</td>
<td>6</td>
<td>591</td>
<td>1 and 2</td>
</tr>
<tr>
<td>OPTIras™</td>
<td>7.6</td>
<td>6</td>
<td>594</td>
<td>-</td>
</tr>
<tr>
<td>OPTIrob™</td>
<td>5.5</td>
<td>6</td>
<td>587</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: *$p < .10$  **$p < .05$  ***$p < .01$  

Table 5.8: Use of electronic information sources

<table>
<thead>
<tr>
<th>Use of</th>
<th>Pearson $\chi^2$</th>
<th>df</th>
<th>N</th>
<th>highest cluster(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer</td>
<td>16.7***</td>
<td>3</td>
<td>604</td>
<td>1</td>
</tr>
<tr>
<td>Optimized during last growth</td>
<td>13.8***</td>
<td>3</td>
<td>575</td>
<td>1</td>
</tr>
<tr>
<td>Decision support systems</td>
<td>7.9**</td>
<td>3</td>
<td>575</td>
<td>1 and 2</td>
</tr>
<tr>
<td>OPTIras™ during last growth</td>
<td>7.4</td>
<td>6</td>
<td>540</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: *$p < .10$  **$p < .05$  ***$p < .01$  

Regarding the value farmers subscribe to factors in cultivar selection, differences are found concerning delivery moment, base weight, and protein content of potatoes; table 5.9 displays Pearson $\chi^2$ values. Quality farmers ascribe higher value to moment of delivery. Top and quantity farmers value base weight more important than quality and normal farmers do. Finally, quality and normal farmers ascribe more importance to protein content of potatoes. No differences exist regarding other factors of cultivar selection between types of farmers ($p < .05$).

Summarising the first questionnaire's findings, different types of farmers differ from each other in terms of not only economic variables, but display differences regarding the way they handle information as well. Electronic channels of communication seem more suitable to communicate with top farmers and quantity farmers; as indicated before, OPTIras™ is intended for quality and normal farmers. Furthermore, apparently top and quantity farmers search personal contact more. They report more participation in social gatherings regarding starch potato growth. Finally, top and quantity farmers seem more critical towards information they receive; they are better capable to determine what criteria are relevant in selecting their cultivars (base weight), than normal and quality farmers (protein content).
5.5. Results

Table 5.9: Important factors within cultivar selection

<table>
<thead>
<tr>
<th>Factor of importance</th>
<th>Pearson $\chi^2$</th>
<th>df</th>
<th>$N$</th>
<th>highest cluster(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Potato:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delivery moment</td>
<td>25.9**</td>
<td>12</td>
<td>581</td>
<td>3</td>
</tr>
<tr>
<td>Ripening time</td>
<td>16.2</td>
<td>12</td>
<td>591</td>
<td>-</td>
</tr>
<tr>
<td>Field weight</td>
<td>9.2</td>
<td>12</td>
<td>591</td>
<td>-</td>
</tr>
<tr>
<td>Under water weight</td>
<td>8.0</td>
<td>12</td>
<td>594</td>
<td>-</td>
</tr>
<tr>
<td>Base weight</td>
<td>18.1**</td>
<td>9</td>
<td>588</td>
<td>1 and 2</td>
</tr>
<tr>
<td>Protein content</td>
<td>26.7***</td>
<td>12</td>
<td>539</td>
<td>3 and 4</td>
</tr>
<tr>
<td>Potato quality</td>
<td>17.8</td>
<td>12</td>
<td>598</td>
<td>-</td>
</tr>
<tr>
<td>Total cropping costs</td>
<td>9.0</td>
<td>12</td>
<td>597</td>
<td>-</td>
</tr>
<tr>
<td>Raise damage sensitivity</td>
<td>17.5</td>
<td>12</td>
<td>578</td>
<td>-</td>
</tr>
<tr>
<td>PCN tolerance</td>
<td>9.1</td>
<td>12</td>
<td>584</td>
<td>-</td>
</tr>
<tr>
<td>PCN resistance</td>
<td>14.9</td>
<td>12</td>
<td>586</td>
<td>-</td>
</tr>
<tr>
<td>PCN pathotype</td>
<td>8.9</td>
<td>12</td>
<td>563</td>
<td>-</td>
</tr>
<tr>
<td>Resistance to fungi</td>
<td>12.3</td>
<td>12</td>
<td>587</td>
<td>-</td>
</tr>
<tr>
<td>Resistance to viruses</td>
<td>11.5</td>
<td>12</td>
<td>584</td>
<td>-</td>
</tr>
<tr>
<td>Resistance bacterium sickness</td>
<td>12.1</td>
<td>12</td>
<td>579</td>
<td>-</td>
</tr>
<tr>
<td>Resistance wart disease</td>
<td>13.1</td>
<td>12</td>
<td>586</td>
<td>-</td>
</tr>
<tr>
<td>Resistance Phytophthora (leaf)</td>
<td>6.4</td>
<td>9</td>
<td>588</td>
<td>-</td>
</tr>
<tr>
<td>Resistance Phytophthora (tuber)</td>
<td>11.5</td>
<td>12</td>
<td>593</td>
<td>-</td>
</tr>
<tr>
<td><strong>Field:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field characteristics</td>
<td>13.4</td>
<td>12</td>
<td>589</td>
<td>-</td>
</tr>
<tr>
<td>Soil type of field</td>
<td>16.1</td>
<td>12</td>
<td>586</td>
<td>-</td>
</tr>
<tr>
<td>Rotation length of field</td>
<td>13.5</td>
<td>12</td>
<td>574</td>
<td>-</td>
</tr>
<tr>
<td>PCN density of field</td>
<td>5.5</td>
<td>12</td>
<td>580</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note: *p < .10 *p < .05 **p < .01

5.5.2 Measurement 2

The average time participants spent using OPTIrast™, is 12.19 minutes ($SD = 5.046$). On average farmers used 12.59 minutes ($SD = 5.209, N = 17$), while other participants on average used 10.50 minutes ($SD = 4.509, N = 4$).

Table 5.10: Scores on SUMI constructs Helpfulness, Control, and Learnability

<table>
<thead>
<tr>
<th>Construct</th>
<th>Farmers ($N = 17$)</th>
<th>Other participants ($N = 4$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average $^a$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Helpfulness</td>
<td>2.35</td>
<td>.150</td>
</tr>
<tr>
<td>Control</td>
<td>2.25</td>
<td>.150</td>
</tr>
<tr>
<td>Learnability</td>
<td>1.62</td>
<td>.360</td>
</tr>
</tbody>
</table>

*Note: *average over 10 questions: 1 = disagree, 2 = undecided, 3 = agree

Table 5.10 reports the scores on SUMI constructs helpfulness, control, and learnability. A distinction is made between farmers and other participants to OPTIrast™ sessions. Both farmers and other participants report above average scores on helpfulness, and control. Similarly, learnability is reported just above average by both groups of participants. In the interviews, all participants reported
to experience no problems using the OPTiras™ application. During the sessions, one participant stopped before finishing a complete OPTiras™ session. This participant expressed to be incapable of handling the computer, and was unable to use any of the system’s functions.

5.6 Conclusions

Farmers, as every human being, have their own ideas and peculiarities, when it comes to the ways they farm. Innovation of the value chain of starch potatoes is inevitable, due to present and expected changes of contextual factors. In realising necessary innovations, AVEBE participates in the Agrobiocon programme, attempting to steer its individual farmers, the targeted unit of adoption, into a sustainable manner of farming. However, these attempts are unsuccessful if farmer characteristics or the ways farmers interact with decision support systems are not considered.

Our results show that different types of farmers use different sources of information. These different uses of information sources have implications for the manner of communication with farmers. High-yielding farmers use decision support systems, the Internet, and study groups and other social sources of information; low-yielding farmers are considered unreachable through these communication channels. Therefore, the present path chosen regarding OPTiras™ does not meet Agrobiocon objectives. OPTiras™ is used to communicate with those farmers who are not using such systems, namely normal and quality farmers. Furthermore, we find that information channels addressing low-yielding farmers need to express farming-related topics much more careful; these farmers are less critical towards information, causing them to use factors in their growth-related decisions that are of lesser relevance (for instance protein content).

Finally, in order to use OPTiras™ as a means to realise an innovation of the value chain of starch potatoes, this system’s learnability needs improvements, for innovation implies learning of and applying new knowledge. The systems OPTiras™ and OPTirob™, which researchers consider to be simple systems, were frequently used by high educated farm extension workers and top farmers, who presumably have similar types of decision processes as these researchers. This finding stresses the importance of user-interaction during the design phase of a decision support system. Only when users are involved in the design process can differences between developers and users be determined and resolved.

We explain the absence of farmers adopting decision support systems for their growth-related decision, based on the lack of user involvement during design. This resulted in a lack of knowledge of farmers, knowledge that is necessary to design the connection between decision support system and farmer. With its focus mainly on research of starch potato growth, the Agrobiocon programme developed knowledge of sustainability of the value chain of starch potato growth; the stage of knowledge production has been realised. Knowledge on among other things costs and benefits of farming and their relations with starch potato biology have been the results. To inform farmers, this new knowledge of sustainability was encoded and offered to farmers using a variety of information channels, attempting to realise knowledge integration. In addition to paper-based communication, several decision support
5.7. Recommendations

Systems were realised either left in a prototypical stage (e.g. TIPSTAR™), or developed into operational systems (e.g. OPTIras™ and OPTIrab™).

However, the translation from scientific research into these decision support systems was hampered, blocking sustainability of knowledge in the starch potato growth. During design, end-users, i.e. farmers, had not been questioned about their needs and requirements. This especially hindered adoption by farmers considering the existence of different types of farmers. While on the one hand the Agrobiokon programme succeeded in enhancing knowledge of sustainability of the value chain of potato starch potatoes, sustainability of knowledge was not assured entirely. Knowledge production was realised, but integration remains absent. Enhancing the sustainability of knowledge of the Agrobiokon programme is necessary for survival of starch potato growth in The Netherlands.

5.7 Recommendations

AVEBE and Agrobiokon's objective has been twofold, namely generating knowledge regarding starch potato growth, and subsequently transferring this knowledge to Dutch starch potato growers. In short, the conclusion is drawn that the first objective has been reached. So far, however, the second objective is not reached entirely. Still, the majority of AVEBE's Dutch starch potato farmers remains uninformed about Agrobiokon research results. Our research, presented in previous sections, provides explanations.

Two elements of analysis are distinguished in our study: decision-making behaviour of farmers, and decision support system design. Regarding decision-making behaviour, our study focused on use of information sources and farmers' use of knowledge. Results show large differences between different types of farmers concerning both topics. The use of decision support systems concentrates primarily on top farmers. Additionally, the OPTIras™ decision support system proved not self-explanatory enough. In the following, we review current OPTIras™ design, and suggest a redesign of its user-interface.

5.7.1 Decision support system design

We argue that AVEBE research has focused too much on optimising farmers' choices regarding their crop, while the focus better lies on explaining the implications of their decisions to farmers, thereby adopting models from descriptive decision theory (see section 3.3).

Currently, Agrobiokon information channels, amongst which the OPTIras™ decision support system, facilitate the choice phase of decision-making. For instance, OPTIras™ is based on Operations Research optimisation models, and optimises for PCN contamination, and costs relating to PCN damage. The chosen optimisation approach positions OPTIras™ as a tool that aids its users in deciding between different alternatives, based on an optimisation function, or in Simon's terminology, in choosing (Simon, 1977).

For normal and quality farmers, we argue that an orientation on intelligence is more suitable (see section 1.2.2). These groups have been identified to use factors in their decision-making that will not generate additional income for them.
OPTiras™ to them, better functions as a tool that explains the importance of cultivar selection regarding their crop and their farm. Additionally, it should provide insight into the implications of selecting less appropriate cultivars. In other words, OPTiras™ should focus on the intelligence phase (see section 1.2.2), if normal and quality farmers are the intended users. Having build-up an understanding of these implications inside these farmers’ minds, the information OPTiras™ presents can be extended, providing its user insight into the variables that underlie the identified implications.

In addition, our analysis shows differences between farmers regarding the information sources they use. High-end sources of information such as websites and decision support systems, are used more often by top-farmers, as well as social sources of information. In contrast, normal and quality farmers participate less in study groups, a finding that also goes for use of computers and decision support systems. This finding leads us to recommend a reconsideration of Agrobiocon’s objectives regarding its various means of communication. In its current form, communication trough the Internet and decision support systems proves more suitable to address top and quantity farmers, whereas paper-based means of communication reach normal and quality farmers. The current focus, whereby normal and quality farmers are addressed through the Internet and decisions support systems has been proven faulty. In combination, a change in orientation of different means of communication regarding the phase of decision-making they address and reconsidering the objectives of Agrobiocon’s various communication channels should enhance its current information exchange with farmers.

5.7.2 Optiras redesign

We concentrate on OPTiras™, following the make-up of decision support systems as formulated in Holtsapple and Whinston’s (1996) framework (see section 3.3).

The OPTiras™ knowledge base is constructed, using domain knowledge that Agrobiocon researchers identify as important in the domain of cultivar selection. Hence, the researcher’s view on cultivar selection prevails in OPTiras™. This is in accordance with our findings that no farmers were involved during the development of OPTiras™. Factors that farmers deem important in relation to their cultivar selection are not included in OPTiras™, which makes farmer acceptance of OPTiras™ difficult. Therefore, for future versions of OPTiras™, we recommend farmer involvement in the conceptualisation of the knowledge domain of cultivar selection as soon as possible. We argue that the inclusion of farmer perceptions in the knowledge base, connects the basic information that OPTiras™ uses in its reasoning to farmer reality. Additionally, we argue that this inclusion is necessary to reach the Agrobiocon objective of knowledge integration.

At the level of the problem processing system, OPTiras™ uses an optimisation model, calculating an optimal set of cultivars based on user inputs. However, only variables that fit in the optimisation model are included. An optimisation model requires a limited set of variables that together form a complete model. In case farmer perceptions are included in future versions of OPTiras™, the prerequisites for using optimisation models probably are not met. Alternatively, a rule-based solution might be appropriate to enable the inclusion of farmer perceptions and
5.7. Recommendations

heuristics, as an addition to optimisation models. The appropriateness of a rule-based solution can only be determined if farmer perceptions are measured and translated into information models.

Lastly, at the level of the OPTIrasm user interface, we suggest a careful synchronisation of the interface to the manner farmers perform the task of cultivar selection. For this, farmers’ task execution needs to be mapped. Protocol analysis techniques (Ericsson & Simon, 1984) for example can be used to make this mapping (as suggested by Schreiber et al., 2000). In order to synchronise OPTIrasm to the ways farmers perform the task of cultivar selection, page content and order need to be based on the suggested protocol analysis. We expect the different types of farmers to have different approaches to the cultivar selection task. In its current form, the OPTIrasm user interface is ambiguous for it aims to accomplish two objectives. On the one hand, OPTIrasm intends to realise knowledge transfer, providing farmers insight in the domain of cultivar selection. On the other hand, OPTIrasm presents results from its calculations. Whereas the latter functions properly, the former objective is not supported in the current implementation of OPTIrasm.

In the following section, we suggest a redesign of the user-interface of the OPTIrasm system. We focus on redesigning the user-interface such that it emphasises the intelligence phase of problem-solving regarding the cultivar selection domain.

Alternative interface design

Based on mentioned design issues, discussed in the preceding section, we explore a possible re-design of the OPTIrasm user-interface. We concentrate on the question how to design the user-interface in order to improve communication with the intended user(s). In seeking an answer to this question, all other parts of the OPTIrasm system, i.e. the problem processing system and knowledge base, remain untouched. The latter implies that we also do not reconsider the use of currently used technology, i.e. JavaServerPages (Sun, 2006) in combination with a Tomcat JSP (The Apache Software Foundation, 2004) / Oracle Containers (Oracle, 2006) server. If a change of technology is required from our suggestions, technology is chosen that is compatible with the mentioned technology.

In designing a new user-interface, we assume that the objective is and has been the transfer of knowledge that was developed during Agrobiocom research to AVEBE starch potato farmers. Based on this assumption, and on our findings, we suggest an intelligence orientation concerning user interface design (see section 1.2.2). Our analysis shows that normal and quality farmers are not entirely aware of the relation between cultivar and PCN contamination of the field they use for their growth. Therefore, we suggest the user-interface to focus on explaining and demonstrating the effects of cultivar selection on the PCN population of a field and reversely the effect of present PCN populations on the cultivar growth process. Top and quantity farmers show a greater understanding of the relationship between cultivar and PCN population. For these two groups of farmers, the current approach of OPTIrasm seems more suitable. However, also for these groups parts of our suggestions for user-interface redesign might be applicable.
The OPTIrasc™ application builds on two mechanisms that define the relationship between cultivar and the PCN population of a field. First, the effect of an existing PCN population on the growth of cultivars is described in the Yield Loss Model. Second, the effect of a cultivar on the PCN population of a field is described in the PCN Dynamics Model. Both models are described in AVEBE (2004). In version 1 of the OPTIrasc™ system, both models have been hidden deep inside the system, and users are only confronted with their respective in- and output variables. In this fashion, the OPTIrasc™ system functions as a sophisticated calculator. Because of this choice in user-interface design, we argue that the objective of knowledge transfer has been lost; a user is unable to reconstruct the actual mechanisms that determine the suitability of one cultivar over the other regarding his field.

Instead of hiding the two basic models of OPTIrasc™, we suggest to present their mechanisms directly through OPTIrasc™’s user-interface, enabling the user to operate these models interactively. The user for example, is given the opportunity to explore the relationship between cultivar PCN tolerance levels and the loss of crop due to the PCN population of his field. This approach corresponds to the suggested intelligence-focus. Interactively using the models of Yield Loss and PCN Population Dynamics enables the user to develop a mental model of the relationships between cultivar and PCN population. We emphasise the idea that farmers need to learn the mechanisms that underlie potato growth and the effect of PCN. Only when a farmer understands these mechanisms, will he be able to oversee the consequences of selecting cultivars that are better or less suited for his fields.

OPTIrasc™ uses three categories of inputs to feed the Yield Loss and PCN Population Dynamics Models, which are cultivars, field data, and a farming objective. These three categories of inputs concern page one and two of OPTIrasc™ version 1 (see figure 5.1). Cultivar data are read from a data file. Currently, 5 cultivars for early delivery and 25 for late delivery are included in the data file. Field data are gathered from the farmer; he is asked to specify soil type and current and history of PCN population of the field the farmer is assessing. In addition, the farmer is questioned about the objective regarding cultivar selection. Hereby, the farmer is asked to specify his preferred cultivar and the yield he thinks to realise using the preferred cultivar on the field he assesses. The farmer specifies the yield in field weight and under water weight (UWW)5. After these three categories of input data are collected, the OPTIrasc™ processes these using the Yield Loss and PCN Population Dynamics Models. But, as indicated before, doing these calculations and only presenting the outcomes to OPTIrasc™ users does not contribute to the objective of knowledge transfer.

To enable knowledge transfer about cultivar selection we suggest the following rearrangement of OPTIrasc™ interface pages. Before an OPTIrasc™ user can start working the two models, he needs to be aware of the parameters that stand central. Hence, at least some pages are required that explain respectively potato and potato growth characteristics, and characteristics of field and its PCN population. These pages not only show the user what factors are of importance regarding

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5The under water weight is a measure of the amount of starch in a standard amount of potatoes. Usually, this standard amount is 5.5 kilograms.
5.7. Recommendations

potatoes; they also present the factors that influence the growth process of respectively potato and PCN population.

In the following, we present six figures (figures 5.5a through 5.8b) that depict the suggested redesign of web pages for OPTIras™'s user-interface. In each page, underlined terms represent terms on which additional information is available. Clicking presents the user with a pop-up screen, explaining the term. For every page we present, we inherently assume that every control is interactive in that each setting the user changes immediately results in corresponding changes in related fields. This kind of interactivity and can be realised using for instance JavaScript (e.g. Wikipedia, 2006).

Similar to OPTIras™ version 1, the application needs to be initialised with a preferred cultivar and an expected yield specified in terms of field and underwater weight. However, in contrast to version 1, we suggest to be an optional page for the user. In version 1, initialising OPTIras™ is a mandatory step in the use of the system. Instead, we suggest the initialisation to take place using pop-up screens, displayed in respectively figures 5.5a and 5.5b, and pre-select a default cultivar (e.g. Seresta) and field contamination (e.g. 'low') at application startup. Figure 5.5a shows the form in which the user can specify his farming objective in terms of his cultivar of preference, and the yield he expects to make using this cultivar (in terms of field weight and underwater weight). Figure 5.5b presents the form in which the user can specify historical data concerning the field for which he is selecting a cultivar. The user can enter this historical data using a rough estimation, or providing the field's PCN sampling data. Alternatively, the PCN population history page can be implemented similar to OPTIras™'s current PCN History page. The current page in OPTIras™ version 1 also enables the user to specify the treatment of PCN contamination of the field in previous years. Key issue of our suggestion is that the initialisation is not a part of OPTIras™'s functionality, especially not from the perspective of knowledge transfer. Therefore, we recommend implementing the initialisation of farming objective and PCN population history in pop-ups, which can be called any time during application usage, from every page (see the top-right of all pages of the main application in figures 5.6a to 5.8b).

Figure 5.6a shows the suggested page presenting potato and potato growth. The chosen setup of this page allows the user to do two things. First, the user is able to gather information on potatoes and its characteristics. Second, the user is able to compare two cultivars regarding their characteristics. Alternative arrangements of this page might contain one panel explaining all potato characteristics, and a second panel displaying a table displaying all available cultivars. Whichever alternative is implemented, the key idea is that the user is informed about the characteristics of a potato that play a role in potato growth. Emphasis needs to be put on the characteristics that relate to PCN damage (i.e. PCN tolerance and PCN resistance).

Using the characteristics that are introduced in the page 'Potato characteristics', the influence of PCN on the growth of potatoes is explained in page 'Influence of PCN on growth'. Figure 5.6b depicts a suggested outline for this page. Key feature of this page is the demonstration of the influence PCN has on potato yield
and the indication of characteristics of a potato that determine this influence. Initially, PCN tolerance and PCN resistance are given the value of the farmer’s preferred cultivar, if specified. Otherwise, the default cultivar is used. In figure 5.6b, we choose Seresta as the cultivar of preference. Using the slide bars called ‘PCN resistance’ and ‘PCN tolerance’, the user is able to observe the effects on damage factor, maximum yield, and yield loss.

Figure 5.7a shows the page, presenting field and PCN characteristics. In principle, this page only provides information about these issues. Additionally, characteristics of field and PCN are presented that are of importance regarding cultivar selection.

To explore the PCN population dynamics, the page ‘influence of potato on PCN’ is suggested, as shown in figure 5.7b. Here, data entered into farming objective and PCN population history are used to initialise the page. The user is able to
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(a) 'field & PCN characteristics'

(b) 'influence of potato on PCN'

Figure 5.7: Page Field & PCN population

 alter the different values to explore the effects of these parameters on damage factor and PCN population next year. Alternatively, the underlying variables M and cp (reported in AVEBE, 2004) can be added to this page\textsuperscript{6}. Principally, this page explains PCN population dynamics and the influence of potato characteristics, i.e. PCN tolerance and PCN resistance, on the development of the PCN population of a field. This page can be extended, incorporating treatments the farmer can apply on his field. Alternatively, instead of using boxes, sliders, and arrows, the effect of potatoes on the PCN population can be explained using animations. Whichever form functions best, needs to be determined through user tests.

Page ‘Potato-PCN interaction’ combines the yield loss and PCN population dynamics models. Figure 5.8a shows the suggested outline of this page. The user is able to explore the effects of his choices on the PCN population, and the magnitude of yield losses. Again, this page can be extended with treatments that can be applied on the field. The user can immediately see the consequences of treatment concerning the PCN population and the loss of yield.

The last page we suggest for OPTIras\textsuperscript{TM} is presented in figure 5.8b, and is called ‘Economic consequences’. This page enables the user to explore the economic consequences of his cultivar selection. Based on the inputs potato, PCN population, field, and farming objective potential return, actual return, and costs are calculated. Alternatively, this page can be extended with additional concepts that lie in between the inputs, and the presented outputs. These intermediate concepts might be the UWW ratio of the selected cultivar and UWW of the preferred cultivar, yield loss, PCN population next year, etcetera. Additionally, PCN treatments can be included.

Figure 5.8b concludes our suggestions for redesigning the OPTIras\textsuperscript{TM} user-interface. The suggested screens, displayed in figures 5.5a through 5.8b, focus on learning and the intelligence phase of a farmer’s cultivar selection decision process. They do not replace the current user interface of OPTIras\textsuperscript{TM}. Instead, the suggested screens need to be seen as an extension to the existing application. Also incorporating intelligence-oriented elements in the user interface of OPTIras\textsuperscript{TM}

\textsuperscript{6}M denotes the theoretical maximum threshold of PCN contamination in a field, assuming no damage is inflicted on cultivars; cp denotes the proportion of PCN eggs that will not hatch.
enhances this decision support system, no longer being a tool only incorporating a business perspective, but a learning perspective as well.

The screens presented in figure 5.5a to 5.8a are a suggestion, which we have designed using theoretical insights (see section 3.3). During actual development of a new OPTIrass™ user-interface, farmers need to be consulted, first about their ideas of the knowledge domain of cultivar selection. Second, several prototypes of user-interfaces need to be tested by these farmers to determine the appropriateness of chosen design for communicating about cultivar selection. Concerning both issues, the AVEBE and Agrobion programme should incorporate end-user involvement in their design processes.

Going beyond redesigning OPTIrass™ and other decision support systems developed by AVEBE, we argue that two additional questions are relevant. First, the question is whether normal and quality farmers are unwilling to use decision support systems such as OPTIrass™. In this study, we focused on the information processing behaviours of farmers to explain why AVEBE decision support systems are used little by farmers. Additionally, the motivations of farmers to use or not use a decision support system might contribute to the information processing perspective.

Second, the question is if farmers in general, and normal and quality farmers in particular, are aware of the societal, technological, and climatological changes that affect starch potato growth. Moreover, do they experience the sense of urgency to change the ways they farm to cope with these changes. If this is not the case, then AVEBE research should have focused on explaining the effects of these changes on farming to AVEBE farmers, instead of focusing research on increasing crops and income. In future research, AVEBE will need to complement its sheer technological focus with a focus on its farmers and their behaviours.

Figure 5.8: Final pages
5.8 Summary

Starch potato farming is experiencing changes that demand AVEBE farmers to change their ways of farming quickly. Subsidies are stopped, new, engineered potatoes and other crops penetrate the global starch market, and climatological circumstances are becoming more extreme.

AVEBE acknowledges the importance of knowledge of sustainability. It focuses on changing the behaviour of its farmers, thus attempting to realise an innovation of the starch potato value chain transforming it in a more sustainable value chain. AVEBE’s attitude contrasts with common thinking regarding sustainability: sustainability is a technological issue that requires technical and technological solutions. At this moment, AVEBE has set the first step towards an improvement of the sustainability of the starch potato value chain. New knowledge of sustainability is generated in various research programmes (knowledge production). The next step is that AVEBE needs to learn how to communicate with its farmers (knowledge integration).

Research outcomes are communicated undiversified to AVEBE farmers, only reaching top and quantity farmers. In the organisation of its communication channels, AVEBE has not consulted farmers on how to tell its story. Instead, AVEBE assumed all farmers to process information similarly. Decision support systems have been constructed to target normal and quality farmers, but are hardly used. Moreover, current decision support system users are top and quantity farmers; those who are expected to require the offered decision support the least.

Our research show that four types of farmers exist, differing in the ways they process information, differing regarding the information sources they use, and differing in the way they make growth-related decisions. Normal and quality farmers make little use of electronic information sources, such as decision support systems and the Internet; electronic sources of information are used by top and quality farmers.

AVEBE’s current arrangement of communication has to be reconsidered, using the appropriate channel for the identified types of farmers. Additionally, in rearranging its communication, farmers need to be consulted about how communication should be organised.

AVEBE has realised an increase in knowledge of sustainability about starch potato growth. However, before this knowledge realises the necessary innovation of the starch potato value chain, AVEBE needs to generate knowledge of sustainability about its farmers and use that to structure its communication to its farmers. Only then will knowledge integration of knowledge of sustainability about starch potato growth be realised.