NOABEREARPEL

Resilient varieties and potato cultivation in De Achterhoek

Abstract

This research aims to explore the possibilities for resilient varieties for de Achterhoek. It touches upon the current situation of potato cultivation in de Achterhoek, chemical use and growing with resilient varieties.

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1. Foreword

I would like to thank my supervisors from Van Hall – Larenstein Arno and Alicia, and commissioners Maurits and Jeanne, for giving me insights, structure and overview in order to do this research. I would like to thank Naomi for her patience and kindness during the whole process.

It has been a most interesting ride through the world of potatoes. I have learned so much and still I am not even close to what it is to grow potatoes for a living, but I did my best. There is so much craftsmanship and experience involved in whatever sort of potato cultivation is being done and even for the professionals, the challenges are great. The largest motivation for writing this thesis was to be able to research something that would help farmers and to tell people about the potential of resilient varieties and I am content with the result. I have always liked potatoes, but look at them different now.

While opening the beginning of this report with a quote from one of the interviews, I cannot help but hearing 'Back Where It All Begins' from The Allmann Brothers Band playing in my head.

> *'Het is ook heel belangrijk om niet te vergeten het aardappeltje in de grond te stoppen.' – D. Monsma.*

2. Table of contents

3. Introduction

This research is about sustainable potato production and is commissioned by True Food Projects from De Achterhoek. It is a company specialised in marketing, innovation and project management

within value chains and advises businesses, NGOs and governments. One of its projects, 'Smaakacademie Achterhoek' or 'SAA', is focussed on local value chains in De Achterhoek in combination with education. This research is also conducted within the SAA, by Reindert Braam, a student at Van Hall – Larenstein.

3.1. The beginning

The reason for this research is an incident that took place at a local organic business, adjacent to Nelles, the True Food Projects office. It was checked by SKAL, an independent institution that monitors compliance to practice requirements for business that are labelled organic. During the check chemicals, which are not allowed by organic standards, were found on the plants even though they were not used on the yard of the business itself. It seemed to come from a nearby potato field, where the chemicals were sprayed and taken on by the wind, landing on the organically grown plants. Many questions arose, such as: What chemicals were used, how far do chemicals drift off and what would the impact of the chemicals be on the environment of De Achterhoek?

It is irrational and impossible to force farmers to abandon the use of chemicals all at once and it would have disastrous effects on production. Additionally, it is a long and complicated process to convert to organic production completely and in between conventional and organic farming, there is little alternative or market for farmers that are willing to diminish the impact of their farm on the surrounding area. Good research is needed in order to facilitate a smooth transition to production with limited pesticide use. Experience from organic farming can take away the risk of failing harvests. The ideal is to have potato production practices that are not harmful for neighbouring farm fields or residents, from which project 'Noaberearpel', which means 'neighbour potato', is initiated.

3.2. The research

3.2.1. Problem definition

The problem this research is aiming to solve, originates mostly from the unsustainable use of chemicals in De Achterhoek. The use is unsustainable because pests can get immune to certain substances (Hammink, H. & Van Loon, K., 2009), surrounding ecosystems are affected and nearby residents unconsciously take in the chemicals. Therefore, the advantages do not necessarily outweigh the disadvantages anymore. Most farmers do not have experience and knowledge with production with less chemicals and there is too much uncertainty regarding yield, profit and market. Separate chemicals have been judged on safety, but there are concerns about how combinations of chemicals react with each other. Chemicals can be found in the environment and in human urine, near places the chemicals have been implemented (Gezondheidsraad, 2020). *True Food Projects* wants to find out what possibilities with resilient varieties there are for farmers who would like to use less pesticides and still make a reasonable profit.

3.2.2. Research objectives

The goal is to be able to offer a well-thought out and practical way of producing potatoes with resilient varieties, using as little chemicals as possible. The projected products are a reliable growing handbook for production with resilient varieties for arable farmers in De Achterhoek with an additional concept of a value chain set up and marketing plan. Findings will be constantly shared in the learning community 'Achterhoek Food'.

The content of the research has already been formulated and different chapters need to be completed within the reserved time. Both desk study and in-depth interviews should provide a complete image of a subject with multiple sources. With the handbook, one should be able to grow

potatoes successfully and the market research is also supported by facts and forecasts of professionals.

3.2.3. Research questions

The problem definition and research objective are addressed in the following main research question:

> *How can alternative production with resilient potato varieties be feasible in comparison to conventional consumption potato production for the local market for arable farmers in De Achterhoek?*

To be able to answer every part of this question, 4 separate sub-research questions have been formulated:

1. *What is the current situation of potato production in De Achterhoek?*
2. *How can potato production with resilient varieties take place in practice with the least pesticide use?*
3. *How could potato production with resilient varieties become a feasible alternative for conventional grown potatoes?*
4. *How could potatoes from resilient varieties be offered on the local market?*

3.3. Methodology

The research consists of desk study and in-depth interviews throughout all discussed subjects. For every sub-research question knowledge from previous research or literature review and practical experience are necessary. Experts of different fields and potato farmers have been interviewed. The results of these interviews will be presented in chapter 5. This is done anonymously, but the names are known by the researcher.

3.3.1. Research design

In general, first a desk study was conducted to be able to understand potato cultivation. During this time, also some experts were interviewed, to fill up gaps in the knowledge obtained by desk research. This was preparation for the interviews with the farmers, in order to keep up with their level of knowledge and experience and to be capable of formulating and asking the right questions within a limited time frame. This step was necessary, as the goal of the interviews was not to find out how potatoes were grown, but what potato cultivation in De Achterhoek looked like, how the farmers dealt with different issues in the sector and how resilient potato varieties would fit in here.

Per sub-research question, different sources or combinations of sources are used.

1. *What is the current situation of potato production in De Achterhoek?*

For this question, general statistics were used and to illustrate and complement these, the interviews with the farmers were used. This way an overview of potato production in De Achterhoek would become most accurate. To the knowledge from desk research on chemical use, experience of a researcher in this field was also added.

2. *How can potato production with resilient varieties take place in practice with the least pesticide use?*

This question could be answered with a combination of desk study, interviews with a potato expert and an expert from the Louis Bolk Institute on resilient varieties. Two organic farmers were approached to fill up the last gaps of knowledge, as they already work with these varieties and are

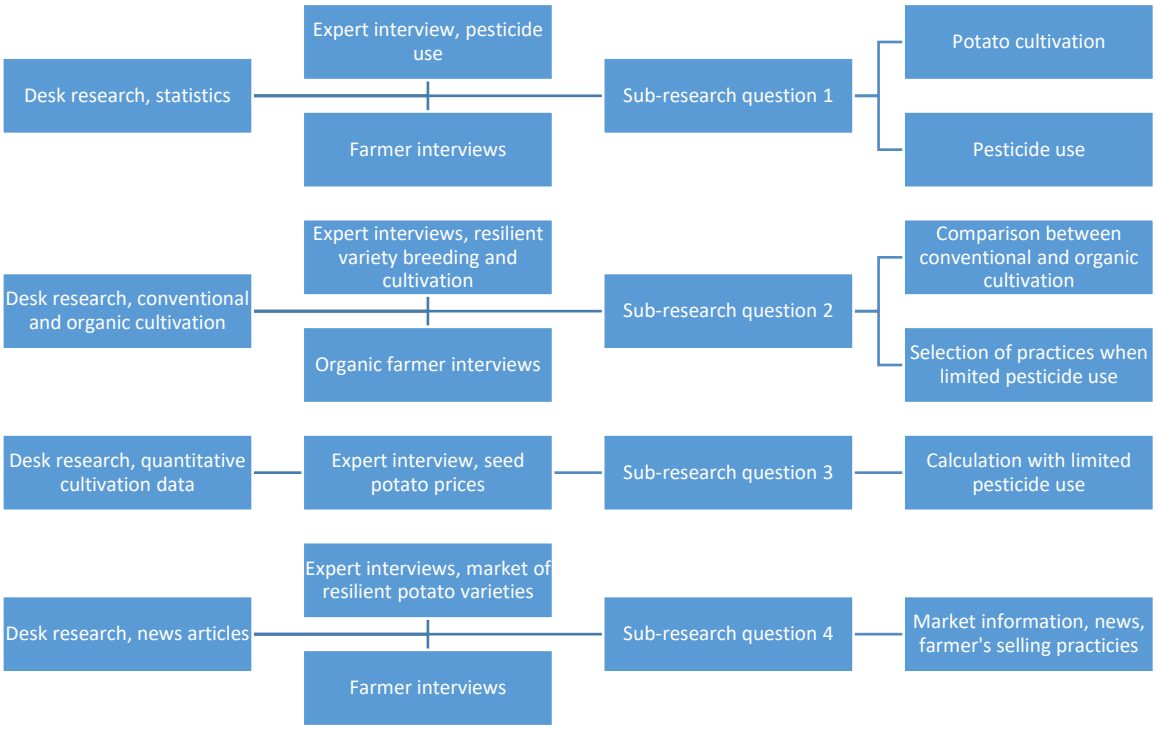
active in the business. A comparison between conventional and organic is made to see what practices are to be adopted in the current system of agriculture.

3. *How could potato production with resilient varieties become a feasible alternative for conventional grown potatoes?*

This question was to be answered with data from model cultivations and knowledge from the practices generated for sub-research question 2.

4. *How could potatoes from resilient varieties be offered on the local market?*

For this question, desk research, knowledge from the experts and ideas from the farmers was used.



3.3.2. Data collection

One potato expert and one breeding expert were interviewed in the beginning with open and formulated questions. This was done to give more direction to the research, as there was still some important information missing in the literature review. The potato expert was interviewed by telephone, the interview with the potato breeder from the Louis Bolk Institute was on location. Notes were taken during these interviews on paper and later processed and structured afterwards on a computer.

An email with specific questions was sent to a researcher of Meten=weten, an organisation with expertise on chemical use in agriculture.

The 6 farmers in De Achterhoek were visited by the researcher and were all asked the same open questions. There were 25 questions, touching on the following subjects:

- Company description (company size, location, products)
- Potato cultivation (crop rotation, variety choice, problems)

- Inputs (fertilizer, pesticides, harvest)
- Costs and benefits (general economic analysis)
- Sales possibilities (buyers)
- Vision (experience with resilient varieties, future)

This way the most complete view of potato cultivation in De Achterhoek could be provided and no useful comments or ideas were missed. This structure can also be seen in the results. The fixed structure of the interview made it possible to compare answers and the open character gave the possibility for the researcher and the farmers to elaborate on certain subjects. The interviews were recorded with permission, notes were taken on paper and later all information was noted more elaborately on a computer, while listening to the recording.

After the literature review and the main interviews had been done, only a few questions were left regarding organic farmers. Through desk study there was a clear overview of what organic practices were and it would have been unnecessary to ask organic farmers all 25 questions in order to get an idea of potato cultivation in De Achterhoek, as only a small percentage of farmers here is organic. One organic farmer was interviewed by telephone with open formulated questions, another was asked questions over email. Most questions were to control or illustrate information found in desk study or other interviews.

A so called 'PESTEL-analysis' has also been conducted together with a 'SWOT-analysis', to understand in what kind of environment the farmers of De Achterhoek operate in. It also helps to give relevant recommendations, possible to implement in practice. These are both composed of knowledge from desk study and interviews, just as table …

3.3.3. Data processing

The information of the experts was mostly to fill up gaps in the knowledge obtained from desk study. The interviews with the 6 farmers was more used to compare with each other and to get knowledge and experience from the field. Some information coming from these interviews could be submitted to potato an expert or organic farmer over email, to see what they thought about a particular subject. However, the main reasons for the interviews with the 6 farmers, was to comprehend potato cultivation in De Achterhoek and what resilient varieties could mean for this environment. The information of these interviews was partly put into an Excel-sheet for comparison and answers from the written interview reports were compared per question.

4. Literature review

4.1.1. History of potato farming and chemical use

In the Netherlands, potatoes are an important staple food and there are so many ways to cook them. It is quite extraordinary how a crop got such an important role in a relative short time. Originally, the potato plant, or *Solanum tuberosum* was already being consumed in America, but once taken to Spain by colonists around 1550, potato growing was spread widely in Europe. First it was used for medicinal purposes, but after people found out it saved them of scurvy, which in Western-Europe was a problem during winter, production increased even faster. Around 1730 potatoes became quite a common crop for human consumption.

There were, however, risks in potato growing. Especially *Phytophthora Infestans*, a rot disease, caused a horrible starvation in the potato dependant Ireland of in particular 1845 and 1846. First, there were more than 8 million inhabitants, in 1911 only 4 million were left. Around the year 1880 mankind discovered the limited development of *P. Infestans* under the presence of copper in the soil.

Later, other substances were discovered with which the disease could also be controlled, both implementations resulting in a more annually stable and higher produce. The substances are vital to the industry, but also have an effect on the environment and health (Ing. De Jong, 1985).

The Dutch potato industry is well-established in world trade. Yearly, around one million tons of consumption potatoes, 700.000 tons of seed potatoes and two million tons of potato based products are exported. The Netherlands are especially famous for high quality seed potatoes.

4.1.2. The potato plant and cultivation

The potato is a plant of the *Solanaceae* family and starts growing when temperatures get warmer by developing sprouts out of a potato, using its stored energy. The sprouts find their way up and a plant is formed, which can develop under the sun and with uptake from atmosphere and soil the plant grows potatoes in the soil, storing starch in them. Beside this reproduction system, the plant also develops flowers for pollination with other potato plants, but in particular in the early growing season, potatoes form perfectly without pollination.

Growing potatoes begins with a crop rotation system. Potatoes are quite sensitive for fungi and different nematodes, or small worms in general indicated as the well-known potato fatigue. A crop rotational system of at least 4 years is advised to mitigate the risk of damage due to fungi or the nematodes. Crops most suitable before growing potatoes in the system are grains and grass, as they leave a good soil structure. Crops such as beans, peas, clover and alfalfa, are not very good before potatoes. Potatoes can grow in practically every soil, however, lightness and looseness stimulate good growth. It also prevents water from staying in the soil to long, which can cause rot and more damage during harvesting, as the skin of potatoes gets soft and more vulnerable. At last, the choice of variety is very important and depends on purpose of processing, present pests and diseases on the farmland, soil type, growing season and costumer demand. The seed potatoes also need to be checked thoroughly on health, which makes a great difference in successful growth. In mechanised farming, the seed potatoes are planted in ridges, for optimal water management and concentrated potato clusters. Sometimes the final ridge form is built up just before sprouts reach the surface. This way, warmth of sunlight can penetrate to the core of a ridge to facilitate a better growing temperature than with a larger ridge.

During growth, apart from seasonal conditions, there are basically the following factors that influence development of the crop: available water and nutrition, competition with weeds and pests and diseases.

On average, 1 ha requires 250 mm water for optimal tuber quantity and formation. It supports in the first stage the forming of a plant and increases the quantity of tubers, in the second stage it protects the potatoes from scab, a mould making potatoes incompliant with the standard and in the last stage it facilitates blooming and growing of potatoes. Nutrition can be divided into nitrogen, phosphate, potash and magnesium. Nitrogen mostly stimulates leaf growth, phosphate facilitates good growth in general and a healthy root system, potash secures good quality potatoes and magnesium helps forming chlorophyll, or leaf green, good for photosynthesis.

Weeds are all other plants that grow in a field along with the potato plants. Weeds take up water, sun and nutrition from the soil and therefore, compete with the potato plants. The uptake limitation of potato plants caused by weeds, is the reason why weeds need to be removed, giving potato plants the opportunity to develop further in order to maximise potato quality and quantity.

Pests and diseases are other organisms, such as fungi, bacteria, viruses and insects that can harm the potato development in whatever way. Pests and diseases are numerous and can already live in the

soil or be brought in through the air, by seed potatoes or machinery and can damage potatoes directly or indirectly by affecting the plant, interfering with potato development (Hammink & Van Loon, 2009).

4.1.3. The different aims of cultivation

For every different potato end product, there are different cultivation practices and quality requirements. This thesis focusses on consumption potato cultivation and crop protection, but multiple potato cultivations are practiced at the same business. This is important, because the inputs and risks also variate. Additionally, it helps understanding the functioning of businesses and evaluating opportunities for cultivation with resilient varieties. At the end a simplified overview is given, again not focussing on all inputs, solely regarding crop protection.

The underwater weight (in Dutch abbreviated as 'OWG') of potatoes largely determines the cooking type of a potato and suitable end uses. Cooking types are classified as 'A' to 'D', with class A keeping its form after cooking, and D being very mealy and soft. The higher the underwater weight is, the higher the dry matter percentage. In the case of the potato, more dry matter often means a higher starch content. Therefore, the OWG is very important for the industry.

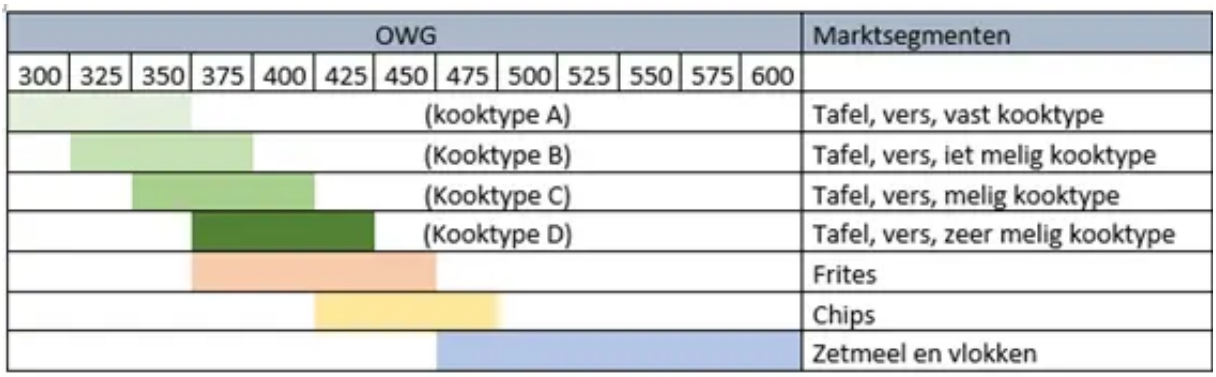


Figure 1: The OWG with the different suitable market segments (Eising Advies, 2022).

The OWG is influenced by many factors, such as variety, soil, fertilisation, water availability, light and temperature, growing pattern and to which extend potatoes are ripe. In general, the longer a potato has grown, the more ripe it is and the higher the OWG. However, the scheme is an indication and different combinations of factors can result in different cooking types (Eising Advies, 2022).

Table potato

The most basic aim for potato cultivation is for home cooking. In this category there are many varieties, including some that can be planted early on in March. One can harvest a table potato when it has reached a suitable size and shape. The earlier harvested, the less long the potato can be stored. When a potato plant has died completely, the potatoes are ripe and can be stored all winter through without much quality loss (Plantaardig.com, 2011). This is applicable in general, but of course storage properties of different varieties also play part here. The quality requirements for table potatoes are good and uniform taste, low blue sensitivity and good colour after cooking.

Chips and crisps potato

The quality requirements of chips and crisps potatoes are, as with table potatoes, very high. Here the aim of baking and frying asks a sufficient dry matter content, low reducing sugars content and low blue sensitivity. In baking and frying, a sufficient dry matter content causes less oil uptake, so a healthier and cheaper end product. Additionally, less water has to evaporate from the potato and the colour after frying is better. Reducing sugars are caused by the *Maillard*-reaction during storage

and cause decolouration and bitter taste. Variety and storage temperature play a large role in this (Ing. De Jong, 1985). Potatoes in this cultivation need to ripen more for a higher dry matter content, which means these stay relatively long in the soil.

Seed potatoes

Seed potatoes grown in more or less the same way as consumption potatoes. However, the aimed end product is very different. Large potatoes are regarded as a success in consumption cultivation. In seed potato cultivation it is rather the large number of potatoes and small size of the potatoes that brings the most revenue, as these are most vital for potato growing and form most consumption potatoes. Therefore, the growing process of potato plants needs to be stopped in an earlier stage, where the number of potatoes is maximised, but have not grown in size yet. This means that the potato plant is still very strong and healthy, so it takes more effort to kill the plant in order to stop potato development and be able to harvest the seed potatoes (Hammink & Van Loon, 2009). The highest priority in this cultivation is to at least have yield that is not affected by any kind of virus, fungus or other defects, as contaminated seed potatoes are devastating for the next harvest. The quality of seed potatoes determines for a large part growth in cultivation. Therefore, much work is put in going through the field and constantly check on any deviating plants and digging them out before they can contaminate neighbouring plants. This cultivation requires most crop protection, also to be seen in Figure 2.

Starch potatoes

Starch potatoes are processed the starch is used in the food industry, but also in other products, such as glue and concrete additives (Avebe, 2022). Nowadays, protein abstraction is also increasingly important (Agrifutures, 2019). These potatoes are also left in the ground longer to reach a higher starch content.

Feed potatoes

Feed potatoes do not have much requirements and are often by-products of sorting lines from farmers and processing factories. The potatoes are added to the diet of cattle and increases muscle growth and a better fat-protein ratio in milk. Feed potatoes are stored outside in bulk, from where they can be transported. It is advisable to store the heaps dry under plastic, especially when transport is in longer than 2 weeks. A paved base is also useful for transport trucks (Van Vulpen veevoeders, 2022) (Strohandel Roose, 2022)

Cultivation type	Aim	Risks	Practical threats	Necessity to mitigate risks	Bruto Revenue (€/ton)
Feed	High volume	Early growth stop, water shortage	P. Infestans, Colorado beetle	Low	0*
Starch	High volume, pure substance	Early growth stop, water shortage, impurities	P. Infestans, nematode, Colorado beetle	Low	90
Chips	High volume, large size, relatively low moisture content for frying	Early growth stop, water shortage	P. Infestans, nematode, Colorado beetle	High	120-140
Table	High volume, appropriate size,	Early growth stop, water shortage, defects	P. Infestans, nematode,	High	140

	good quality and cooking properties		Colorado beetle		
Seed	High number, small size, healthy and vital properties	Early growth stop, water shortage, defects, contaminations	P. Infestans, nematode, Colorado beetle, aphid	Very high	310

*Figure 2: Different potato cultivations with a risk rating and gross revenue. *Is a by-product and mostly part of a land renting deal with a dairy farmer as a favour.*

4.2. Conventional potato growing

Conventional potato growing is a very high yielding sector supplying the large potato industry. Dependent on the work width of spraying installations, tracks are left open for the tractors to drive through the potato field in such a way that there is the most efficient coverage with the least tracks that take up planting space. The spraying installations are used to spread fertilizers over the land, mostly before planting and at the stage where potatoes are formed. Additionally, the spraying routes are also used to apply pesticides on the potatoes.

Especially control of *P. Infestans* requires measures for a successful harvest. This is also the disease that demands the most preventive measures that begins with making the chance *P. Infestans* can enter fields as low as possible. Primary preventive measures are checking the field before planting for potato plants of previous growing seasons, checking the seed potatoes to be planted on diseases and placing heaps of rejected potatoes as far away from the growing fields as possible, properly sealed. After that, secondary preventive measures can be applied, of which spraying fungicide is an important one (Ing. De Jong, 1985). Without spraying it can be very difficult to prevent development of colonies of *P. infestans* in large monoculture potato fields. There are much more pests and diseases that can harm development of healthy consumption potatoes. Most can be controlled by different pesticides. Dosage and timing are based on experience and systems that can advise certain measures in regard to weather, soil and growth stage (Hammink & Van Loon, 2009).

Weeding can be done mechanically, although it takes some precision as there is a risk of potatoes or potato plants getting damaged. Stirring the soil also means moisture loss in the soil. After the plants get larger and cover all soil it is harder to weed mechanically, but there is also less necessity, as weeds are less capable to break through the existing potato canopy. However, often herbicides are used to control weeds, and are applied in combination with for example a fungicide against *P. Infestans* (Hammink & Van Loon, 2009).

Harvesting starts when the potatoes have reached a good quality and circumstances allow harvesting. The plant needs to be killed first, so the plant lets go of the potatoes. This process is important, as the potato can heal naturally and no wounds are made, which are easy entrances for rot and diseases. The plants are often cut of, followed by spraying fungicides and plant killing substances. This way the potatoes are easier to harvest, but it makes it also harder for fungi to enter the plant without presence of green and living structure. Dependant on weather conditions, plants can also die a natural death, but this takes more time and thus more fungicide application. In conventional growing, it is more sustainable and feasible to spray plant killing substances as soon as the potatoes are ripe (Hammink & Van Loon, 2009).

Figure 3: Haulm topping and harvesting in one machine (GIANTS Software, 2017).

In storage, potatoes need to stay dry, dark and cold. To prevent potatoes that are stored long from sprouting again, sprout inhibitors are often applied. Some of them need to be sprayed in the field on healthy plants, so it is taken up, others are sprayed when the potatoes are already in storage. Storage temperature really depends on the end use and how long potatoes stay in. The natural decrease in temperature in autumn should form a good base.

4.3. Chemical use and risks

The use of chemicals made a huge difference for the quantity, quality and consistency of potato yield and for the processing industry. To illustrate the importance and the scale of implementation, 40% of all crop protection chemicals used in 2016, was for potato cultivation. Approximately 936000 kg crop protection chemicals were used for consumption potatoes, 827000 kg for seed potatoes and with 502000 kg significantly less was used for starch potatoes.

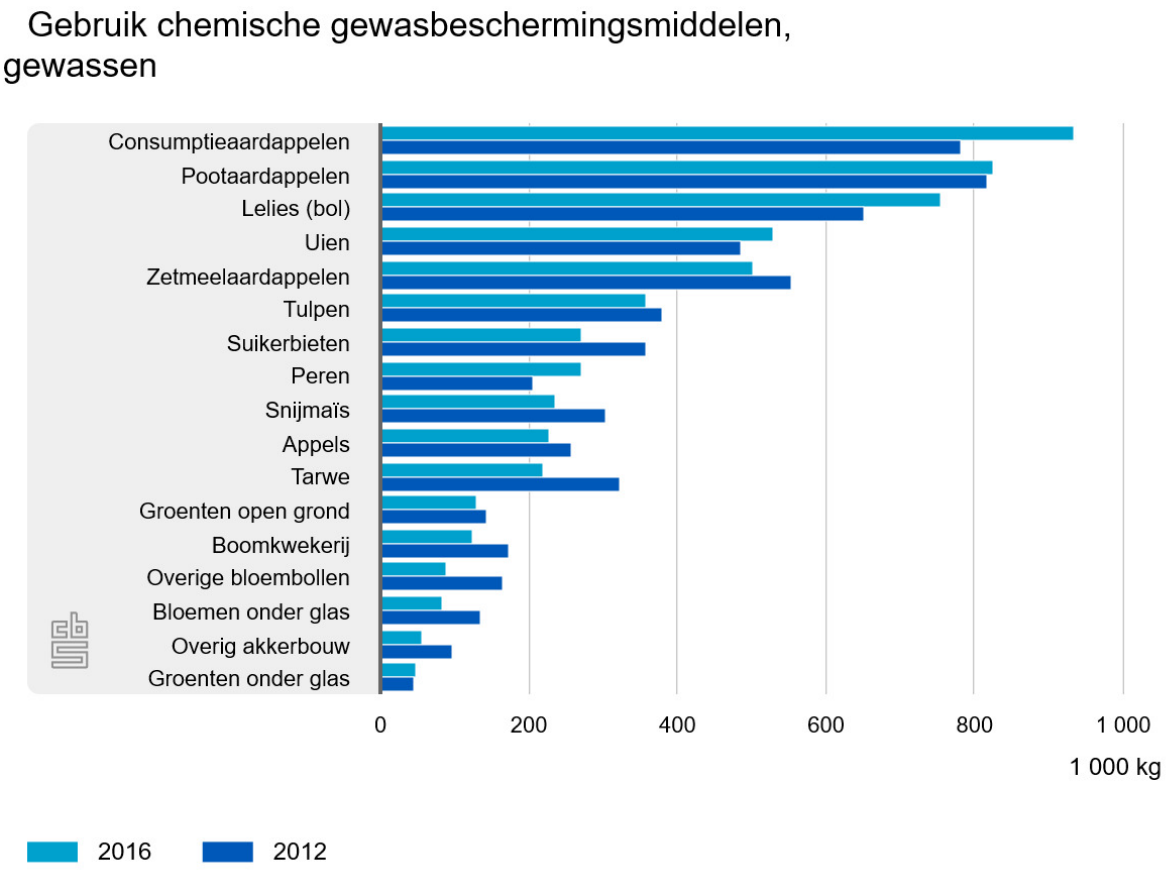


Figure 4: Use of crop protection chemicals in kg in 2012 and 2016 in the Netherlands. Cultivation of consumption and seed potatoes applied most chemicals (CBS, 2018).

Although the total weight of used chemicals in potato consumption is high, it should not be forgotten that it is a very common crop to be cultivated. Looking at the intensity of chemical use, 12,8 kg per ha was used for consumption potatoes, 20 kg for seed potatoes and 11,6 kg for starch potatoes. The almost two times higher intensity in seed potato cultivation correlates with the information from *figure 1*¸ showing more acres are used for consumption than for seed potatoes, but the total use in kg for seed potatoes is well approaching that for consumption potatoes (CBS, 2018).

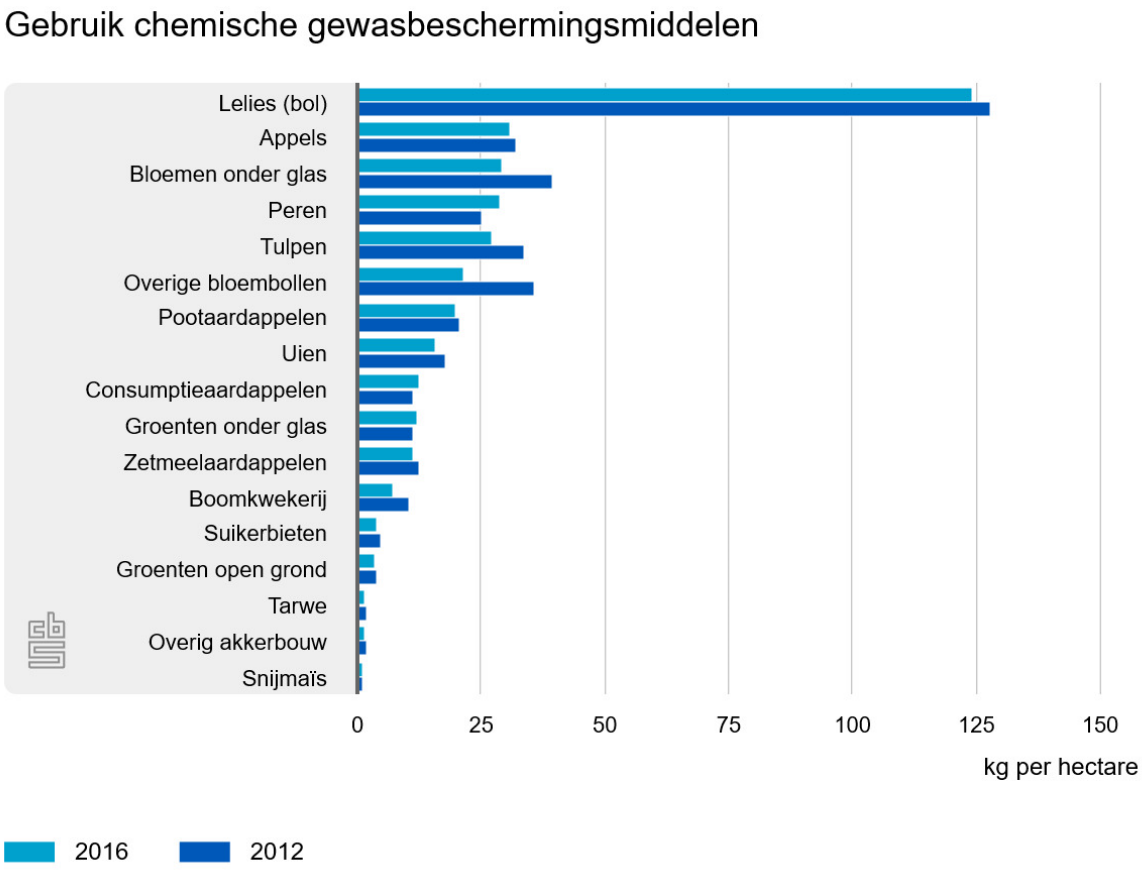


Figure 5: Use of crop protection chemicals in kg per ha in 2012 and 2016 in the Netherlands. Seed potatoes are 7th and consumption potatoes are 9th in intensity of all crops. The use for Lily bulbs is most intensive (CBS, 2018).

Most crop protection chemicals are not very selective, so are also working on other organisms that were not decreasing yield potential, such as fungi and bacteria that help crop growth. This makes production and processing extremely efficient for the short term (Unie van Waterschappen, 2022).

In the Netherlands, chemicals are evaluated by the 'College voor de toelating van gewasbeschermingsmiddelen en biociden' or 'Ctgb', an independent institution. It works within the boundaries of the European laws and regulations. *Ctgb* provides lists of allowed and forbidden chemical substances every year, and crop protecting chemicals containing these chemicals all have a very precise description of how it should be applied and what dose is allowed.

4.3.1. Risks

However, another issue with crop protection chemicals is the harm that is done outside of the field of where it is applied. This happens when chemicals that are sprayed on the field, are swept away by the wind before it reaches crop or soil, called 'drift'. The chemicals descend and have a negative effect on surface water, random plants, arthropods, such as bees and the chance nearby living residents are exposed to chemicals increases (WUR, 2022). Sometimes, residues of applied chemicals are also found in food products (EenVandaag, 2022).

To reduce this drift, the government has a law that prohibits application of crop protection chemicals within 1,5 m of surface water. This rule is different when a barrier of trees, shrubs or other crops is grown between the main crop and surface water. This growth can filter chemicals from the air, allowing less drift in the adjacent environment. Other measures can be for example screens or caps over spraying installations and different spraying nozzles that spray more precise. Both reduce drift

and different laws apply on these measures. Spraying very close to the crop also reduces the chances of drift (Overheid, 2019).

All chemicals have been approved separately by the European Commission and the *Ctgb* and are regarded as safe, but little is known about exposure to a mix of multiple chemicals at the same time. There are indications that exposure to combinations would hinder brain development of children and could lead to Parkinson's disease (Gezondheidsraad, 2020).

Research is still being done on the effects of pesticides on the environment. What is clear, is that the concentrations in air, urine and house dust decrease with larger distances from fields where pesticides are applied. Concentrations of for example chlorpropham were on average 2 times higher within 250 m from a sprayed field than 500 m and further from the field. Nowhere concentrations exceeded legal norms, but measurements differed per chemical and season and more research is needed on different chemicals and the effect of mixtures (RIVM, 2022).

4.3.2. Chemical use in potato cultivation

In general, there are five different kinds of crop protection chemicals:

- Systemic substances spread through the whole plant to protect them from pests and diseases that mean to enter the plant.
- Contact working substances are sprayed onto plants, leaving a coating effective against pests. Another group of this kind are the translaminar substances and have the same ability, but can move through leaves also coating the bottom of leaves.
- There are also substances that can cover plants and sealing them against fungi and insects.
- For insects, mineral oil is used, also to protect the plant against viruses the insects bring with them. The oil clogs the breathing systems of insects.
- Another kind of chemicals are soil working substances, mostly herbicides. It prevents weeds from developing (Royal Brinkman, 2022).

The following figures can give a clear overview of for what purpose chemicals have been used in different potato cultivations, which can be further explained with information from reality.

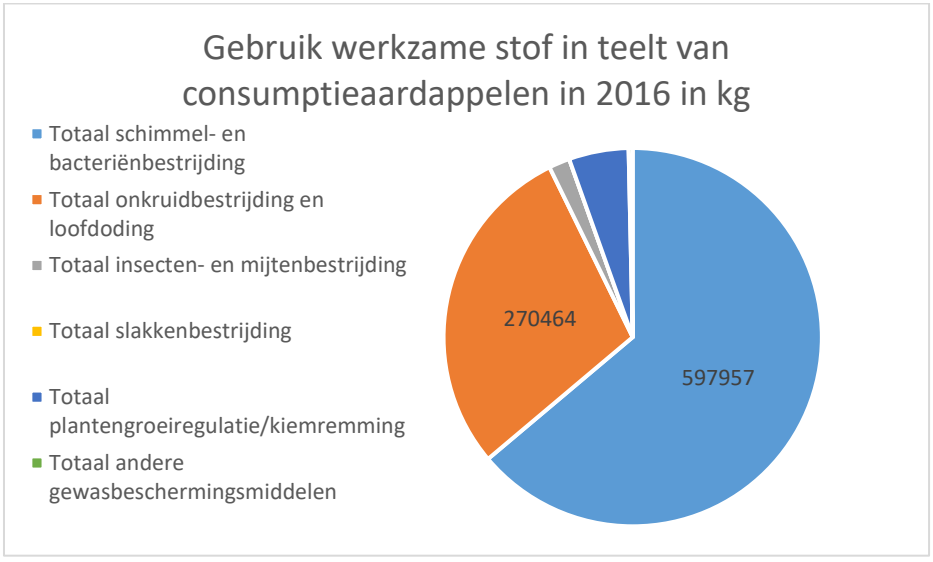


Figure 6: Applied effective chemicals in kg in consumption potato cultivation in 2016 for different purposes (CBS, 2018).

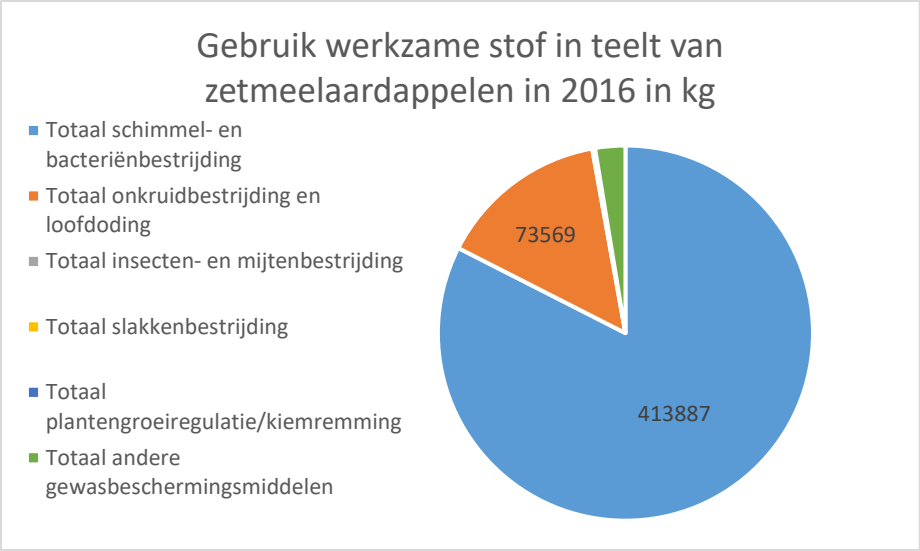


Figure 7: Applied effective chemicals in kg in starch potato cultivation in 2016 for different purposes (CBS, 2018).

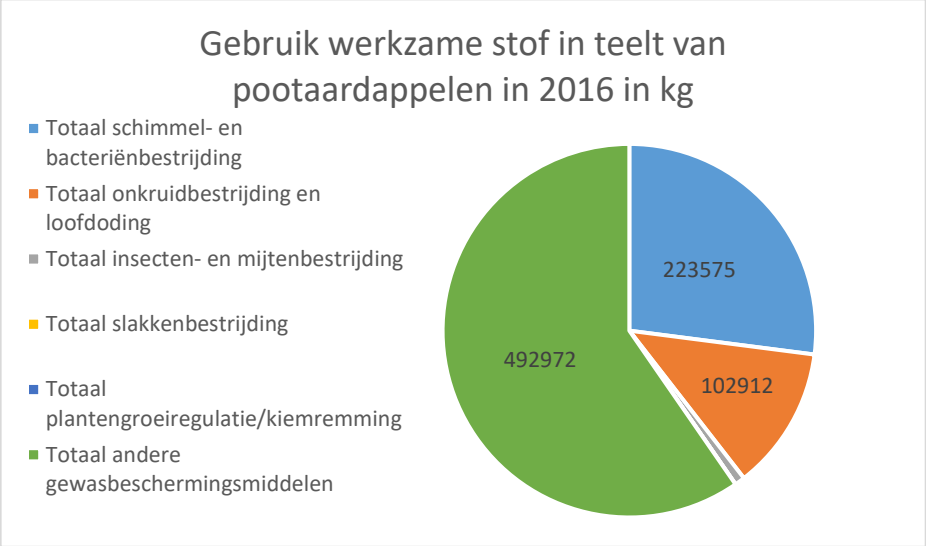


Figure 8: Applied effective chemicals in kg in seed potato cultivation in 2016 for different purposes (CBS, 2018).

The next three figures give insight about the ratio between most used working chemicals. It is impossible to show every single chemical, so a minimum of 40000 kg used in 2016 in at least one of the three cultivation types is taken as criterion for depiction in the graphs. This results in the chemicals diquatdibromide and prosulfocarb, which are herbicides also suitable for defoliation, propamocarb and mancozeb, which are fungicides, Maleinehydrazid, a sprout inhibitor and mineral oil against aphids.

The first two graphs show that in cultivation of consumption and starch potatoes more or less the same effective chemicals are used. The exception is that in consumption cultivation some sprout inhibitor (dark blue) is applied because some of these potatoes are kept in storage longer for later consumption and quality needs to be maintained in the meantime. Maleinehydrazid, or MH, (red) was the mostly used sprout inhibitor and is still used. There are no negative side effects known from this chemical. Starch potatoes are often transported shortly after harvesting and therefore, do not need sprout inhibitor.

In both cultivations, fungicides (light blue) and herbicides (red) make up the largest part of all chemicals. In 2016, Mancozeb, or MZ, (grey) was the mostly used fungicide together Propamocarb, which is shown in *figure ….* Mancozeb is a non-systemic, contact working chemical, interfering with the harmful metabolism of the fungus, which affects the potato plant. It also prevents spores from sprouting. However, it also seems to have definitive, negative effect on animals and humans. The allowance of the substance was not prolonged anymore and the chemical had to be used up until 2021. Propamocarb is still allowed by the Ctgb (Parkinson Vereniging, 2019) (NIH, 2023).

As herbicide, Glyphosate is also used, also the active chemical in 'Round Up'. Its use is not taken up in the graph, as use did not exceed 40000 kg in any of the cultivation types. This chemical is subject of discussion, because it is also harmful for other organisms. Herbicides are often applied before seed potatoes are planted, when the previous crop was grass. After the herbicide is applied, the soil is prepared for the potatoes and grass and weeds do not develop. This gives the potato growth a head start and the soil still has the good properties grass provides. Diquatdibromid and Prosulfocarb are the most used herbicides.

In seed potato cultivation other crop protection chemicals (green) are mostly used. Looking at *figure seed potatoes,* this large share can be explained by use of mineral oil (yellow), against insects and in particular aphids. Aphids are often carriers of different viruses that are harmful for potato plants and will cause deviations in quality of yield the next year. Mineral oils are stable chemicals and hard to break down organically, but are allowed by SKAL. The mineral oils have no toxic and working components, but can harm the environment and presumably organisms living in water and bees (Royal Brinkman, 2022) (Certis Europe, 2022).

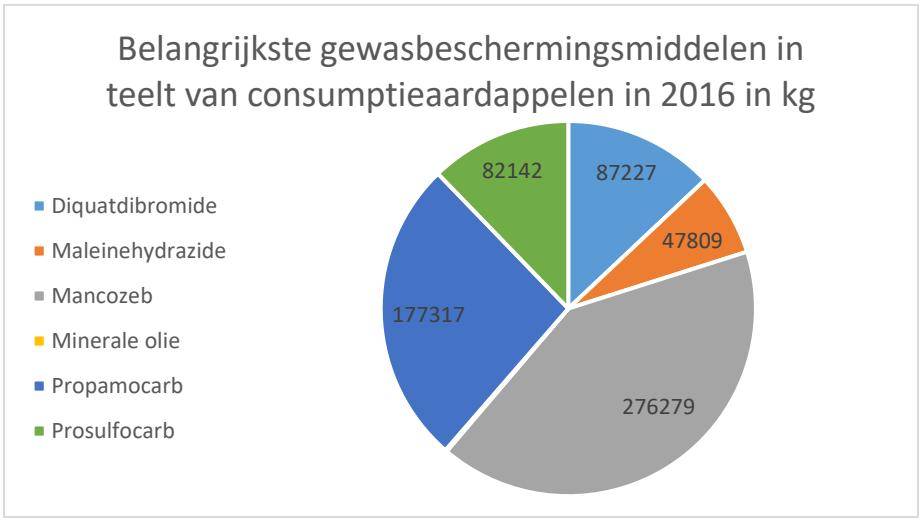


Figure 9: Most important effective chemicals in kg (use above 40000 kg in at least one cultivation type) in consumption potato cultivation in 2016 (CBS, 2018).

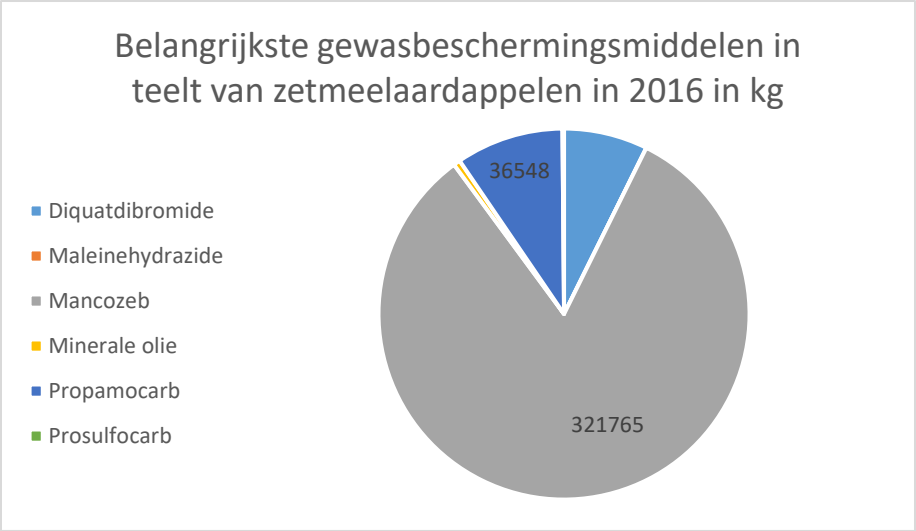


Figure 10: Most important effective chemicals in kg (use above 40000 kg in at least one cultivation type) in starch potato cultivation in 2016 (CBS, 2018).

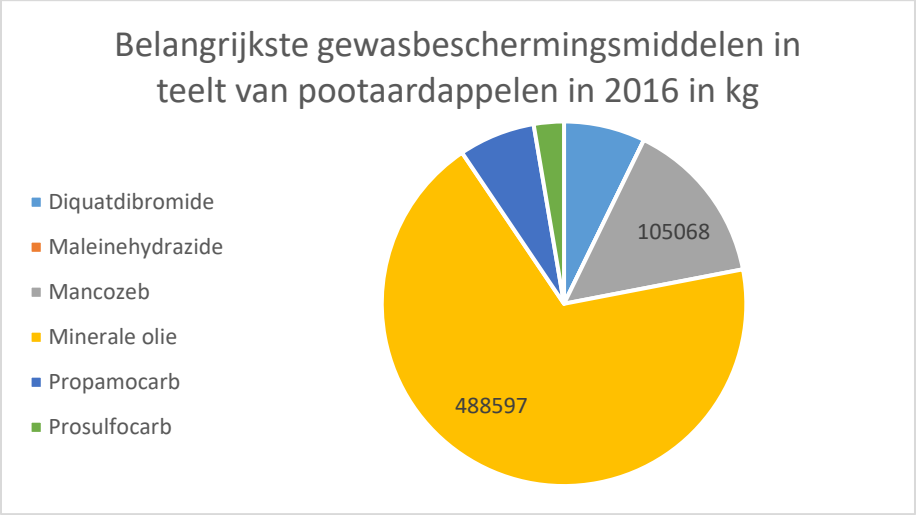


Figure 11: Most important effective chemicals in kg (use above 40000 kg in at least one cultivation type) in seed potato cultivation in 2016 (CBS, 2018).

4.4. Organic potato growing

Organic potato growing is already being done, but there are difficulties in this system. In late cultivation, it is almost a must to make use of *P. Infestans* tolerant potato varieties, which significantly reduces the rate at which the disease can spread. By the point the plants are infected, potatoes have already developed successfully (Hammink & Van Loon, 2009). The time of planting and seasonal conditions can make a huge difference in development of the potatoes. Very humid summers are in general very favourable for spreading of *P. Infestans,* where more dry conditions hinder rapid spread. On smaller scale, it is also advised to make the planting ridges in length with the main wind direction, to stimulate quick drying after the plants are humid due to rain or morning dew. Planting as early as possible can secure early potato development and less chance of infection, as many fungi, insects and viruses are not active at colder temperatures. This can even be done with potato varieties without resistant genes.

Crop rotation is often more variable and less intensive, with potatoes being planted once every 6 years or less in the same soil. This prevents many soil bound pests to continue to develop on potato

plants the following years. Additionally, it gives farmers the opportunity to build up nutritional value in the soil with other crops, as application of chemical fertilizer is not allowed in organic farming (SKAL, 2022). Potato plants that start growing from waste from a previous harvest, should be destroyed as much as possible. This is achieved by sowing a crop directly after the potatoes that can be mowed, leaving the land fallow and let frost do the work or have animals graze the land. Especially pigs also eat potatoes from underground (Bremer, et al., 2007). The health and intake of potatoes per animals should be monitored though. A measure prior to these, is minimizing the amount of waste potatoes and plants are left on a patch. Seed preparation is also a good way to give the potato plants a head start once they are in the soil, but this needs some investments.

Fertility of the land is hard to regulate, as organic matter is used and the distribution of nutrients out of the manure depends on the rate of mineralisation. Mineralisation is done by micro-organisms, which only become active above certain temperatures. It is important to apply fertilizers with easy mineralisation, or to keep nutrient levels in the soil high in general. Additionally, one can make use of resilient varieties that have strong early growth, regardless of nutrient availability. A vast root system in an early growing stage could also compensate for nutrient scarcity. Fertilizing as an instrument can also be used indirectly against for example *P. Infestans.* Plants that are well accommodated are less receptive to all kinds of diseases (Bremer, et al., 2007).

At the end in the growing stage, the plants can be cut off in hot weather, so the stems dry out quickly and the potatoes separate themselves from the plant. This way fungi have the least chance of entering the potatoes via the living part of the plants. Burning the potato plants is also allowed to kill the potato plants.

However, looking at resiliency management and without the ability to use chemicals, it is not only important to be alert and to adequately remove and destroy any infected plants to prevent spreading, it is also enforced by law. Without the plant, potatoes cannot develop further, so with it production stops immediately. Observation is key in preventing diseases from spreading (Bremer, et al., 2007). Therefore, the risk mitigation in organic growing practically comes down to the primary preventive measures, mentioned in chapter 4.2.

In 2016, copper was applied as fertilizer, but was in fact illegally used to mitigate development of *P. Infestans*. As fungicide, copper is not allowed in conventional potato farming because it has a deteriorating effect on the surrounding environment (Bionext, 2017). The average yield with organic production is approximately 40-45 tons per ha, but is giving more profit per ha than conventional grown potatoes (Rapol & Van Moorter, 2021). However, yield depends mostly on if the conditions for *P. Infestans* are favourable and in what stage the disease hits.

4.5. Comparing conventional, organic potato growing and Planet Proof label

Here a quick comparison of conventional, Planet Proof label, and organic potato cultivation will be made. The Planet Proof label is also covered, as this label is meant to be in between the two others and can be interesting to look at, regarding less pesticide use and not organically certified.

Conventional cultivation is done within the boundaries of the law and the ultimate goal is to generate as much yield as possible of high quality. For example regarding nitrogen, there are many rules from the government. In total, it is allowed to apply 235 kg of fertilizer per ha for potato cultivation, from which 170 kg is cattle manure. The cattle manure is allowed to be complemented with chemical fertilizer. However, when grass land is destroyed to follow it up with potato cultivation, 65 kg less nitrogen may be used, which brings nitrogen use back again to the 170 kg from cattle manure. This reduction does not apply when the grass was sowed previous growing season as

green manure crop. The numbers can differ further per variety and soil type (RVO, 2022). Only pesticides allowed by the *Ctgb* are used.

Organic cultivation aims to produce as much yield as possible of high quality and natural origin, with care for soil and environment. This cultivation is also bound to the 170 kg from cattle manure, but it should be from organic origin. When this limit is reached, it is not allowed to add more fertilizer from other organic origins. Nutrients are more provided by crop rotation and care for the soil. SKAL has made a selection of pesticides from the list of the *Ctgb* that are allowed in organic farming (SKAL, 2022). Pesticides are only allowed when other methods of crop protection fail.

The requirements of the Planet Proof label consist of a bonus-malus system, stimulating sustainable practices on 6 different categories, namely: crop protection, fertilization, soil fertility, biodiversity & landscape, energy and water. Every practice is rated with a positive or negative amount of points. When the total of points is above 10, products produced on the farm can be certified with the Planet Proof label. For pesticides, it makes a distinction between chemicals in the list of the *Ctgb* based on the negative effects on the environment they have. For consumption potatoes, 7,5 kg of working chemicals is allowed per ha per growing season. For Glyphosate, mineral oil and MH, different rules apply. When more than 15 malus points are reached within 'crop protection', points may be compensated with bonus points from other categories. Other relevant practices for bonus points, are for example use of a pesticide application advice system and use of resilient varieties (AgroVision, 2019) (Overheid, 2017).

4.5.1. Economic analysis

As mentioned before, yields and revenues of conventional and organic farming are different. Looking at the costs and benefits of the cultivations the economic differences become evident. For the comparison, average data from model cultivations of Wageningen University & Research form 2022 is used, seen in 10.1. The most important differences are presented here in a table.

Cost	Conventional	Organic
Potato price (€/Kg)	0,14	0,30
Seed potato price (€/Kg)	0,48	0,70
Yield (Kg/1 ha)	48.400	32.500
Bruto revenue (€/1 ha)	6566	9716
Pesticides and haulm topping (€)	884	121
Fertilizer	318	400

Although the data from the organic cultivation are on clay soil, the differences can be observed in costs that do not depend on this. Especially the difference in price for seed potatoes and potatoes are large. The higher organic price is for example due to a lower yield and monitoring of SKAL-certification. Inputs for organic farming are often also more expensive, as these sources also need to be organic certified. For conventional cultivation a mix of chemical fertilizer was used and for the organic cultivation the fertilizers were organic cattle slurry and dry manure.

However, organic farming spends very little on pesticides. Sometimes organic farmers use chemicals from the list of the Ctgb, that are approved by the organic sector as well. In this cultivation it was not even used, but €121.- was used on gas for burning the potato plants before the harvest. It is put next to the total costs of pesticides and haulm topping in conventional cultivation, as here it is done with a herbicide, in order to make a fair comparison.

4.6. Resilient potato varieties

The course of the EU directed at sustainable farming and less pesticide use seeks solutions in a more resilient ecological environment in general. This way, crops are not protected directly, but indirectly by creating a resilient and self-balancing environment, where chances of excessive outbreaks are limited thanks to more biodiversity. Chemicals are only applied when yield is in direct danger, and are not so much part of preventive measures anymore. This also keeps chemicals effective, instead of regular use, by which pests can build up immunity. Essential in this more holistic approach are varieties that can endure the challenges of climate change and biodiversity in the field (Overheid, 2020).

There are many different potato varieties, each with their own characteristics, abilities and immunities. However, there is not yet a potato that can fully endure every possible danger and potatoes can still be vulnerable for different pests and diseases. Which variety to use, depends on for example what the soil consists of and if there are present infections in the soil, climate, time of year and the end use (Kennisplatform Aardappels, 2022). Using different varieties can also be a way of spreading the risks of damage circumstances or diseases can do. Partly, it is the rate at which disease can spread to other fields with the same variety, but more this measure is to minimise the amount of gates a disease has to enter the cluster of potato production. Additionally, preventing infection of for example *P. Infestans* may be the most important. This disease is flexible and always developing and letting it around resilient varieties for too long, could give it enough time to develop a way around the resisting properties and into the plants, throwing away years of research, selection and crossbreeding. Making sure resilient genes stay relevant, is called resiliency management (Bdeko, 2023).

BioImpuls is a project running with research on resilient varieties. Breeders that are involved, are C. Meijer BV, Den Hartigh, Fobek, HZPC, Plantera en TPC (BioImpuls, 2023).

4.6.1. CRISPR-cas

To speed up the creation of new varieties, scientists can make use of CRISPR-cas, a technology to change DNA very precisely to develop certain abilities in potato plants. However, resilience management stays very important here (WUR, 2022). Besides, the organic farming sector does not allow any use of genetically modified organisms, also ‘GMOs’. In 2018, the European Court of Justice decided that varieties created with CRISPR-cas officially need to be labelled as ‘GMO’ (Duurzaam Nieuws, 2018).

4.6.2. Breeding

The more easily accepted way of creating new resilient varieties, is to pile resilient properties or genes. Varieties are found in the nature of Southern America and are selected on resilience and the varieties are crossbred. One disease resistant property on its own can protect a plant, but piling multiple properties will make it increasingly harder for diseases to infect a plant (Groene Veredeling, 2023).

4.7. General analysis of the potato sector in De Achterhoek

From all agricultural land in the Netherlands in 2021, 3,94% was used for consumption potato cultivation. It is also the most important kind of potato cultivation, as 44,52% of land was used for consumption potatoes, with the rest equally shared between seed and starch potato production.

In De Achterhoek, the land used for consumption potatoes is about the same as the national average with 43,06%, but the share of seed potatoes is much higher in De Achterhoek with 34,91%. This is

worth mentioning, for seed potatoes are subject to the most intensive use of crop protection substances of all kinds of potato cultivation.

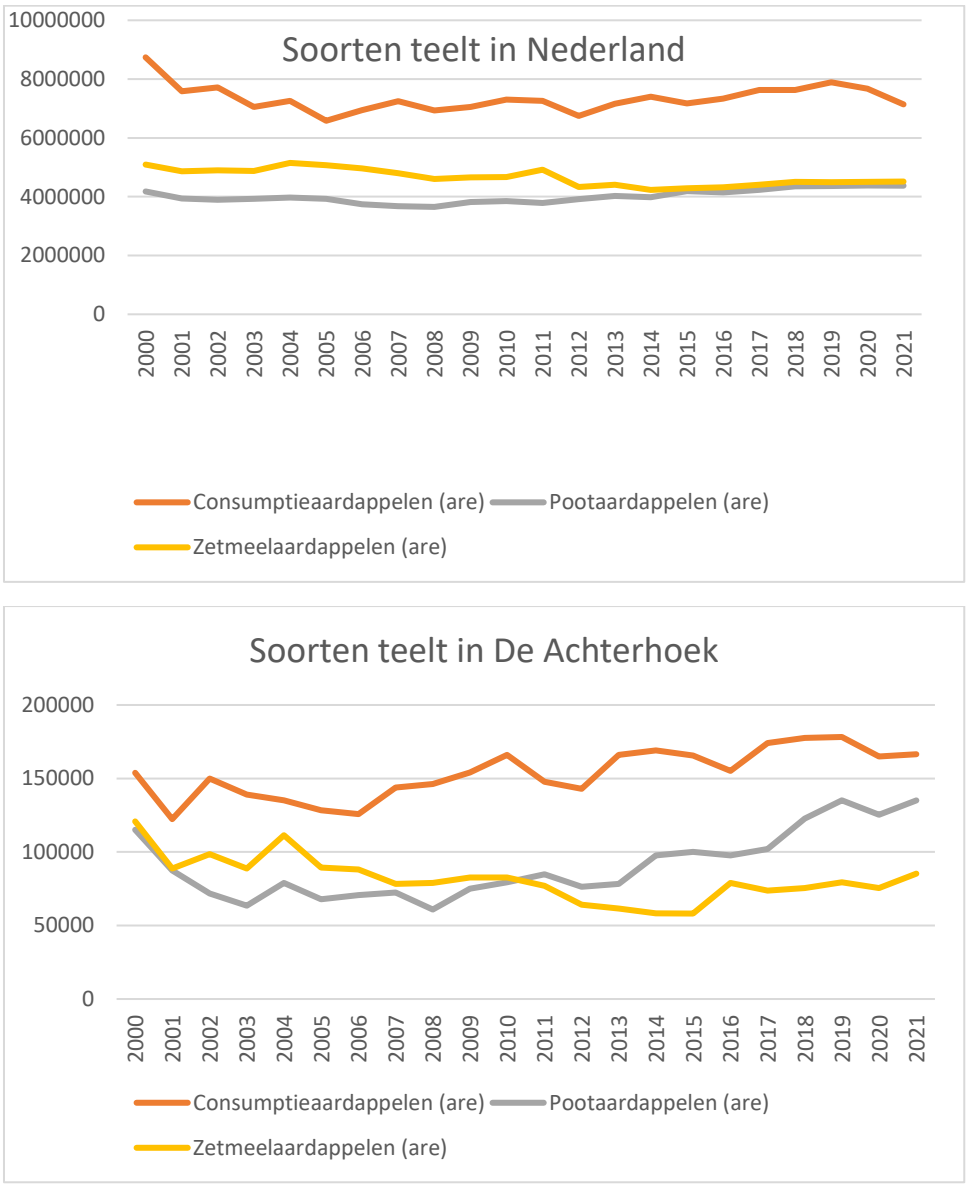


Figure 12: Amount of acres used for consumption, seed and starch potatoes in the Netherlands compared to De Achterhoek (CBS, 2018).

In 2011, the average number of ha per arable agricultural business is with 16 half of the national average of 38,5 ha. It shows the relative small scale of most farms in De Achterhoek. The total amount of agricultural businesses decreased, but the amount of arable farms has been quite stable with 611 businesses in De Achterhoek in 2019 (CBS, 2023). Industrial companies are relatively large in terms of the amount of jobs per business and in De Achterhoek, Aviko is one of them. Again in terms of jobs, agricultural businesses on average are somewhat smaller than the average of the total in the Netherlands. At the same time, there is a relative higher amount of agricultural businesses with more than a 100 jobs, making up for 13% of all employment in the agricultural sector in De Achterhoek, for which the national average is 7%. In conclusion, the situation of the agricultural sector in De Achterhoek is, in regard to the Netherlands, very unique because in general it has smaller businesses both in number of ha and jobs and more larger agricultural companies (Fontein, et al., 2013).

5. Results

Political factors

After WWII, the 'Common Agriculture Policy' (CAP) was established, aiming for more food security within the EU. The rules of this policy also apply in the Netherlands. In the 2023, a new *CAP* will be presented, which still focusses on self-sufficiency, but also on sustainability in order to contribute to the European Green Deal. This is the aim of the EU to have a neutral carbon-dioxide emission by 2050, to stop causing further climate change (Europa Nu, 2022).

Recently, the Ministry of Agriculture, Nature and Food Quality presented a vision on crop protection. It is called 'Toekomstvisie gewasbeschermingsmiddelen 2030', and aims for sustainable use of crop protection substances and less dependency on these substances, through a new, more resilient agriculture system by 2030. The Netherlands participate in the Sustainable Development Goals from the UN and this vision is supported by all relevant Dutch stakeholders and contribute to SDGs 12, 13, and 15 (Overheid, 2020)

Economic factors

Since the covid-19-pandemic, some farmers noticed more customers coming to the farmer's shops. However, the high petrol and energy prices are pressing on potato farmers. Producing costs become much higher and organising recreation days for customers with for example a chips stand is also not doable anymore. Putting water on the land in dry periods is also not possible for all fields, due to lack of equipment or employment. It often is just not feasible regarding the revenue that is expected (Farmer 1 & Farmer 2, 2022).

Social factors

The number of residents is decreasing slightly in De Achterhoek in the last years and the demographic composure shifts with a growing amount of elderly, less youth and smaller working population. Together with increased mobility of the average inhabitant, small, local stores disappear, as people travel further to shop in stores with a broader offer of products (Fontein, et al., 2013).

However, local food is getting more popular and local producers also exchange products, to be able to differentiate the offer in their store. People want to be closer to the origin of their food again and this is possible in local stores (Farmer 1, 2022). The potato may have become a less essential part in Dutch meals (Farmer 4, 2022), but it is still a large industry in the Netherlands.

There is unrest in the Netherlands regarding agriculture. Many farmers are angry about the nitrogen policy of the government and there is polarisation and incomprehension between farmers and consumers (WUR, 2022). There is a lack of understanding from consumers regarding farmer's practices and farmers feel unfairly judged. For example, spraying machines are often associated with poisonous chemicals, but they are also used for fertilizers (Farmer 2, 2022).

Recently on the 16th of November 2022, different supermarkets have signed an agreement about selling and promoting resillient potato varieties in the organic section. Additionally, the supermarkets ask for more use of resilient varieties for organic baking and frying products. The agreement is signed by Albert Heijn, Jumbo, Aldi, Lidl, Ekoplaza and Superunie. This is a good step as supermarkets play a large role in educating consumers and influencing potato product suppliers (Dodde, 2022).

Technical factors

The range of crop protection chemicals that can be used is getting smaller. The requirements of the Ctgb become more demanding, as there is ongoing research that reveals the negative effects of certain chemicals. New chemicals are developed, just as new varieties. In the last decades potato breeding programs have not only been focussing on yield and quality, but also on resiliency. In the

first place new varieties were meant for the organic sector, but shortly after, relevance for the conventional sector was also discovered. This caused the research to be supported more broadly, and more and more new varieties are available . Most seed potato suppliers restrict their breeding to traditional practices and do not use genetic modification. This means it takes around 10 years to develop a new variety (Keijzer, 2022).

Wageningen University is doing research on innovative ways of agriculture, regarding less nitrogen use, robotisation, more biodiversity and closed, local resource and waste cycles (WUR, 2022).

Environmental factors

De Achterhoek currently experiences problems due to drought. Not only the time spans of dry weather between March and October become longer in the future, in large parts the ground water level also drops due to more built areas, water collection and intensive agriculture (Fontein, et al., 2013).

This not only provides more stress during growth for potato plants and makes them more prone to diseases, but sometimes it also causes the yield to be half the projected yield (Farmer 3, 2022). However, in the near future this aids accessibility of agricultural land and water for potato cultivation can to some extent be brought on artificially. In reality the problem is experienced very directly by farmers, as not all can access a water source or have the means to water the potatoes. Additionally, the potato root system is relatively shallow till around 60 cm, making potato plants prone to lack of water (Yara, 2022).

Soft winters also seem to become more of a problem. Frost is good for soil structure, as it breaks the ground open again after compaction from machines, but is also kills many pests and diseases present in the soil. It ensures a fresh start the next season (Eising Advies, 2022)

The ‘Beter leven’ label, assessing the conditions for animals in different food chains, has forbidden dairy farmers to rent out land to potato farmers completely (Beter Leven, 2022). Potato cultivation is quite dependant on land trade with dairy farmers and it broadens crop rotation for both parties. The traded land often has grass on it, leaving it with good water absorbing properties. However, together with this trend and without grassland, potato farmers would need to find other ways to keep up a good soil structure. If the structure of the soil is not maintained, drought will eventually make it impossible to still grow potatoes. The main solution is a higher organic matter content in the soil, which stimulates micro-organism populations that create a steady nutrient supply and water absorbing soil structure. A higher organic matter content can be achieved by applying compost, dry manure, a green manure crop, broader crop rotation, deep rooting crops, fixed tracks, lighter vehicles and lower tire pressure. Additionally, soil with high organic matter content absorbs chemicals where they were applied and prevents nutrient and pesticide leaching (Lijster, et al., 2016).

Legal factors

The Netherlands have to comply to many rules from the *CAP* that are established in the EU. This is translated into laws and policies by the Dutch government and change quite often. This causes a very instable legal environment. Most influential are new regulations around nitrogen emissions, which directly hit cattle farmers. It also affects potato farmers as many depend on borrowing land from cattle farmers. The changing rules cause cattle farmers to be reluctant to rent out land, as they have to be very exact with how much nitrogen is used.

There are also rules directly applying on potato farmers, such a harvesting deadline, to promote the sowing of a green fertiliser after potatoes have been harvested. The green fertiliser can take up any

excessive nitrogen from the land and prevent it from reaching ground water or surface water. However, a harvesting deadline is far from realistic, as every year and cultivation is different.

The instable legal environment causes uncertainty and stress in the potato sector.

5.1. Potato farmers of De Achterhoek

For a more reliable image of potato farming in De Achterhoek, 6 farmers have been interviewed about farming practices, chemical use and resilient varieties. All farmers were asked the same questions, but the answers are very different for the interviews consisted of open questions. The results will be presented here, structured by the subjects from the interviews, starting with some general information about the situation of the interviewees.

5.1.1. General results

The following figures show general information of the interviewed farmers. It helps creating an image of every separate business.

Farmer	Soil type	Potato land (ha)	Table potato land (ha)	Cultivation type	Same season crop	Crop rotation	Buyer
1	Sand	8	8	Table	Asparagus, strawberry, kale	Grass, maize, wheat	Shop, Postuma
2	Sand	24	11	Table, starch	Grass	Grass, maize	Shop, Avebe
3	Sand	40	?/40	Table, chips, starch	-	Maize, wheat, sugar beet	Shop, Plus, Jumbo, Avebe
4	Sand	20-30	15	Table, chips	Green manure crop	Grass, maize, asparagus, pumpkin	Shop
5	Sand	250	?/250	Seed, table, chips, starch	Grass, green manure crop	Grass, maize, wheat, peas, carrots	Aviko, Farmfrites, McCain, Interseeds, Den Hartigh, Schaap, STET
6	Clay	60	?/10-20	Seed, table, chips	Grass	Grass, maize, strawberry	Shop, Agrico, Aviko

Figure 13: General information about agricultural business of the interviewees.

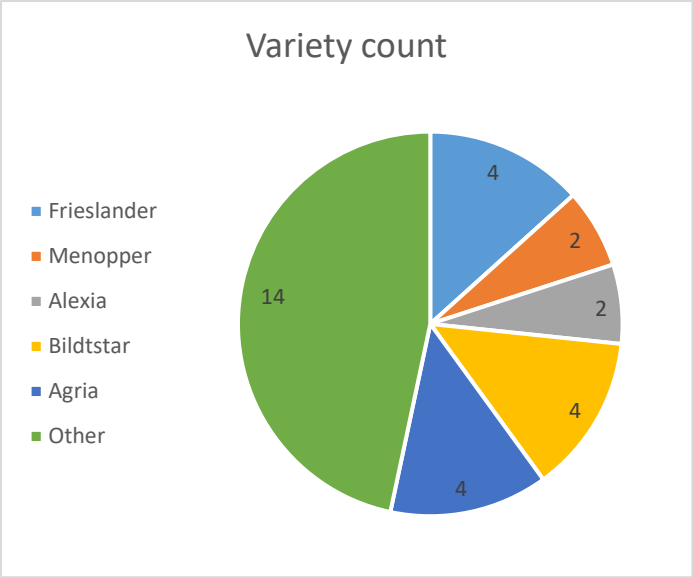


Figure 14: Different varieties and how many farmers cultivate each variety. Varieties under 'Other' were only counted once. These are Alouette, Belana, Bindje, Donald, Doré, Fontane, Hansa, Lekkerlander, Markies, Miranda, Obama, Red fantasy, Venezia and Zorba.

From all grown varieties, Frieslander, Bildtstar and Agria were most mentioned. Frieslander was at every farm used as variety that could be harvested very early. Despite the fact that Frieslander is a traditional variety, *Farmer 4* claims to not use chemicals in its cultivation. This is possible, as temperatures are still too low and the weather too dry for fungi and bacteria to become active. Doré, Donald and Lekkerlander are also early potato varieties. Bildtstar is a well-known variety and Agria is a very flexible variety, suitable for both table cooking and chips. Alexia is also an established variety and the count of Menopper is rather a coincidence, as *Farmer 3* and *Farmer 4* are the only potato growers beside the local breeder that cultivates this potato. Red fantasy is a potato meant to still perform well in dry conditions.

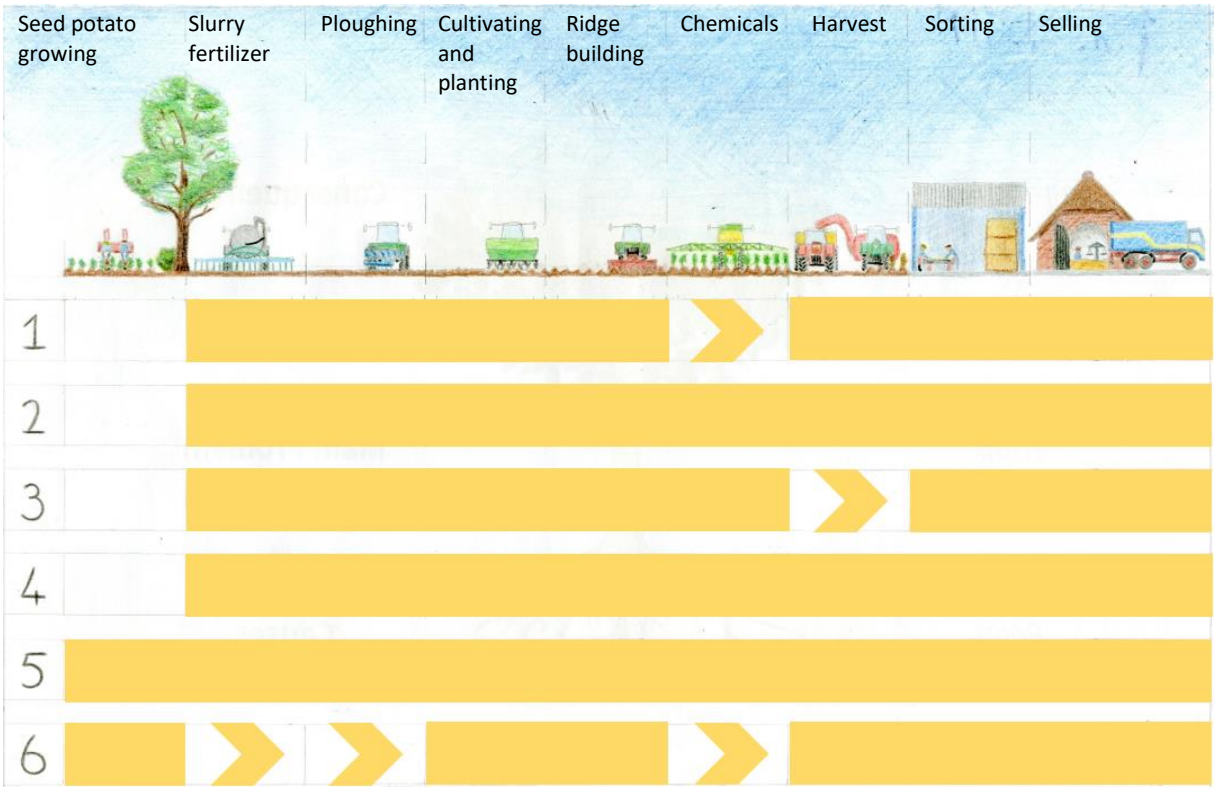


Figure 15: Different stages in potato growing in which every farmer is active. On the left the farmer numbers can be seen, on top the different stages. A full bar represents full involvement, an arrow outsourcing.

In the figure seen above, it can be seen that farmers 1-4 have no cultivation of seed potatoes. *Farmer 4* shares some equipment with another potato farmer on the other side of the village, but is involved in every stage.

Two organic farmers were interviewed. One was farming on a large scale outside of De Achterhoek in the Noord-Oostpolder, in this research called 'Organic farmer 1'. The other had a business with a more horticultural character, called 'Organic farmer 2'.

About the yields of different cultivations, Eising provided the following numbers. As said in the literature review, organic yields are not necessarily lower but differ more per year. The average yield of conventional potato growing in the Netherlands can be estimated on 50 tons per ha, while for organic growing this is 25-50 tons per ha. Sand soil is more sensitive in relation to drought than clay soil. However, if a farmer has the ability to irrigate the land, yields of sand soil are not necessarily lower than yields of clay soil.

5.1.2. Farming in De Achterhoek

Potato growing

In general, all interviewed farmers have a crop rotational system of potatoes once every 4 years and rent land from local dairy farmers. The essence of this trade is that dairy farmers can get rid of manure excess and potato farmers can use the manure and part of the land. In most cases, it is also grass that is sown after potato cultivation because this can easily cover the land in the same season and animals, especially dairy cows, can graze on it. *Farmer 2* even takes care of calves of dairy businesses and has a rotational system with only potatoes, grass and maize. Rest products resulting from the potato sorting process are often fed to animals. *Farmer 6* has seen the development of

potato businesses becoming large, also described in chapter 4.7. At the same time they need proper crop rotation, hence the land trade with dairy farmers.

Farmer 3 is uncertain if maize is the right addition to his rotational system (See Figure 15: Different stages in potato growing in which every farmer is active. On the left the farmer numbers can be seen, on top the different stages. A full bar represents full involvement, an arrow outsourcing.) as it supports survival of soil diseases. However, when in need of land, there is not much choice than to exchange land with dairy farmers that often put maize there.

This trade between potato farmers and dairy farmers, very common in De Achterhoek, is under pressure though. According to *Farmer 2,* some dairy farmers get reluctant of such concepts as they do not wish to be bound to certain rules and regulations in the current policy. Additionally, *Farmer 6* points out the rules about nitrogen do not really accomplish their goal. By the rules, farmers start with applying cow manure and there is a limit for this. After this limit is reached, it is allowed to apply chemical fertilizer, while this contains almost two times the nitrogen concentration of cow manure. *Farmer 5* believes that many rules are made to serve a certain goal and that there is too little knowledge about how the rules turn out in practice.

Different table potato varieties are chosen in regard to costumer demand in the first place. This is to secure more certainty that the potatoes can be sold. For all that have a farm store, the aim is to be able to offer a difference in cooking type all year round. After the type, the colour in relation to the soil is important and then the aim of cultivation and variety properties.

Farmer 1 buys all seed potatoes, as it saves space on the land and it gives flexibility in choice of variety. He also does seed preparation before planting the potatoes under foil.

Farmer 6 does not apply sprout inhibitors because this interferes with the sprouting abilities of the seed potatoes that he keeps in the same storage facility.

Farmer 3 states that one can take more risks in starch potato cultivation, as the requirement standard is lower and the potatoes are picked up quite soon after harvesting. In this cultivation also less chemicals are applied and *farmer 2* is experimenting with putting resilient varieties among these starch potatoes, to create more value.

Farmer 4 does not use herbicides before harvesting to kill potato plants, but just haulm topping. He believes there is no risk when doing it on a hot summer day, on which the stems dry out and die very quickly. Most other farmers use herbicides in this stage to prevent *P. Infestans* from entering the stems.

The wireworm is quite a problem consumption potato cultivation. It eats tunnels in potatoes, leaving the potato unsuitable for offer. In the past there were some chemicals against wireworms, for example Mocap, but since they have been prohibited, it is hard to meet the requirements for chips potatoes. *Farmer 2* still tries to sell affected potatoes by explaining it to customers, not always with success. A solution to prevent damage by wireworms is to start growing potatoes early under foil. Wireworms together with many other pests and diseases are not active yet then. According to *Farmer 3,* another measure is leaving the land fallow after harvesting, so hopefully wireworms do not survive winter. There is the presumption green manure crops stimulates growth of wireworms and other larvae. *Farmer 4* is experimenting with applying garlic granulate before sowing to repel wireworms, with different results until now. Wireworms do not form a problem for starch potatoes, as aesthetic requirements do not play a part here.

Also nematodes seem to thrive on green manure crops. *Farmer 5* does only apply these crops because of regulations. Nematodes or *Potato fatigue* are especially a problem for seed potato cultivation.

The Colorado beetle is not so much a problem in conventional growing and is easily controlled with insecticides. In the same way with aphids, mineral oil also works against the Colorado beetle. However, *Farmer 6* is trying to spray as little as possible and developed a mechanical way of controlling the beetle. Driving on a tractor through the field, a rubber flap in front touched the plants, after which many beetles fell out of the plants onto the ground. The tractor would ride them over, and at the rear equipment would rebuild the potato ridges, burying beetles that had fallen on the slopes. The experience was that the beetle population could be kept at an acceptable level. In organic farming, some insecticides are also allowed, such as NeemAzal, which also works well, according to *Organic farmer 2*.

For aphids the alternative for mineral oils could be a very fine net, but this can be difficult to apply on a large scale, as it takes many working hours to set the nets out.

Inputs

Only *Farmer 5* waters all potato fields regularly and has the means to do so because of the scale of the company. Others can only irrigate parts of their land and are forced to differentiate between the end uses of the potatoes. As consumption potatoes provide the most revenue, these are often chosen for irrigation. *Farmer 2* also has a variety that can withstand drought, but is also thinking about what otherwise can be done with the drier parts of the land. *Farmer 3* doubts the influence of watering on sand soil and uses it more to cool the plants down, which can also be beneficial for the plants. For 1/3 of the consumption potatoes, *Farmer 4* uses a drip irrigation system and indicates his position high above the 'NAP', relying more on water from above.

Before planting the seed potatoes, most farmers begin fertilizing the land with cattle manure slurry and when the potato plants are growing, farmers analyse the status of the crop. From this, conclusions can be drawn and the right minerals can be applied to support the crop in the short coming nutrition. Other minerals mentioned are 'KAS', containing calcium and ammonium, 'NPK', containing nitrogen, phosphorus, and potassium and 'Kali', which is potassium.

About half of the interviewees says to also do mechanical weeding, but spraying herbicides is the main way of controlling weeds. However, with none of the interviewees herbicide application seems to exceed 2 times per growing season because regulations and lack of necessity. Herbicides are often applied preventive around the time of planting. After that it is sometimes necessary to intervene again, but later weeds are not a problem anymore, as the potato plants cover all soil. Earlier in the growing season weeds are not yet developing so much. For *Farmer 6* weeding is harder to do, as the clay soil is often too hard after the ridges have been formed for a weeding machine to perform properly.

Application of fungicides really depends on the character of the growing season. When it is a dry summer, most farmers already spray very little with fungicides. The conditions are so unfavourable for fungi, that farmers can be sure there is no risk of their development. It saves costs, which is welcome when drought presses on the yield. According to the experts, it comes down to spraying fungicides 12-16 times per growing season (Jacob Eising).

Organic farmer 1 points out sowing a crop that can be mowed after potatoes have been harvested is a good way to clean a patch from any remaining potatoes, capable of carrying diseases.

Costs and benefits

The highest revenue is achieved by selling table potatoes and 5 farmers do this at the farm itself. However, this production also brings the highest costs due to higher quality requirements which means more inputs and more thorough sorting and packaging. A storage facility is also necessary and 2 farmers have mechanical ventilation, while 4 farmers even have cooling facilities. *Farmer 2* used to source storage out elsewhere, but has now invested in a cooled storage room himself. The process of table potatoes takes up so much time and effort that *Farmer 3* thinks his son will have to specialise in one cultivation type, in order to keep working efficient. *Farmer 4* also says the demanding production of table potatoes was the reason to not grow chips potatoes for Aviko anymore, together with the increasing price of table potatoes.

Nevertheless, the 5 farmers with a shop claim it is an important source of income and it brings many other benefits. It gives freedom of variety choice and setting prices, it encourages customer loyalty and it divides the income over multiple sources, mitigating impact in case of economic shocks.

Farmer 5 thinks crop protecting chemicals make up for 13-14% of the total costs in production. All farmers would be happy to use less pesticides. However, *Farmer 4* claims seed potatoes of resilient varieties are also more expensive and there is a waiting list for them. He also says herbicides are expensive and *Farmer 2* points out new chemicals sometimes need to be applied 2-3 times more than older chemicals that have become prohibited, which makes chemicals extra expensive. The same goes for herbicides, so they have to be applied a couple of times during different growing stages. One round of such a herbicide is often 30-40 euros per ha and reduction is most welcome.

Sale possibilities

As mentioned before, almost all farmers have their own farm shop. *Farmer 3* also provisions local Plus supermarkets and others using the network of 'Van Onze Grond'. 2 Farmers supply Avebe with starch potatoes and 2 other farmers supply wholesale companies, with both seed and consumption potatoes.

About customers at the farm shops, *Farmer 4* says that most are 45 years of age or older and ¼ is younger than that. They are different types of people that all come for the quality of his potato. *Farmer 3* believes consumers can be influenced to some extent and the right education will help consumers to choose for different ways of cultivations or varieties. According to *Farmer 2,* the covid-19 pandemic has resulted in more customers. In their shop they are also explaining the damage of the wireworms, but not all people can understand these imperfections. They also organise, just as *Farmer 1,* open days on which people are informed and can harvest potatoes themselves. People pay for the experience and it is a profitable concept. *Farmer 2* points out the time of re-entering of chemicals plays part here though. It is the time after a chemical has been supplied and no health risks are present anymore.

Producing for wholesalers is a very different matter. In advance the amount of tons a farmer needs to deliver is recorded in a contract, but not the price. The requirements of wholesaler depend on the offer there is on the market. If the offer is scarce, the requirements will be readjusted and be less demanding to also accept potatoes of lower quality. Abundance in offer causes adjustments to requirements for higher quality. This causes many potatoes to be rejected and *Farmer 6* believes this freedom gives wholesalers such as Aviko too much power within the chain. With pressure of other chain actors, such as supermarkets, this could change.

Vision

Farmer 1 observes the trend of people wanting to have more contact with their food sources. He sees his future also more in the shop and interaction with customers than in the more conservative

way of farming and would like to bring customers even closer to the origin of their food. Also *Farmer 4* sees the increase in demand for locally produced products, but also acknowledges the fact that the potato becomes less popular in nowadays' dishes. His aim is to diversify the products he has to offer. Additionally, he would like to make part of his business certified as organic. Resilient varieties are going to play a large role here, but for the farm to become completely organic, there is too little staff to weed and there is also less demand for organic products among his customers. About the combination of organic and conventional farming on one farm, *Farmer 6* says it is hard because the risk of residues of chemicals among the organic potatoes is too high. His experience with the monitoring of SKAL was that they are often reluctant of the combination beforehand and there was lack of trust in his practices.

There are also many factors pressing on the business though. *Farmer 2* points out drought of the last 5 years and the less unreliable weather in general. 'During dry periods we do not water the starch potatoes and with that we miss out on 300 to 350 tons (of 13 ha). That is about 20000 euros.' The inconsistency of temperature during winter is also detrimental for storage purposes, as potatoes stay best under stable cold and dry conditions. Therefore, storing over winter with only mechanical cooling and ventilation systems is becoming less reliable.

In this environment, especially resilient varieties can contribute to a solution. At the shop of *Farmer 1,* where demand for organically produced products grows, resilient varieties would fit. He said:

> *'If the new variety is of good quality and not too expensive, it is most welcome! Rather today than tomorrow.'*

He is also experimenting with Sweet potatoes and it is quite a success. *Farmer 2* has been growing 3 new resilient varieties among starch potatoes. Cooking and storing properties are still to be rated and will determine which one is going to be planted next year. For *Farmer 3* and *4* the Menopper was not really a success yet, according to the grower due to the dry weather. The result was damage from the Y-virus, carried by aphids.

Some obstacles for *Farmer 4* are the long queues in order to get resilient varieties and the relatively high price. One has to pre-order such varieties about a year in advance. He would be happy with a resilient variety for later in the season, when fungi are very active. *Organic farmer 2* says the pressure of *P. Infestans* also causes the offer of resilient varieties to be small in comparison to drier years, in which there is enough offer. Eising adds that breeding takes some time and is very costly and a breeder needs to earn these costs back with a licence fee on all potatoes that are sold from that variety. Besides, costs of planting also depend on the distance between the seed potatoes. *Farmer 5* is for seed potato production more searching for resilience against viruses than against *P. Infestans* and says Avebe has some available.

Farmer 3 also wishes to be less dependent on pesticides and also would like to have a good solution against wireworms. *Farmer 6* believes more willingness from consumer, supermarket and farmer could really accommodate the change to more resilient varieties. He thinks lower pesticide usage is in particular economically appealing for farmers. Beside resilient varieties, more knowledge about pesticides and manure would also help development.

Farmer 6 has now grown the Alouette, a resilient variety from Agrico, for two times. The first time in 2021 without pesticides, unfortunately resulting in a low yield of about 25 tons. The second time last season, with having sprayed against *P. Infestans* 4 times a full dose on moments he thought were crucial for repelling the fungus. The Colorado beetle was again controlled mechanically, already mentioned earlier. The yield of 2022 was normal and had not been affected by *P. Infestans.*

5.2. Potato trade in De Achterhoek

5.2.1. Chain actors and varieties

Here all chain actors mentioned in the interviews in De Achterhoek are sorted. Resilient varieties they have in stock are also taken up in the table.

Supplier	Resilient variety	Other involvement
Agrico	Alouette	Also supplies consumption potatoes
Den Hartigh	Nola	BioImpuls
Hof Balkbrug		
Schaap		Also supplies consumption potatoes
STET		Also supplies consumption potatoes
Interseed		
Averis Seeds BV		Is daughter company of Avebe
Europlant BV		

Buyers of consumption potatoes are supermarkets, such as Plus. The supermarkets source table potatoes directly from farmers within the Netherlands. Other companies make products out of potatoes, such as baking potatoes or chips. These are Aviko, FarmFrites and McCain. A processing company for starch potatoes is Avebe. The industry is more about the nutrients and the potatoes do not really keep their recognisable form. Agrico was mentioned 2 times, as well as Aviko and Avebe. For inputs, there is Agrowin in Winterswijk. It is a supplier for all kinds of inputs, from fertilizers to pesticides.

Here are the seed potato suppliers and varieties of *Organic farmer 1.*

Supplier	Resilient variety	Comments
McCain	Sarpo mira	Deep rooted, drought resilient
Agrico	Twister, Twinner, Carolus, Alouette	
Geersing	Cammeo	
Europlant BV		
Plantera	Vita bella	
	Sevilla	

5.2.2. Locations with potato sale

Beside to the farmers' own shops, excess of table potatoes is sold by *Farmer 1* to wholesaler 'Postuma'. *Farmer 3* is member of 'Van Onze Grond', a network of farmers delivering their products to local supermarkets. His potatoes can be found in many supermarkets of Plus and Jumbo.

5.3. Resilient potato varieties

Beside resilience, yield properties are also important for a variety to become successful. New varieties need to be at least as profitable as currently used varieties, as otherwise there is no economic interest from growers in the potatoes. If these two requirements are met, new varieties have to pass the last station in the value chain, yet the most important one, namely the consumer. Consumers are very used to and prefer certain smells, textures, aesthetics and quality and are not fond of change. Even if a potato is delicious, marketing needs to make consumers aware of it and persuade them to try it. If no sales can be made with it, there is also no reason to invest in a new variety. Large brands of wholesalers, such as McCain from Canada, are intensively involved with new

variety development to ensure stable demand from consumers. Agrico is also breeding new varieties and also has most gene sources in the Netherlands.

Development of new varieties is also propelled out of the interest of organic organisations and the sustainability trend in society. In the Netherlands, there are now three organisations testing many different varieties, namely 'Pootaardappelacademie Zuid-West', 'BDEKO' and 'BioWad' in the South, middle and North of the country (Jacob Eising 13-07-2022).

5.3.1. CRISPR-cas

The allowance process of GMOs is too time consuming and the label itself is unappealing to invest in GMOs. Additionally, seen the current course from the EU directed at sustainable and organic farming, CRISPR-cas does not fit this picture. Cross-pollination between GMOs and organic crops would occur and the previously organic crop, could not be sold as organic anymore. Without the right laws, this would mean huge losses in revenue for organic farmers. Eventually, it would become impossible for smaller breeding and organic companies to compete with large companies using CRISPR-cas and their patented varieties. Therefore, if CRISPR-cas would be allowed more regularly, at least the responsibility for any contamination with other crops should by law be with the companies providing these GMOs (Keijzer, 2022).

5.3.2. Breeding

An actor in variety breeding in the Netherlands is BioImpuls, and is a collaboration of the public and business sectors. The project develops genitors, which are varieties that own both resilient genes and have commercial potential. Other breeders need to refine these varieties and make them commercially available for the potato sector. BioImpuls started mainly for the organic sector, but shortly after advantages for conventional cultivation were acknowledged, which also formed a good argument for more governmental support. In 2012 'Nola' was presented and is one of the 38 resilient varieties available. The many different varieties also help containing the risk of rapid spread of diseases. However, most resilient varieties are still relying on one immune gene and BioImpuls is now working on varieties with way more genes. Jacob Eising, a potato variety expert, explains it as follows: '*To open a door, one needs the right key. The more locks on the door, the smaller the chance one has all the right keys to open it.*' Therefore, resistant properties are much more effective if combined in one variety (Keijzer, 2022).

Alongside the breeding programs, research is done on gene recognition. The goal is to discover gene series and link them to certain properties, with resilient properties being prioritised. If a valid link is discovered, it can be used as a gene marker and can make breeding way more efficient. Especially when working with multiple resilient genes, from experiments it is hard to know how many of these genes a plant has, as for example *P. Infestans* could be stopped by one gene. A data base with all these markers could not only help research within BioImpuls, but as half a business project it could also provide a gene check service for breeding companies. They can send a sample of their own varieties and BioImpuls could tell what genes it contains (Keijzer, 2022).

Given that most varieties only have one resilient gene, it is still advised to spray at least 3 times per growing season against *P. Infestans*, to maintain immunity and prevent the disease from mutating. Would such a mutation survive over winter, it could find its way around the immunity and decades of breeding and the most of the resilient varieties would go to waste. Like organic farmers, conventional farmers should also check on their crop regularly to discover diseases as soon as possible. These practices make cultivation still more sustainable than using varieties prone to *P. Infestans*. In Germany, the organic sector does not approve the use of varieties with only one gene,

pointing out the possibility of *P. Infestans* becoming more flexible. However, here copper is still being used against the disease (Keijzer, 2022).

Within BioImpuls, research is also done regarding the seed potato sector. Here the focus is mainly on immunity to viruses. This is a relatively young research, as the Netherlands are large in seed potato export, so having resilient varieties would hit crop protection businesses and would endanger the monopolistic position of potato breeders. Research on immunity against *Alternaria* is not prioritised, as organic farmers often have a crop rotation of 7 years, so do not experience problems with this pest (Keijzer, 2022).

5.3.3. Local market

According to Keijzer, other than BioImpuls, Agrico has most sources of resilient genes and develop many new varieties. *Farmer 6* is growing one of these varieties, the Alouette, supplying Agrico for export of seed potatoes to Algeria, but also keeping some for his own cultivation. Using the Alouette for his own cultivation, Agrico still receives part of the revenue generated with this variety, as Agrico has patent on it. Eising says McCain is also very active in moving towards a new way of agriculture, with resilient varieties also playing a large role. *Organic farmer 1* is growing with the Sarpo Mira, a resilient variety from McCain with also good resistance against drought because of a deep root system. Another breeding company that was mentioned in the interviews and collaborates with BioImpuls is Den Hartigh and is marketing the resilient Nola, mentioned earlier. Despite the many resilient table varieties, there are not yet many chips varieties. This is simply because there is still not much demand for processed potato products of organic origin.

Many of the interviewed farmers had a farm store and was an important part of their income. People like local food and the customers seem to be quite loyal, as also *Farmer 4 experiences.* Many farmers are also trying to have the least impact on the environment and also use this for marketing. *Farmer 1* indicates the sustainable aspects of his cultivation in his shop and *Farmer 6* developed his own branding by calling the cultivation of Alouette 'Vrijlogisch', a Dutch wordplay implying it is almost organic.

5.3.4. Research on chemical use

Although these measures are being applied, researchers still find pesticides far from the fields where it was applied. Beside drift, evaporation of chemicals into the air play a large role in this spreading. Additionally, with dry weather, dust from the soil is blown away by the wind, also transporting pesticides. Especially pesticides in the air can travel far and are being inhaled by farmers and local residents and make skin contact. None of these ways of spreading are taken into account by the Ctgb, which is only focussing on theoretical drift directly after application by wind. Wood banks and hedgerows, also found in De Achterhoek, seem to help a little to contain drift rate, but also in these cases pesticides are found 4 km away from where they were applied (Nijland, 2022).

5.3.5. Less pesticide use and conventional potato growing

Implementing resilient varieties in the current and most conducted way of potato growing, would result in more or less the same agricultural practices, but with less pesticide use. The emphasis in this cultivation would be more on primary and preventive measures against *P. Infestans,* derived from the organic sector, without yield loss. Trust needs to be shifted from reliance on secondary and curative measures, to reliance on resilient varieties. From the interviews, the following practical measures became evident:

- Aim for a healthy soil
- Store potato heaps as far away as possible, properly sealed

- Mitigate the risk of surviving diseases on a patch that is going to be sowed, this can be done by for example low-intensity crop rotation, leaving land fallow over winter or follow potato cultivation up with for example clover or grass, which can be mowed, also destroying surviving potato plants
- Check seed potatoes thoroughly on deviations
- Plant seed potatoes that are in optimal physiological condition
- Monitor the field regularly when the potatoes are planted on deviations
- Watch the weather closely for conditions favourable for *P. Infestans.*
- Use decision making devices

For potato cultivation with an early harvest, there is the following:

- Give seed potatoes a head start by doing seed preparation
- Choosing varieties that can be harvested early, evading the high pressure of *P. Infestans* later in the season

In chapter 6.3 these measures are complemented with practices gathered from literature. According to the experts, it is possible to reduce the times of applying fungicides to 4-8 times per growing season, at least 3 times. When risk of spreading of *P. Infestans* is too high, apply a fungicide. When spraying fungicides, it could be useful to differentiate between areas in the field based on risk of spreading of fungi. Areas alongside a treeline for example, stay wet longer, making it easier for fungi to develop hear.

5.3.6. Feasibility

Though it is key to also communicate the way of cultivation to the customer as a unique selling point, the decrease in used pesticides can also be a reason to change practices on its own because it saves costs. The extra revenue is only possible if the seed potatoes are non-organic, as organic seed potatoes are expensive, seen in Annex 10.2. From an economic perspective, cultivating completely organic potatoes is only profitable if they can be sold as organically certified or if customers can be persuaded about the applied organic practices.

According to the experts, 12-16 or 15 times fungicide application per season is average. Their advice while growing with resilient varieties is to apply fungicides 3 times still. Assuming that in this way of potato growing fungicide application can decrease to 4-8 times, it would be possible to also make this visible in costs. Here the experience of *Farmer 6* with the Alouette of spraying 4 times is not yet taken into account because this was a For this calculation again data from Annex 10.1 is used. In this data, a growing season with average conditions was taken as starting point. Therefore, the average number of the expert information is taken for the calculation, for the quantitative data does not say how much rounds are sprayed with fungicides, only quantities.

$$\frac{12 + 13 + 14 + 15 + 15 + 16}{6} = 14.17 \approx 14$$

To be able to determine the average new amount of times of fungicide application, the median of the expert information is taken, so this is 6 times.

Working chemical	Sort	Quantity (kg/l)	Cost (€)
Oxamyl (10%)	insecticide/nematicide	10.00	145
Metribuzin (600)	herbicide	0.25	12
Mandipropamid (250)	fungicide	2.40	96
Benthiavalicarb-isopropyl (70), oxathiapiproline (30)	fungicide (zorvec)	1.20	108
Fluopicolid (62,5), propamocarb (625)	fungicide	4.80	98
Cyazofamid (160)	fungicide	2.00	102
Pyraflufen-ethyl (26,5)	herbicide	0.80	47
Carfentrazon-ethyl (60)	herbicide	0.50	26
Orange oil (99,91%)	insecticide(bio)	3.13	58
Metribuzin (80), prosulfocarb (800)	herbicide	5.00	78
Prothioconazool (125), fluopyram (125)	fungicide	0.45	22
Difenoconazool (250)	fungicide(systemic)	1.00	48
Lambda-cyhalothrin (100)	insecticide	0.10	13
Acetamiprid (20%)	insecticide	0.25	30
Mineral oil	insecticide	0.20	1
Total			884
Fungicides total			474

Figure 16: Different used crop protection chemicals in a consumption potato cultivation in sand soil (WUR: Open Teelten, 2022)

Together with the cost of fungicides from the quantitative data, which is €474,-, the amount of application is brought down from 14 to 6 times, regardless of what working chemicals are used. All fungicides are summed up with their prices and are decreased proportionally. This results in the following calculation and shows in theory what a decrease in fungicide use would save in relation to conventional farming:

$$(1 - \frac{6}{14}) * €474 = €270{,}86$$

With this practice, €270,86 could be saved on fungicides per ha. Additionally, less field rounds would result in less gas use by tractors. This saved budget should be spend on resilient variety seed potatoes.

6. Discussion

6.1. General observations

Seed potato cultivation used most kg of working chemicals in 2016, but this mostly consisted of mineral oil. It is hard to say objectively if this cultivation is really more polluting than for example table potato production regarding pesticides, as mineral oil on itself does not have a toxic chemical in it. Nevertheless, mineral oil is not selective and seed potatoes are sprayed with this coating often.

From literature, the researcher got the impression that the choice of variety was determined what was the best for the type of soil and climate. It became clear from the interviews that it was customer demand that determined the choice of variety in the first place. In hindsight this seems logical, as there is no reason to grow potatoes when there is no demand. This makes properties of a variety, such as baking colour, peeling qualities, taste and texture, very important.

From all 6 farmers, 5 had a farm store. All stated that it took most effort and time, but at the same time it gave most revenue. As mentioned before, it gives more independency and flexibility, binds customers and having an extra source of income makes farmers more resilient to economic shocks.

Some farmers point out to sometimes spray against *P. Infestans* only 2 times per growing season in dry years, while the experts give the mean of 12-16 or 15 times per growing season. The farmers making this claim had among other varieties also varieties for early harvest on their land. This makes it indeed possible to spray very little or even nothing, as done in organic cultivation. However, it could also be an evading strategy, as only few of the farmers gave an elaborate answer on how many and when pesticides were used. Pesticides are subject to critique from society and farmers also wish to not use them and it could be they would like to leave a good impression. All farmers confirmed to use pesticides, with *Farmer 3* using an advice system, and *Farmer 4* describing quite detailed what was used.

A difference in perception of the risk of disease during haulm topping between *Farmers 3 and 4,* was also perceived. *Farmer 3* said to take no risks regarding consumption potatoes and always sprayed a herbicide to kill the plants before harvesting. This way the potatoes separate themselves from the plant and the harvest machine can process the plant material. *Farmer 4* pointed out when haulm topping is done in summer during a hot day, the stems dry out quickly enough and there is no danger from fungi. Two weeks later he would be able to harvest the potatoes. This difference seems to be based on personal view, as there was not really a difference in type of cultivation. However, maybe different harvesting machines are used or the harvesting date is different.

The future is also perceived differently. Some farmers are quite positive about the future and are trying to adapt to the new environment of climate and course of the government. Others are indifferent or negative about the future. The situations are very different per farmer, which may declare the differences in perception, but it is still interesting. Nevertheless, the farmers are trying their best to keep growing potatoes in the changing environment.

There is also a difference in tactics for the future. Some are trying to diversify their products to be more flexible, in contrast to others who specialise in certain products. It depends on the scale of the business and the role of the farm shop in it. Large companies can supply large quantities and specialising can secure even better quality. Diversifying is probably more relevant when there is a loyal customer base, that want different products and more sustainable cultivation practices.

6.2. Drought

During the research, drought came out as a very large problem, but it was not a research subject. Although it is in itself effective against *P. Infestans,* it has influence on many things, especially on sand soil and it may be the most important issue beside pesticide use to tackle. Different farmers stated that yields on sand are directly affected by drought with half of the projected yield as a result, for only 2 out of 6 farmers could irrigate all of their land. Indirectly, it also causes stress for potato plants, resulting in lower resilient qualities. Irrigation is a good solution on the short term for those who have the means. However, taking care of the soil is a more sustainable way of making potato cultivation drought resilient. A healthy soil is loose and has organic matter and micro-organisms in it, providing better water uptake, less pesticide leaching and healthy, more resilient plants. Because of the shallow rooting of potato plants more extreme weather conditions, they are often dependant on rain or irrigation and a soil that can take up water as much and as fast as possible is essential.

6.3. Less pesticide use and conventional potato growing

Chemical use still has negative effects on the environment, but using less is also progress. Using less pesticides is in this case resiliency management and the resilient genes stay relevant. Until varieties with more resilient genes are available, this is the most sustainable way of conventional farming. This makes these practices temporarily.

Desk research and results from the interviews with experts and organic farmers, provide the following list of measures, which should make growing resilient varieties successfully possible:

- Aim for a healthy soil
- Try to keep the resilient properties of the plants as high as possible by optimising water and nutrient supply (Bremer, et al., 2007)
- Store potato heaps as far away as possible, properly sealed
- Mitigate the risk of surviving diseases on a patch that is going to be sowed, this can be done by for example low-intensity crop rotation, leaving land fallow over winter or follow potato cultivation up with for example clover or grass, which can be mowed, also destroying surviving potato plants
- Check seed potatoes thoroughly on deviations
- Plant seed potatoes that are in optimal physiological condition
- Monitor the field regularly when the potatoes are planted on deviations, also in consumption cultivation
- Watch the weather closely for conditions favourable for *P. Infestans.*
- Use decision making devices

For potato cultivation with an early harvest:

- Choosing varieties that can be harvested early, evading the high pressure of *P. Infestans* later in the season
- Give seed potatoes a head start by doing seed preparation
- Built up ridges later to stimulate faster growth (Hammink & Van Loon, 2009)

It is possible to reduce the times of applying fungicides to 4-8 times per growing season. When risk of spreading of *P. Infestans* is too high, apply a fungicide. When spraying fungicides, it could be useful to differentiate between areas in the field based on risk of spreading of fungi. Areas alongside a treeline for example, stay wet longer, making it easier for fungi to develop here. Adjusting spraying dose can also be used as a fine-tuning tool.

However, especially when there is little experience with this way of cultivating, it can pose a larger risk for farmers. It is unclear whether or not the benefits of less production costs will outweigh the uncertainty of farmers, placing their trust in unfamiliar potato varieties. *Farmer 6* plays a crucial role in this, as he has already grown potatoes this way successfully. Some farmers say to spray way less in dry years and resilient seed potatoes are more expensive. Therefore, it is also a question if they would like to make use of resilient varieties, regarding the drought and with that less pressure of *P. Infestans,* which makes it less necessary to make use of resilient varieties. In those cases it could probably give more revenue to stick to old varieties. However, wet periods will always exist and always growing the same varieties is probably more comfortable than switching often. Additionally, the character of seasons is impossible to predict.

6.4. The consultation

On the 1st of March, a consultation was held on Nelles. Present were *Farmer 3 and 4* and three other interested individuals. Here are the outcomes of the consultation.

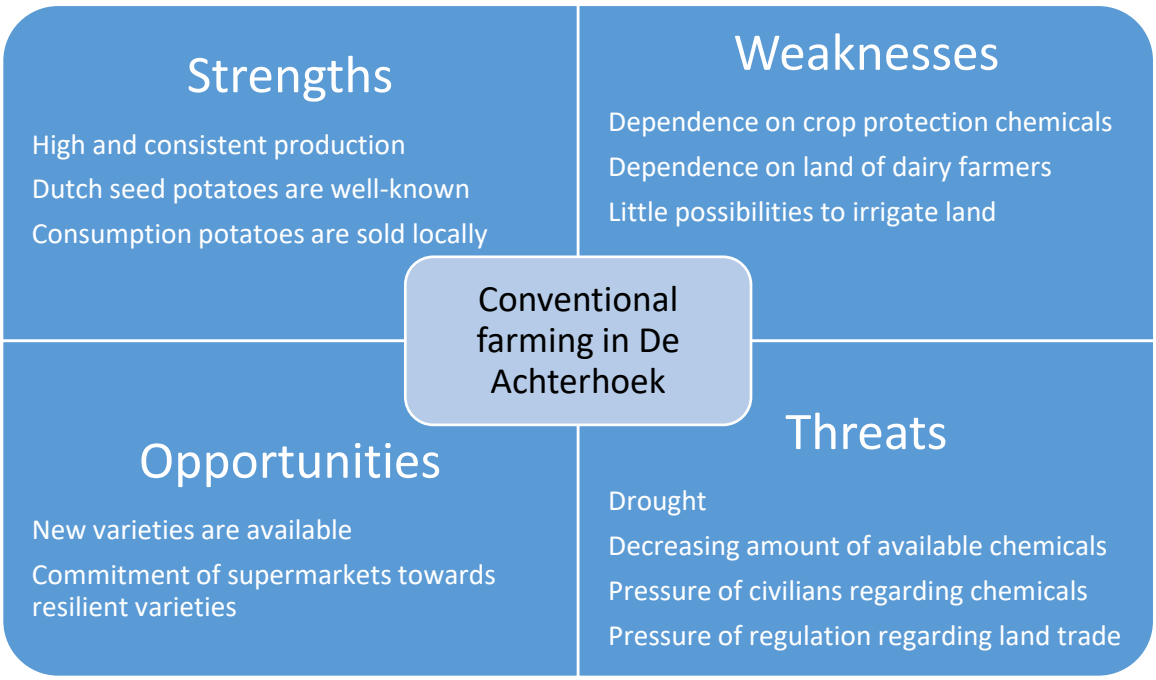
Regarded purely economic, it is possible to grow a resilient variety and pay it extra price with the money saved on crop protection chemicals, given the resilient variety is bred non-organically. Organically grown seed potatoes are more expensive and the savings on costs would never be enough to afford these varieties. Resilient varieties are also interesting for starch potato cultivation, as here the plants are already sprayed less and the risk of yield failure is lower as the revenue generated from starch potatoes is also lower.

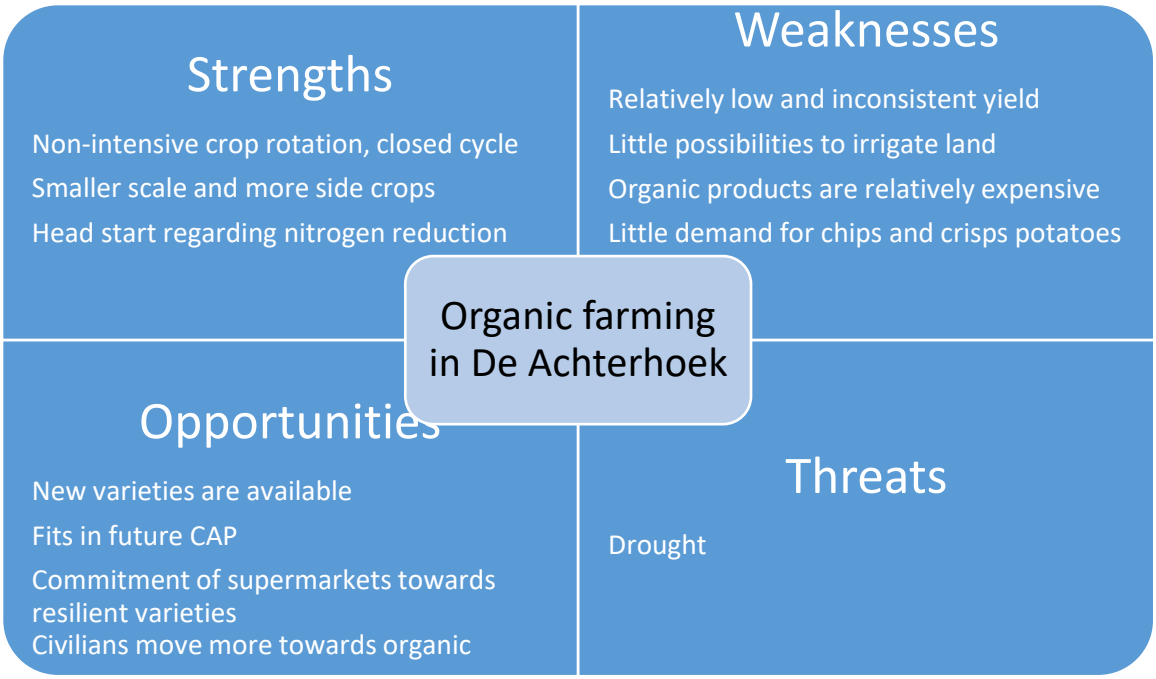
The consultation session also brought new ideas about how to offer resilient potatoes. The first and most important was that the taste of a resilient variety should be good. Then there are some customers that only buy a certain variety and do not alternate. Customers searching for more organically produced potatoes also seem to be more familiar with irregularities, so this segment could be a good starting point. Offering more sustainably produced potatoes next to conventionally grown potatoes can cause doubts about the latter. This has also been discussed and the conclusion was that the focus would be more on the local character of de Achterhoek and the tough image of resilient varieties, rather than on less chemical use. Additionally, there is again part of the customers that will stick to one variety, no matter how it is grown, so introducing resilient variety would not endanger sales of conventional potatoes.

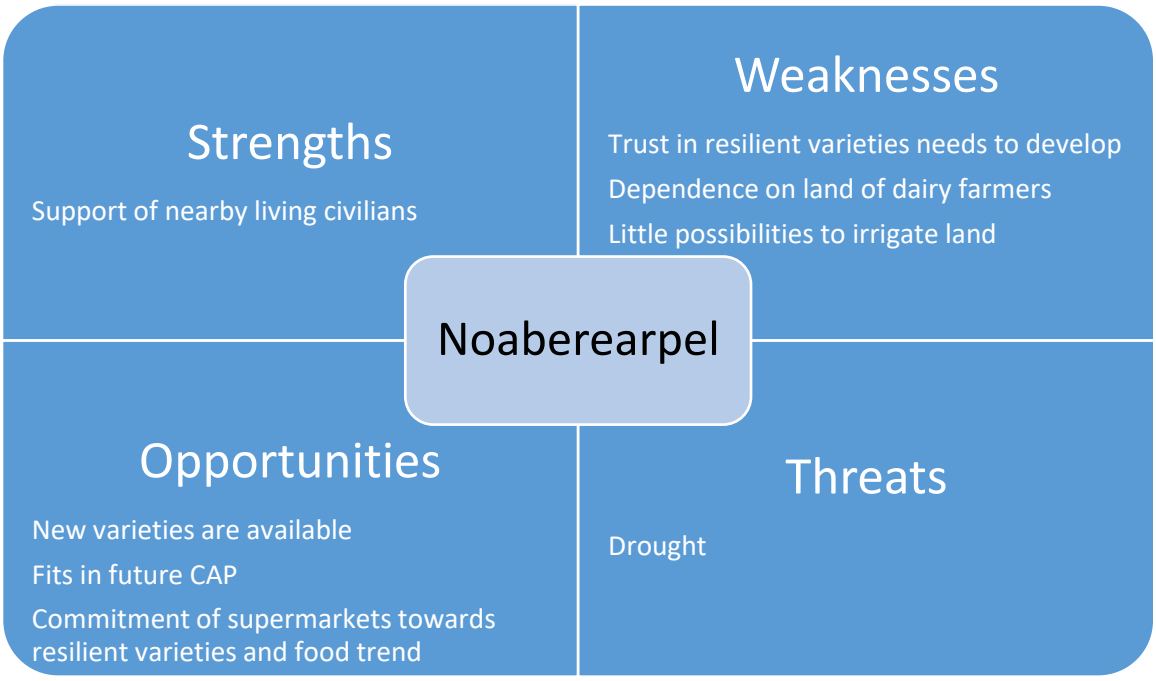
The proposed measures to mitigate the effects of drought cannot really stand a chance in such extreme dry conditions. Beside drought, also the intense heat is pointed out as being unforgiving, regardless the measures taken.

7. Conclusion

All information resulted in the following SWOT-analyses of conventional farming, organic farming and conventional farming with resilient varieties, or 'Noaberearpel'. Basically, conventional farming with resilient varieties takes the best of organic farming, but without the inconsistency and uncertainty of yield.







The main research question was:

> *How can alternative production with resilient potato varieties be feasible in comparison to conventional consumption potato production for the local market for arable farmers in De Achterhoek?*

This question will now be answered by summing up results answering the sub-research questions.

1. *What is the current situation of potato production in De Achterhoek?*

Conventional consumption potato growing was responsible for most working chemicals in kg in The Netherlands, followed by seed potatoes. Looking at all different potato cultivations, fungicides make up the largest part. De Achterhoek has more seed potato cultivation, in which more kg of pesticides

are used including mineral oil, in comparison with the Netherlands. In general, agricultural business are somewhat smaller compared to the Netherlands, but some companies have become very large in De Achterhoek. Large buyers of seed potatoes, consumption potatoes and starch potatoes are Agrico, Aviko and Avebe, in that order. Most potato farmers rely on trade with dairy farmers for land in order to maintain a sufficient crop rotational system. Most of the soil consists of drought-sensitive sand and former grassland increases its fertile properties. Drought has become a larger problem, which presses on yields, soft winters cause more surviving pests and together with heavy machinery cause soil compaction and lower ground water level makes the shallow rooting potato plants dependant on rain water and irrigation. Many farmers do not have the means to irrigate all their land.

From society, also many factors influence farming practices. The *Beter Leven* label prohibits the trade between potato and dairy farmers directly. The EU and the Dutch government are aiming with the *CAP* and the *Toekomstvisie gewasbeschermingsmiddelen 2030* for less pesticide use, more organic production and national regulations are inconsistent. Also consumers seem to be more concerned with their food and would like more sustainable food. It provides opportunities for farmers but also causes lack of understanding between farmers and civilians.

2. *How can potato production with resilient varieties take place in practice with the least pesticide use?*

The resilient potato varieties with one resilient gene are already widely spread among organic farmers. Implementing resilient varieties in conventional cultivation reduces the times of fungicide application and adopts some practices from organic farming in order to keep yield assurance. According to the experts, spraying 4-8 times per season against *P. Infestans* would be enough in most cases, at least 3 times. This is not only necessary for higher yield, but also regarding resiliency management, as most resilient varieties only have 1 resilient gene. There is a shift needed from trust in pesticides to trust in the immune qualities of new varieties. In the discussion, all gathered practices are presented that can be applied. However, farmers need to get experience with the resilient varieties first and need to determine what is most applicable in their individual situations.

3. *How could potato production with resilient varieties become a feasible alternative for conventional grown potatoes?*

Cultivation with resilient varieties saves costs on pesticides, in particular fungicides. However, seed potatoes of resilient varieties are sometimes more expensive than old varieties because of breeder licence fees. Breeding can take up to 10 years, before a variety is commercially ready, so the breeders need to be compensated. Economically, production with resilient varieties would become more feasible than conventional production if the savings on pesticides would outweigh the extra costs of seed potatoes of resilient varieties. In the research, €270,86 per ha was otherwise spent on fungicides, based on a model cultivation from *WUR*. This budget should be enough to purchase resilient varieties, given these are grown non-organically. Apart from economic factors, lack of knowledge and experience with resilient varieties could make farmers choose for conventional cultivation, as there is too much uncertainty regarding yield when using less pesticides.

4. *How could potatoes from resilient varieties be offered on the local market?*

Currently, there are many resilient varieties available as table potatoes and not so much for other potato products, such as chips potatoes. However, many farmers sell their table potatoes in their own shop and it forms the perfect opportunity to convince customers of trying new varieties. Taste, texture, aesthetics, peeling qualities and cooking and baking colour are most important. Customers

of certain varieties will stick to these, while customers of more organic products, familiar with imperfections will be more likely to try a resilient potato. Initially, the focus of branding resilient varieties should be on sustainability, local value chains of de Achterhoek and the tough character of resilient varieties. Resilient varieties also bring opportunities for farmers supplying wholesalers and supermarkets. Recently, supermarkets signed an agreement to sell more organic potato products from resilient varieties. Companies such as McCain also take measures towards sustainability and could also brand conventionally grown resilient varieties.

8. Recommendations

Many potato farmers depend on the land trade with dairy farmers. If this would be prohibited in the future, some farmers would not be able to do potato cultivation anymore. Assuming that the potato sector lobby will halt this development, it will not form a direct threat. However, the decrease of allowed inputs, both cattle manure and pesticides, is already going. Together with drought, it is important to look for ways to build up a healthy soil. Organic matter has much potential, as it improves soil structure, is more effective than cattle manure and releases nutrients more gradually. This is most applicable for cultivations later in the season, for then drought occurs more often and mineralisation has surely started. In these cultivation often more nitrogen is needed so it is also possible to start with cattle manure and ad organic matter.

Resilient potato varieties are fit for the new challenges of the more dynamic environment due to climate change and less pesticide use. It takes some time to get familiar with the new varieties and with using less pesticides. The practices summed up in the discussion are recommended when growing resilient varieties. Until this way of cultivation is adopted, the risk of a decrease in yield needs to be mitigated as much as possible. Every farmer has a different situation where resilient varieties can play a different role.

- The first model is relevant for farmers that also harvest early potatoes. The early potato variety can stay the same, with a resilient variety for growing later in the season. This way, not a complete transition to resilient varieties is needed, which could save some extra costs on resilient seed potatoes and a decrease in fungicide use later in the season will leave more revenue for the farmer.
- The second model is relevant for farmers growing starch potatoes. As starch potatoes are sprayed less with fungicides, it forms the perfect environment for a resilient table potato variety. Looking at the much higher revenue of table potatoes in comparison to starch potatoes, this practice can generate much more value, while using less fungicides and perhaps even fuel.
- Plant many resilient varieties in the same season, so one can observe how different varieties perform and taste and eventually choose the variety with the best properties.

Together with the other recommended practices from the discussion, these form safe ways to get familiar with resilient potato varieties and less pesticide use.

It is helpful when starting with resilient varieties, to share knowledge and experience with farmers who do the same. Two know more than one and this can improve the chances of successful harvests and give ideas for marketing strategies. For example, already four different farmers are going to grow the 'Alouette' this season. This would be a perfect opportunity for knowledge sharing. A group of farmers can also develop their own brand or label, describing the practices they apply. Buying resilient seed potatoes together could also reduce costs. Maybe within the group of farmers seed potatoes can even be multiplied, for an independent, local and sustainable value chain.

According to the outcome of the consultation about marketing the 'Noaberearpel', the emphasis should lie on the tough image of resilient potato varieties rather than on less chemical use, as this may arise questions about other ways of potato cultivation. It is quite impossible to stick to one potato variety in the project because it would not be the best variety in every soil and taste of the same variety differs in relation to the soil. Therefore, sticking to one variety would not accomplish a distinguishable taste, so the project would be more about the group of local farmers dedicating their cultivation more to resilient potato varieties and more sustainable practices.

Following research should monitor the progress of farmers cultivating resilient varieties. Much more clarity is also needed on the marketing side of resilient potatoes and how customers receive them. This all will help to make it a successful project.

9. References

Agrifutures, 2019. *Teelt zetmeelaardappel gaat crescendo.* [Online]
Available at: https://agrifutures.nl/teelt-zetmeelaardappel-gaat-crescendo
[Accessed 2022].

AgroVision, 2019. *Kennisdocument PlanetProof.* [Online]
Available at: https://www.agrovision.com/wp-content/uploads/2020/10/Kennisdocument_PlanetProof.pdf
[Accessed 2022].

Avebe, 2022. *Producten.* [Online]
Available at: https://www.avebe.nl/producten
[Accessed 2022].

Bdeko, 2023. *Robuuste aardappel.* [Online]
Available at: https://bdeko.nl/watisdebioacademy/robuuste-aardappel/
[Accessed 10 03 2023].

Beter Leven, 2022. *Melkrunderen.* [Online]
Available at: https://beterleven.dierenbescherming.nl/zakelijk/deelnemen/bedrijfstypen/veehouderijen/melkrunderen/
[Accessed 2023].

BioImpuls, 2023. *Projectpartners.* [Online]
Available at: https://www.bioimpuls.nl/projectpartners/
[Accessed 10 03 2023].

Bionext, 2017. *Aardappelconvenant.* [Online]
Available at: https://bionext.nl/thema-s/gezondheid/aardappel-convenant/
[Accessed 21 06 2022].

Bremer, E., Hospers-Brands, M. & Tiemens-Hulscher, M., 2007. *Phytophthora-beheersing in de biologische aardappelteelt.* [Online]
Available at: https://www.louisbolk.nl/sites/default/files/publication/pdf/1883.pdf
[Accessed 08 07 2022].

CBS, 2018. *Landbouw gebruikt 57 miljoen kg chemische middelen.* [Online]
Available at: https://www.cbs.nl/nl-nl/nieuws/2018/30/landbouw-gebruikt-5-7-miljoen-kg-chemische-middelen
[Accessed 20 9 2022].

CBS, 2023. *Landbouw; gewassen, dieren en grondgebruik naar hoofdbedrijfstype, regio.* [Online]
Available at: https://opendata.cbs.nl/#/CBS/nl/dataset/80783ned/table?dl=2E108
[Accessed 12 05 2023].

Certis Europe, 2022. *Olie h.* [Online]
Available at: https://www.certiseurope.nl/producten/productwijzer/product/detail/olie-hr#skip-content
[Accessed 2022].

Dodde, H., 2022. *Supermarkten tekenen voor 100 procent robuuste aardappelen.* [Online]
Available at: https://www.nieuweoogst.nl/nieuws/2022/11/10/supermarkten-tekenen-voor-100-procent-robuuste-aardappelen
[Accessed 23 11 2022].

Duurzaam Nieuws, 2018. *Uitspraak EU hof Crispr-cas valt onder gmo-wet.* [Online]
Available at: https://www.duurzaamnieuws.nl/uitspraak-eu-hof-crispr-cas-valt-onder-gmo-wet/
[Accessed 10 03 2023].

EenVandaag, 2022. *Omstreden landbouwgif gevonden in wijn van nederlandse supermarkten.* [Online]
Available at: https://eenvandaag.avrotros.nl/item/omstreden-landbouwgif-gevonden-in-wijn-van-nederlandse-supermarkten/

Eising Advies, 2022. *Aardappelplanten zonder stress zijn sterker en worden minder snel aangetast door phytophthora.* [Online]
Available at: https://www.eisingadvies.nl/aardappelplanten-zonder-stress-zijn-sterker-en-worden-minder-snel-aangetast-door-phytophthora/
[Accessed 2023].

Eising Advies, 2022. *Hoe belangrijk is het onderwatergewicht (owg) voor de verschillende marktsegmenten?.* [Online]
Available at: https://www.eisingadvies.nl/hoe-belangrijk-is-het-onderwatergewicht-owg-voor-de-verschillende-marktsegmenten/
[Accessed 23 10 2022].

Europa Nu, 2022. *Landbouwbeleid (GLB).* [Online]
Available at: https://www.europa-nu.nl/id/vg9pir5eze8o/landbouwbeleid_glb
[Accessed 2022].

Farmer 1, 2022. *Interview* [Interview] (10 2022).

Farmer 1 & Farmer 2, 2022. *Interview* [Interview] (10 2022).

Farmer 2, 2022. *Interview* [Interview] (10 2022).

Farmer 3, 2022. *Interview* [Interview] (10 2022).

Farmer 4, 2022. *Interview* [Interview] (10 2022).

Fontein, R. J. et al., 2013. *Kracht van de Achterhoek: de waarde van voedselketens voor de regio.* [Online]
Available at: https://www.wur.nl/nl/Publicatie-details.htm?publicationId=publication-way-343431383032
[Accessed 2022].

Gezondheidsraad, 2020. *Vervolgadvies gewasbescherming en omwonenden.* [Online]
Available at: https://www.gezondheidsraad.nl/binaries/gezondheidsraad/documenten/adviezen/2020/06/29/vervolgadvies-gewasbescherming-en-omwonenden/Vervolgadvies-gewasbescherming-en-omwonenden_20200629.pdf
[Accessed 21 06 2022].

GIANTS Software, 2017. *Farming Simulator '17.* Frankfurt: GIANTS Software.

Groene Veredeling, 2023. *Merkers voor resistentie tegen de ziekte Phytophthora in aardappel.* [Online]
Available at: https://www.groeneveredeling.nl/lopende-projecten/merkers-voor-resistentie-tegen-de-ziekte-phytophthora-in-aardappel/
[Accessed 15 09 2023].

Hammink, H. & Van Loon, K., 2009. *Aardappel signalen.* Zutphen: Roodbont.

Ing. De Jong, J. A., 1985. De teelt van aardappelen. In: *De teelt van aardappelen.* Drachten: s.n.

Keijzer, P., 2022. *Interview* [Interview] (22 09 2022).

Kennisplatform Aardappels, 2022. *Aardappelrassen.* [Online]
Available at: https://kennisplatform.aardappels.nl/aardappelrassen-1
[Accessed 21 06 2022].

Lijster, E. et al., 2016. *Waarderen van bodemwatermaatregelen.* [Online]
Available at: https://www.clm.nl/publicaties/waarderen-van-bodemwatermaatregelen/
[Accessed 2023].

NIH, 2023. *Mancozeb.* [Online]
Available at: https://pubchem.ncbi.nlm.nih.gov/compound/mancozeb
[Accessed 10 03 2023].

Nijland, G., 2022. *Mailwisseling* [Interview] (10 2022).

Overheid, 2017. *Mestbeleid.* [Online]
Available at: https://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi-nKC42tX7AhUnsaQKHf2KBTEQFnoECA0QAQ&url=https%3A%2F%2Fwww.rvo.nl%2Fsites%2Fdefault%2Ffiles%2F2016%2F12%2FTabel-1-Stikstofgebruiksnormen-

2017.pdf&usg=AOvVaw0uVzVOb2jKCSFjFAZwLPXs
[Accessed 2022].

Overheid, 2019. *Wetten overheid.* [Online]
Available at: https://wetten.overheid.nl/BWBR0022762/2019-10-01#Hoofdstuk3_Afdeling3.5_Paragraaf3.5.3_Artikel3.79
[Accessed 2022].

Overheid, 2020. *Toekomstvisie gewasbeschermingsmiddelen 2030.* [Online]
Available at: https://www.rijksoverheid.nl/documenten/kamerstukken/2020/09/28/uitvoeringsprogramma-toekomstvisie-gewasbescherming-2030
[Accessed 2022].

Parkinson Vereniging, 2019. *Mancozeb.* [Online]
Available at: https://www.parkinson-vereniging.nl/archief/bericht/2019/12/09/Mancozeb
[Accessed 2022].

Plantaardig.com, 2011. *Aardappel handleiding.* [Online]
Available at: https://www.plantaardig.com/groenteninfo/aardappel_handleiding.htm
[Accessed 2022].

Rapol, J. & Van Moorter, A., 2021. *Rassenproef aardappelen biologische teelt 2021: Natte zomer stelt ook plaagresistente rassen op de proef.* [Online]
Available at: https://www.pcainfo.be/Kenniscentrum/Rassen/category/bio/rassenproef-biologische-aardappelteelt-2021
[Accessed 04 07 2022].

RIVM, 2022. *Samenvattend rapport over blootstelling en mogelijke gezondheidsproblemen.* [Online]
Available at: https://www.rivm.nl/publicaties/bestrijdingsmiddelen-en-omwonenden-samenvattend-rapport-over-blootstelling-en-mogelijke
[Accessed 2022].

Royal Brinkman, 2022. *Producten op de SKAL-inputlijst, Olie h.* [Online]
Available at: https://royalbrinkman.nl/gewasbescherming-desinfectie/biologische-gewasbescherming/producten-op-de-skal-inputlijst/olie-h-20-ltr-180701190
[Accessed 2022].

Royal Brinkman, 2022. *Verschil systemische, contactwerkende, translaminaire en bodemwerkende bedekkingsmiddelen.* [Online]
Available at: https://royalbrinkman.nl/kennisbank-gewasbescherming/verschil-systemische-contactwerkende-translaminaire-bodemwerkende-bedekkingsmiddelen
[Accessed 2022].

RVO, 2022. *Landbouw.* [Online]
Available at: https://www.rvo.nl/landbouw
[Accessed 2022].

SKAL, 2022. *Meststoffen.* [Online]
Available at: https://www.skal.nl/certificeren/teelt-van-gewassen/voorwaarden/meststoffen
[Accessed 2022].

Strohandel Roose, 2022. *Voederaardappelen.* [Online]
Available at: https://www.strohandelroose.com/nl/ruwvoeders/voederaardappelen
[Accessed 2022].

Unie van Waterschappen, 2022. *Gewasbeschermingsmiddelen.* [Online]
Available at: https://unievanwaterschappen.nl/waterkwaliteit/gewasbeschermingsmiddelen/
[Accessed 2022].

Van Vulpen veevoeders, 2022. *Aardappelen.* [Online]
Available at: https://veevoer.nu/product/aardappelen/
[Accessed 2023].

WUR: Open Teelten, 2022. *KWIN-AGV Kwantitatieve Informatie Akkerbouw en Vollegrondsgroenteteelt,* Lelystad: Business unit Open Teelten.

WUR, 2022. *Drift.* [Online]
Available at: https://www.wur.nl/nl/Onderzoek-Resultaten/Onderzoeksinstituten/plant-research/Geavanceerde-landbouwtechnologie/Onderzoeksthemas-en-expertises/Spuittechniek-gewasbescherming/Drift-gewasbeschermings-middelen.htm
[Accessed 2022].

WUR, 2022. *Stikstof.* [Online]
Available at: https://www.wur.nl/nl/show/stikstof-1.htm
[Accessed 2023].

Yara, 2022. *Landbouwkundige principes van de aardappelteelt.* [Online]
Available at: https://www.yara.nl/gewasvoeding/aardappel/landbouwkundige-principes-van-de-aardappelteelt/
[Accessed 2023].

10. Annexes

10.1. Conventional consumption potato cultivation balance 2022

6.2.3 Consumptieaardappelen, zandgrond, Zuidoost Nederland

Gemiddelde van alle voorkomende rassen	Hoeveelheid	Eenheid	Prijs	Eenheid	Bedrag
hoofdproduct	48.400	kg	0,14	€/kg	6.566
BRUTO GELDOPBRENGST (a)					6.566
UITGANGSMATERIAAL					
pootgoed	2.300	kg	0,48	€/kg	1.104
BEMESTING					
Kalkammonsalpeter 27% N	188	kg N	0,82	€/kg N	154
Tripelsuper 43-45% P2O5	40	kg P2O5	0,84	€/kg P2O5	34
Kaliumchoride 60% K2O	250	kg K2O	0,52	€/kg K2O	130
GEWASBESCHERMINGSMIDDELEN					
oxamyl (10%)	10,00	kg,l	14,50	€/kg	145
metribuzin (600)	0,25	kg,l	47,50	€/l	12
mandipropamid (250)	2,40	kg,l	40,00	€/l	96
benthiavalicarb-isopropyl (70), oxathiapiproline (30)	1,20	kg,l	90,00	€/l	108
fluopicolide (62,5), propamocarb (625)	4,80	kg,l	20,50	€/l	98
cyazofamid (160)	2,00	kg,l	51,00	€/l	102
pyraflufen-ethyl (26,5)	0,80	kg,l	59,00	€/l	47
carfentrazon-ethyl (60)	0,50	kg,l	52,00	€/l	26
sinasappelolie (99,91%)	3,13	kg,l	18,50	€/l	58
metribuzin (80), prosulfocarb (800)	5,00	kg,l	15,50	€/l	78
prothioconazool (125), fluopyram (125)	0,45	kg,l	49,50	€/l	22
difenoconazool (250)	1,00	kg,l	48,00	€/l	48
lambda-cyhalothrin (100)	0,10	kg,l	125,00	€/l	13
acetamiprid (20%)	0,25	kg,l	118,00	€/kg	30
olie mineraal	0,20	kg,l	3,50	€/l	1
ENERGIE [1)]					
diesel	330	liter	1,18	€/l	389
elektriciteitsverbruik bewaring	750	kWh	0,15	€/kWh	112
AFZETKOSTEN					
opscheppen	48	ton	3.50	€/ton	169
OVERIGE PRODUCTGEBONDEN KOSTEN					
berekende rente	1.537	EUR	3,40	%	52
N-mineraalmonster	0	keer	36.25	€/monster	4
potatopol	1	ha	20.20	€/ha	20
TOEGEREKENDE KOSTEN (b)					3.052
SALDO PER EENHEID EIGEN MECHANISATIE (c=a-b)					3.514
ARBEIDSBEHOEFTE					
Grondbewerking	4,7	uur			
Bemesten	1,2	uur			
Zaaien/poten/planten	1,4	uur			
Beregening	9,0	uur			
Gewasbescherming	7,5	uur			
Handwieden	0,0	uur			
Overige gewasverzorging	0,0	uur			
Oogsten	15,0	uur			
Verwerken	0,0	uur			
	38,8	**uur**			

[1)] *Energiekosten bij luchtgekoelde bewaring tot eind januari, inclusief opwarmen voor aflevering.*

10.2. Organic consumption potato cultivation balance 2022

7.2.1 Consumptieaardappelen, kleigebieden

	Hoeveelheid	Eenheid	Prijs	Eenheid	Bedrag
hoofdproduct [1]	32.500	kg	0,30	€/kg	9.716
BRUTO GELDOPBRENGST (a)					9.716
UITGANGSMATERIAAL					
pootgoed [2]	3.000	kg	0,70	€/kg	2.100
BEMESTING					
runderdrijfmest (BIO)	25	m3	10,00	€/m3	250
vaste rundermest (BIO)	10	ton	15,00	€/ton	150
ENERGIE					
diesel	288	liter	1,18	€/l	340
elektriciteitsverbruik bewaring	504	kWh	0,15	€/kWh	75
gas loofbranden	200	liter	0,61	€/l	121
AFZETKOSTEN					
opscheppen	32,5	ton	3,50	€/ton	114
OVERIGE PRODUCTGEBONDEN KOSTEN					
berekende rente	1.667	EUR	3,40	%	57
potatopol	1,0	ha	20,20	€/ha	20
TOEGEREKENDE KOSTEN (b)					3.227
SALDO PER EENHEID EIGEN MECHANISATIE (c=a-b)					6.489
LOONWERK					
bemesten; stalmeststrooier	1	ha	180	€/ha	180
bemesten; bouwlandinjecteur	1	ha	300	€/ha	300
aardappelen rooien	1	ha	645	€/ha	645
TOTAAL LOONWERK (d)					1.125
SALDO PER EENHEID LOONWERK (e=c-d)					5.364
ARBEIDSBEHOEFTE					
Grondbewerking	5,1	uur			
Bemesten	0,0	uur			
Zaaien/poten/planten	1,4	uur			
Beregening	6,0	uur			
Gewasbescherming	4,5	uur			
Handwieden	10,0	uur			
Overige gewasverzorging	2,0	uur			
Oogsten	15,0	uur			
Verwerken	0,0	uur			
	44,0	**uur**			

[1] *De opbrengst is in kg afgeleverd product bij bewaring tot eind januari, inclusief 3% bewaarverlies.*
[2] *Dit gewas valt onder categorie 1 van de Nederlandse Annex. Biologisch uitgangsmateriaal is verplicht. In het saldo is gerekend met prijzen die gelden voor biologisch uitgangsmateriaal.*

10.3. Interview structure

Algemeen

1. Omschrijving bedrijf
2. Hoe bent u hier gelegen en wat zijn specifieke voor- en nadelen van deze locatie?
3. Hoeveel land bewerkt u per jaar (voor aardappels)?
4. Welke buren heeft u en is er samenwerking met andere bedrijven?

Aardappelteelt

5. Wat is de gemiddelde gewasrotatie op uw bedrijf?
6. Wat is de geschiedenis en eigenschappen van de percelen?
7. Met welk ras kweekt u en waarom?
8. Wanneer in het groeiseizoen kweekt u aardappels en waarom?
9. Wordt er nog meer verbouwd naast de aardappels op hetzelfde land in hetzelfde groeiseizoen?
10. Wat zijn de eisen van de afnemer ten aanzien van ras en kwaliteit?

Inputs

11. Welke meststoffen gebruikt u en waarom?
12. Hoe(vaak) en wanneer worden de meststoffen aangebracht?
13. Hoe(vaak) bestrijdt u gedurende het groeiseizoen onkruid?
14. Welke gewasbeschermingsmiddelen gebruikt u en waarom?
15. Hoe(vaak) en wanneer worden de gewasbeschermingsmiddelen toegepast?
16. Hoe ziet het proces van loofklappen tot het transport eruit op uw bedrijf?

Kosten en opbrengsten

17. Op welke dingen behaalt u de meeste winst denkt u?
18. Wat is het aandeel van gewasbeschermingsmiddelen in de kosten per ha?

Afzetmogelijkheden

19. Waar verkoopt u uw aardappels?
20. Wat zijn de voor- en nadelen van deze verkoop?

Visie

21. Hoe ziet u de toekomst van uw bedrijf?
22. Wat kan er volgens u beter in de aardappelsector?
23. Zou u bereidt zijn om te werken met resistente aardappelrassen?
24. Zou u bereidt zijn om samen te werken met akkerbouwers in de regio?
25. Zijn er nog kwesties die niet aan bod gekomen zijn en/of die u kwijt wil?