BACHELOR THESIS

THE FUTURE OF FRUIT FARMING

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The future of fruit farming

The impact of technological applications on work

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Abstract

Objective– The objective of this research is to give an overview of new technological applications in fruit farming and the impact of these on work on Dutch top fruit farms. **Methodology**– To reach the objective, a literature study has been conducted consisting of three phases: searching information, assessing the information obtained and synthesizing the assessment of information. **Results–** First, current technological applications and future technological applications in fruit farming are described. Second, the impact of technological applications on work is being identified based on the change in the nature and organisation of work, the quality of work, the scope of work and the distribution of work. **Conclusion**– There will be no impact of new technological applications on work on Dutch top fruit farms in the short-term. However, in the long-term the impact of new technological applications on work on Dutch top fruit farms could be that the nature of work changes to autonomous, smart, data-driven processes that can be remotely controlled and are fully integrated in the supply chain. This will lead to an increase in the quality of work, a decrease in the scope of work and a new division in the distribution of work between higher and lower educated people. **Discussion**– The expected impact of technological applications on work are further examined in this research for Dutch top fruit farms. However, limitations of the study are that the research used only literature, that a non-systematic method was used to gather articles for research question one, that articles were gathered with help of snowballing, that the Product Life Cycle Theory was used to categorize the technological applications into current and future applications while this theory is originally intended for products and not for technologies and that the research took into account that technological applications will be applied in fruit farming while this might not be the case. Further research is recommended on the adoption of new technological applications in fruit farming in the Netherlands and the applicability of the results for other countries and/or product groups.

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1 Introduction

In this chapter, an introduction to the research is presented in order to clarify and limit the content of the research. The chapter will include the background of the problem, the objective, the key concepts and definitions, and a reading guide.

1.1 Background

The world population is growing and is expected to peak at 11.2 billion in 2100 (United Nations, 2017). There will be more mouths to feed, but the current carrying capacity of planet Earth is already exceeded with the current way of agricultural production (Sundmaeker, Verdouw, Wolfert & Freire, 2016). The climate is changing and resources such as water, land and other natural resources are becoming scarcer. Feeding the growing world population while lowering the ecological footprint is a challenge that asks for a change in the current way of agricultural production.

A different way of working is also required in fruit farming (Ossevoort, Verdouw, de Jong, Hennen & Robbemond, 2016). Fruit farms are growing which means that the farmer needs technical support and management automation. Moreover, a combination of low economic results and high labour costs creates a demand for affordable technological solutions and there is a greater need for technological resources by the temporary workers requested. Fruit farmers also have to deal with extensive environmental requirements regarding resources, energy and water consumption. New, advanced cultivation techniques are desirable.

Besides the growing demand for technological solutions by the farmer, parties within and outside the supply chain have a growing demand for information from the fruit farmer (Ossevoort et al., 2016). The sort of information requested is still the same, but there is a growing demand for more precise information to limit risks, plan sales and provide customers with track and trace information (Kruize, Verdouw, Bondt & Puister, 2018). This includes sharing information about the use of pesticides, harvest forecasts and quality of the fruit with different parties of the supply chain like sales organisations and customers. But also exchanging data for regulations and certification. Since the demand for information from the farmer and other parties' perspectives is changing from orchard level to row- or specific tree level, there is a growing demand for technological applications in the fruit sector (Ossevoort et al., 2016).

To contribute to the world food problem and respond to trends and developments on the fruit farm and in the chain, technologies can be applied. Today there is an increase in the use of robots that can take over manual labour and sensors that can measure and monitor processes (Kruize et al., 2018; Ossevoort et al., 2016). Drones and cameras have already been used in orchards and smart systems to analyse the big amounts of data that is being produced by these technological innovations are becoming more available and applied. Existing business management systems are more likely to be linked with sensors and machines that are used in the field. Examples of available management systems in fruit farming are web applications or registration systems offered by supply chain partners.

However, new technologies create uncertainties about the future of work (SER, 2019). It is uncertain what the effect of new technologies will be on the amount and type of work that will be available. New jobs can arise while existing jobs may disappear due to new technologies. In addition, it is uncertain whether new technologies will enrich or undermine the tasks and functions of workers and whether this will change their required competencies. It is important for companies to be aware of coming changes in order to determine how these can best be incorporated and facilitated in their company.

A wide variety of publications, as well international as national, from macro to micro level, are available on the effects of technological applications on labour. However, the consequences of technological applications on work differ per sector. An overview focusing on the impact for fruit farming is lacking. Therefore, a knowledge gap exists on what the impact of technological applications on work on fruit farms is.

1.2 Objective

The objective of this research is to give an overview of new technological applications in fruit farming and the impact of these on work on Dutch top fruit farms. To be able to reach the objective, the central research question that will be answered in this research is:

"What is the impact of new technological applications on work on Dutch top fruit farms?"

To be able to provide an answer to the central research question, the following sub-questions need to be answered:

1. What are the new technological applications in top fruit farming?
2. How do new technological applications change work on Dutch top fruit farms?

1.3 Key concepts and definitions

Key concepts of the central research question and sub-questions are: technological applications, work and Dutch top fruit farms. The key concepts will be explained using definitions from dictionaries or literature.

Technological applications

According to the Cambridge Dictionary (n.d.b) technological is something relating to, or involving, technology. An application is "a way in which something can be used for a particular purpose" (Cambridge dictionary, n.d.a). Therefore, a technological application is a technology used for a particular purpose. Technological applications that are already being applied in fruit farming as well as future technological applications will be described in this research. To categorize the technological applications, the Product Life Cycle Theory of Vernon (1966) is used. The Product Life Cycle Theory does not apply 1 on 1 for technologies since the cycle is originally intended for products and not for technologies. However, this research is specifically about technological applications which are technological products that can be used on the fruit farm. Therefore, the Product Life Cycle Theory will be used in this research to categorize the technological applications.

According to the theory of Vernon, a product goes through four stages from the invention of a product to its demise due to a lack of demand: introduction, growth, maturity and decline (Figure 1). In the introduction phase, there are only a few users of the product. In case of technologies, this are usually companies who are more open to try new things, are technically skilled and can take risk. In the growth phase, the demand of the product increases which reduces the production costs of the product. The product

Figure 1 Vernon's international product life cycle. Source: Vernon, 1966

becomes widely known and different versions of the product will be offered by competitors. In the maturity phase, the product is widely used. When a downward slide in sales occur, the product is in the decline phase. Technological applications in fruit farming that are in the growth, maturity and decline phase will be considered in the state of the art of technological applications in this research. Technological applications in fruit farming that are in the introduction phase or that are even prior to this phase and still in development will be considered in the future technological applications in this research. Technological applications in the introduction phase are considered as future technological applications in this research because there are only a few users of the technological application and the majority of farmers are not yet using the application on their farm.

Work
Work is "an activity, such as a job, that a person uses physical or mental effort to do, usually for money" (Cambridge dictionary, n.d.c). Ossevoort et al. (2016) divided work on a fruit farm into two categories: operational and management processes. *Operational processes* include orchard, post-harvest and monitoring operations. Orchard operations are all operations in the orchard necessary to produce fruit and includes the registration of these operations. Post-harvest operations are operations that take place after harvest and monitoring includes the collection of data from crops, soil and environmental conditions. *Management processes* include analysing orchard management information, planning fruit growth tasks and controlling the execution of fruit growth tasks. Management processes can usually be executed with help of a computer. The analysis of orchard management information includes the analysis of registration, agronomic advice, monitoring, post-harvest and benchmark information to generate insights about the status of the orchard management that are used to plan and optimise orchard operations. Harvest forecasts can be shared with sales organisations based on these insights. Planning the fruit growth task includes translating inventories, prioritization, and optimization of all orchard operations into an orchard operations planning that ensures optimal control of the orchard. Finally, controlling the execution of the fruit growth tasks includes making sure the planned operations are executed according to the in the previous step determined operational planning. An overview of operational- and management processes is given in Appendix I. These processes, that are determining work on fruit farms, are used in this research to check whether technological applications are available for these purposes.

To determine the impact of technological innovations on work, the following factors determined by the Sociaal-Economische Raad (2019) will be used:

- *The nature and organization of work* which implies changes in production and work processes and organisational adjustments that need to be made in order to imply the technologies;
- *The quality of work* which implies the change in working conditions and labour relations;
- *The scope of work* which implies the increase or decrease in the number of jobs;
- *The distribution of work* which implies the distribution of jobs among lower and higher educated people.

Dutch top fruit farms
Fruit farming is the practice of growing or farming fruit (Collins Online English Dictionary, n.d.). Fruit faming can be divided into 5 categories: top fruit, soft fruit, stone fruit, citrus fruit and exotic fruit (World of food, n.d.). In this paper the impact of technological innovations on top fruit farms (apples and pears) will be described. Because top fruit farming differs from country to country, this research will only describe the impact of technological applications on work on Dutch fruit farms. The defined impact will hold for the average fruit farm in the Netherlands which is about 7.6 hectares (Agrimatie, 2018).

1.4 Reading guide

After a description of the methods used for this research in chapter 2, the results of the research will be presented in chapter 3 and 4. In chapter 3 an overview of the new technological applications in fruit farming is presented, answering the research question: "*What are the new technological applications in top fruit farming?*". In chapter 4 the impact of the new technological applications on work on Dutch fruit farms is given. In this chapter the research question: "*How do new technological applications change work on Dutch top fruit farms?*" will be answered. The conclusions and a discussion are included in Chapter 5.

2 Methodology

In this chapter, the methodology used to answer the research questions will be explained. To answer the research questions mentioned in section 1.2, a literature study was conducted. The literature study consisted of three phases: searching literature (section 2.1), assessing the literature obtained (section 2.2) and synthesizing the findings (section 2.3).

2.1 Literature search

The literature search was an iterative search-refining process that consisted of finding an appropriate database, building a search query and improving the search when too many or too few results were found.

Finding an appropriate database

For the literature search, the WUR Library online catalogue, search engine Google Scholar and bibliographic databases like Scopus and Web of Science were used. The WUR Library can help to identify books and other media on the subject since it searches for journal or periodical titles in the Library Catalogue, various article databases and Staff Publications. However, periodical or journal articles are rarely included. Google Scholar provides a simple way to find scientific literature on a topic, but the search engine has some disadvantages. Google Scholar has no quality check for indexing journals, so search results can contain fake journals or books. Besides this, sources that are found are often not full-text accessible. Scopus and Web of Science are bibliographic databases that have a quality check for indexing journals and students of Wageningen University have access to these databases as they can login via the university. Since WUR Library and Google Scholar were not giving a complete overview of available literature on a certain topic, these databases were only used for simple search on the topic. To answer the central research question and sub-questions, bibliographic databases Scopus and Web of Science were used since these databases are able to search for sources based on search terms relating to specific parts of a document (e.g. title, author, keywords, ISSN) and therefore were able to provide a complete overview of the available literature on the topic.

Building a search query

Based on the concepts of each sub-research question, a search query was generated. An example of a search query is presented in Figure 2. Because authors are using different words for the same concept, synonyms, broader terms, narrower terms, related terms, other word forms and singular/plural forms were identified for each concept. When conducting the search in the database, Boolean operators and several filters were used to reduce the number of hits. To decide whether a hit was useful for the research, the title, keywords and abstract were scanned. When the title, keywords and abstract of the source looked useful, the text was skimmed. In this way it became clear if the source contained useful information to answer the research question. The reference section of each source was consulted to check if more relevant sources could be found, this method is called ‘snowball effect’ (Blumberg, Cooper & Schindler, 2014).

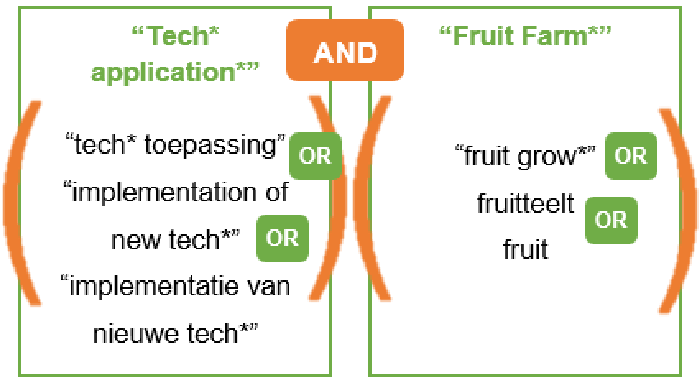

Figure 2 Search query sub-question 1

Improving the search

Unfortunately, the search query used to find relevant articles to answer the first research question only resulted in three relevant hits. To improve the search, multiple search queries were tried in the databases by removing or adding words to the search query. More relevant terms were found in dictionaries or encyclopaedia, or titles, keywords and abstracts of relevant sources. Also, several filters were applied to the search. However, the search query did still not result in articles with information about specific technological applications in fruit farming. The articles obtained only named the word *technological application* and were mostly explaining general concepts of technology but did not explain which applications exactly existed. In addition, these articles were very broad about agriculture and not specifically about fruit farming. In order to find the right articles, a small preliminary search was carried out on possible technological applications in fruit farming so these could be used as search terms in the databases. The preliminary search was conducted in the archive of publications from the magazine of the Nederlandse Fruittelers Organisatie (NFO). New search queries were conducted based on the search terms found in the archive and resulted in relevant articles for the research. When the literature that was found covered most of the sources mentioned in the reference lists of the core articles of the literature search and contained some additional, more recent, articles, enough literature was obtained to start reading and evaluating the obtained literature.

2.2 Reading and evaluating the obtained literature

To evaluate the obtained literature, each possible useful source obtained from the literature search was structurally read. After reading the title of the publication, an idea of the general structure of the text was obtained by looking at the table of contents or abstract of the publication. To get an idea of the main point the authors wants to make, the preface and introduction was read. Finally, the parts and chapters that contained important information to answer the sub-questions were read. After reading the text, the usefulness and quality of the source was evaluated using the following criteria: suitability, authority, purpose, reference and source, type of source, and currency. For each criterion, a checklist of questions is presented in Appendix II (Wageningen University & Research, n.d.b). A source was seen as relevant if it suited to the arguments in this research, either by supporting them or contradicting them. Another criterion of usefulness and quality of a source was the authority. Articles published in one of the top management journals or books from well-known publishers usually have a greater impact than articles from ‘smaller’ journals or publishers. Sources that were frequently cited by other scholars working in the field were considered most important and therefore included in the research. Currency of the source was considered important since more recent articles offered a better idea then older ones of the current state of knowledge. After reading and evaluating the obtained literature, the findings could be synthesized.

2.3 Synthesizing the findings

In the last stage of the literature review, the obtained findings were synthesized. Synthesizing started with comparison of the information obtained from different resources to identify differences and congruencies. After that, the differences and congruencies were explained or interpreted. For example, for the sub-research questions, the general trends in technological applications and the impact of technological applications on work were defined first whereafter these general trends and impacts were interpreted for the fruit sector.

3 Technological applications

In this chapter, technological applications in fruit farming will be described. In the first section, the state of the art will be described, giving an overview of technologies that are currently being applied in fruit farming. After that, future technological applications that are still in development or not widely adopted yet will be described. With the description of the current and future technological applications, the sub-research question "*What are the new technological applications in fruit farming?*" will be answered in the concluding section.

3.1 State of the art

In this section, an overview of technologies that are being applied in fruit farming nowadays will be given. This includes technological applications that are in the growth, maturity or declining stage of the Product Life Cycle of Vernon (1996). Technological applications in fruit farming are going hand in hand with agricultural technology revolutions. During the first agricultural technology revolution, which is about 100 years ago, farming was done with the use of animal power (Zambon, Cecchini, Egidi, Saporito & Colantoni, 2019). This first agricultural technology revolution was followed by the second agricultural technology revolution in the 1950s when the combustion engine was invented. Both, the first and second agricultural revolution caused an increase in mechanization of orchard operations (Miranda, Ponce, Molina & Wright, 2019). Today we are in the third agricultural technology revolution, making use of guidance systems and precision farming (Zambon et al., 2019). This revolution also implicates the use of robotics and the (partly) automation of orchard operations (Miranda et al., 2019).

Currently, many orchard operations in fruit farming are still largely dependent on seasonal human labour (He & Schupp, 2018; Lu, Zhang & Pothula, 2017; Silwal, Davidson, Karkee, Mo, Zhang & Lewis, 2017). Looking at the costs of growing fruit, the labour costs are the largest cost item with 32% of the total costs (Agrimatie, 2019). Harvesting, pruning and thinning are the most labour-intensive orchard activities (Lu et al., 2017; Silwal et al., 2017). The change in orchards systems from low-density, unstructured systems to high-density, structured systems has created opportunities for orchard mechanization and automation (Lu et al., 2017). The introduction of the tractor also caused an increase in mechanization of orchard operations since the tractor can be used to pull, carry and/or drive many machines (Atkinson, 2011).

For *harvesting*, several efforts have been made to automate parts of the picking process (Bogue, 2020). Where ladders and picking bags have been traditionally used, harvest assistant platforms and picking trains are now state of the art (Lu et al., 2017; Heijerman-Peppelman, van der Knijff, Roelofs, Ruijs & Zijlstra, 2010). There are various harvest assistant platforms on the market (Lu et al., 2017; Silwal et al., 2017). Sazo, Marree and Robinson (2010) are presenting an overview of available self-propelled and tractor-pulled harvest assistant platforms in Europe and the United States. Harvest assistant platforms can replace parts of the manual work since they are for example able to transport the fruits to the bin, fill the bin and can pick up and unload the bin automatically (Lu et al., 2017; Pekkeriet, Heijerman, Otten, van Tuijl, Wigham & Jalink, 2009). Platforms can also automatically navigate themselves through the orchard. Although picking performance is increased because the distance of walking to the bin and putting the fruits in the bin is shortened, a lot of manual labour is still needed to place and remove the bins in and from the orchard (Heijerman-Peppelman et al., 2010). When using a picking train, the bins do not have to be placed in and removed from the orchard. However, the transport to the bin and bin filling is still manual work when using a picking train.

Pruning is currently operated with the use of manual loppers, pneumatically or battery-powered shears (He & Schupp, 2018; Tabb & Medeiros, 2017). Ladders or platforms are used to reach high branches. The fruit farmer selectively removes branches from fruit trees by selecting the unwanted branches and deciding on the cutting point based on pruning rules like canopy size and shape.

Thinning fruitlets has been conducted manually over centuries (Pflanz, Gebbers & Zude, 2016). However, hand thinning was time consuming and costly due to shortage of labour and increasing labour costs (Pflanz et al., 2016; Schupp, Baugher, Miller, Harsh & Lesser, 2008; Veal, Damerow & Blanke, 2011). Therefore, blossom thinning is being operated chemically for more than 40 years now and hand thinning of fruitlets is now restricted to a final fruit thin for removing diseased or under-sized fruitlets in July (Heijerman-Peppelman et al., 2010; Veal et al., 2011). But the chemicals that are being approved in fruit farming are getting restricted and factors such as weather conditions and tree response can cause inconsistency in chemical thinning results (Hehnen, Henrahan, Lewis, McFerson & Blanke, 2012; McClure & Cline, 2015; Pflanz et al., 2016; Veal et al., 2011). Due to these reasons, various machines for mechanical thinning have become available in recent years. An infrequently used mechanical thinning machine is the limb or tree shaker which removes small fruits from the tree (McClure & Cline, 2015). Another machine is the mechanical blossom thinner which can consist of rotating strings, rods, or brushes that are able to remove flowers from fruit trees (Hehnen et al., 2012; McClure & Cline, 2015; Pflanz et al., 2016; Veal et al., 2011). In comparison to hand thinning, the mechanical blossom thinner reduced follow-up hand thinning time (Schupp et al., 2008). However, when comparing the mechanical blossom thinner with chemical thinning, chemical thinning is still the best thinning method since it is delivering best results in terms of fruit quality and consistent bearing (Hehnen et al., 2012).

There are also increasing possibilities to mechanize and automate other orchard operations (Ossevoort et al., 2018). With the introduction of the tractor, various tractor mounted machines including soil cultivation machinery, fertilizer spreading machinery, mowing machinery and spraying machinery were developed which could be driven from power take-off (Atkinson, 2011). Root pruning is also operated with a tractor mounted machine (Heijerman-Peppelman et al., 2010). Currently, tractors are also able to drive autonomous (Ossevoort et al., 2018). For *planting*, GPS-based software can be used to set out the orchard (Heijerman-Peppelman et al., 2010). With a trencher, a trench can be dug, eliminating the need to manually drill posts and planting holes. The trench can also be closed mechanically. Machines for *disease and pest control* are already in use since the late 19th century (Fox, Derksen, Zhu, Brazee & Svensson, 2007). Where handguns were used in the beginning, sprayers with efficient fans are now state of the art. A lot of improvements have been made on air-blast sprayers and nozzles to reduce spray drift[1] and produce more uniform coverage. Also, a double tunnel sprayer was developed that reduces 40% of spraying time (Heijerman-Peppelman et al., 2010).

To summarize, current technological applications in fruit farming that are in the growth, maturity or declining stage of the Product Life Cycle are harvest assistant platforms, picking trains, pneumatically or battery-powered shears, mechanical and chemical thinners and various tractor mounted machines such as soil cultivation, fertilizer spreading, mowing and spraying machinery.

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[1] Drift is the spray liquid that is blown away during the application of plant protection products (Wageningen University & Research, n.d.a)

3.2 Future technological applications

In this section, fruit farming technologies that are still in development or not widely adopted will be described. This includes technological applications in the introduction phase of the Product Life Cycle, or technological applications that are even prior to this phase and still in development (Vernon, 1966). The agricultural technology revolutions belonging to future technological applications are the third and fourth agricultural technology revolution. According to Zambon et al. (2019), the transition towards the fourth industrial revolution has started, which implies that farm activities are connected to the cloud. The fourth revolution is characterized by concepts as Cloud Computing, Internet of Things, Big Data, Blockchain, Robotics and Artificial Intelligence which will change agriculture in a data-driven, intelligent, agile and autonomous connected system of systems (Figure 3 and Appendix III) (Lezochea, Hernandezb, Díaz, Panettoa & Kacprzyk, 2020). This new technology revolution is aiming at reducing process costs, minimizing water, fuel and fertiliser usage, and promoting the use of renewable energy (Miranda et al., 2019).

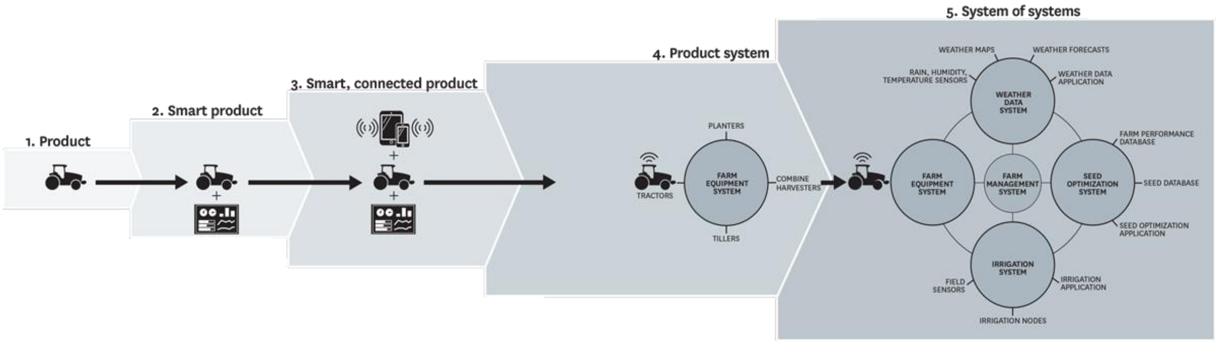

Figure 3 Towards Smart Systems of Systems. Source: Porter & Heppelmann, 2014 (larger scale in Appendix III)

As described in section 3.1, many new technologies for mechanization and semi-automation have been applied in fruit farming over the past decades. However, most orchard operations are not fully automated yet and therefore still require highly on manual labour. Since the supply of manual labour is declining and labour costs are increasing, farmers experience difficulties in recruiting enough employees (Bogue, 2020; He & Schupp, 2018; Silwal et al., 2017; Zhang, Heinemann, Liu, Baugher & Schupp, 2016a). Therefore, since the start the third agricultural technology revolution, a lot of efforts have been made to develop robots that can partially or fully automate orchard operations, in order to reduce costs and overcome labour shortages (Bogue, 2020). In the coming years, there will be an increase in robots that will partly or fully take over manual tasks due to technological developments in the field of vision, gripping techniques and data processing (Schmeitz & van Wijk, 2016). Orchard operations that are already mechanized can also be optimized by using precision farming to be able to produce more fruit while using less resources (Kruize et al., 2018).

Automation

For *harvesting* apples*,* two types of robots have been developed, being a bulk harvester and a selective (apple by apple) harvester (Beaten, Donné, Boedrij, Beckers & Claesen, 2007; Silwal et al., 2017; Zhang et al., 2016a). A bulk harvester is a semi-automatic harvester that detaches all fruits from a tree by shaking the trunk or branch of the tree and catching the fruits. But using the shake and catch system for fresh market fruit requires amongst others that the fruits have a uniform level of ripeness at harvest and are resistant to damage (Beaten et al., 2007). Due to the high bruising incidence of apples and damage that is caused to the limbs and bark, the shake and catch system is only used to harvest fruit for the processing industry (Zhang et al., 2016a).

The selective harvester is a fully automatic harvester that detaches selected fruits from a tree using a robotic arm and sensor technology (Silwal et al., 2017; Zhang et al., 2016a). Research on harvesting robots have been conducted over decades (Bogue, 2020; Silwal et al., 2017) and several harvest robots have been developed and were successfully tested (Beaten et al., 2007; Silwal et al., 2017; Zhao, Lu, Ji, Zhang & Chen, 2011). However, these robots are not commercialized yet. Complications for commercial development include insufficient fruit detection and picking that causes damage to the apples (Pekkeriet et al., 2009; Silwal et al., 2017). Besides this, robotic harvesters still have a high overall harvesting cycle time. This is due to the extensive variability that exists in the orchard environment, for example because of the complex tree structures (Beaten et al., 2007; Silwal et al., 2017). Also, a lot of research have been conducted about the typical components of the robotic harvester being the machine vision system that needs to indicate the fruits and decides which fruits can be picked and the manipulator and end-effecter to pick the fruit and transport it to the bin (Beaten et al., 2007; Pekkeriet et al., 2009; Silwal et al., 2017). Gongal, Amatya, Karkee, Zhang and Lewis (2015) presented a review of machine vision systems for detecting and locating fruit.

In 2019, the first robotic apple harvester has been commercialised in New Zealand (Bogue, 2020). The robotic harvester developed by Abundant Robotics is an autonomous tractor-style vehicle that is equipped with a vision system to detect the apple and a robotic arm with a vacuum mechanism to remove the apple with suction and place it into a bin. However, this is only applicable to trees trained to grow in a flat two-dimensional plane while traditionally trees are three-dimensional. Another approach to replace manual labour of fruit harvesting is the drone developed by Tevel Aerobotics Technologies (Bogue, 2020). The drone is equipped with a gripper to detach the fruit from the tree and transfer it to a bin, and it can determine the size, colour and ripeness of a fruit. This technological application is not yet commercialized.

In 2016, a self-propelled apple harvest and in-field sorting machine was developed by the Michigan State University (Lu et al., 2017). Besides the transport, bin filling and bin handling functions of a harvest assistant platform, the machine contains a machine vision-based sorter which sorts the fruit according to the quality grade of each fruit in the orchard. The prototype of the machine is still under development since there are several areas of improvement. For example, the prototype of the machine is currently only sorting culls or processing apples from fresh market fruit.

Pruning is a manual activity that can be mechanized by non-selective mechanical pruning (also called hedging) or automized by precise robotic pruning (He & Schupp, 2018). For mechanical pruning, a cutting tool is run over rows in orchards trees and cuts all branches beyond certain distance from the tree. A few types of mechanical pruners are available on the market, however, using this type of pruners for fruit trees causes excessive growth of shoots which has a negative effect on the quality of the fruit and the yield. Therefore, mechanical pruning is only applied to fruit trees in the summer to remove some exterior shoots which creates more light interception to the fruits. A robotic pruner for fruit trees has not been developed yet. However, a lot of research has been conducted on the components of a robotic pruner being a machine vision system to identify tree branches and an end-effector to cut the branch. Vázquez-Arellano, Griepentrog, Reiser and Paraforos (2016) presented the state of the art of three-dimensional vision systems in agriculture.

Precision fruit farming
According to the Wageningen University and Research (n.d.c), precision agriculture implies that "plants get precisely the treatment they need, determined with great accuracy thanks to the latest technology". Wolfert, Sørensen and Groense (2014) are presenting precision farming as a control cycle that includes smart sensing & monitoring, smart analysis & planning and

smart control (Figure 4). *Smart sensing & monitoring* implies the continuous measurement and monitoring of orchard operations and post-harvest processes making use of sensors, automatic identification (such as barcodes and RFID), drones and satellites. *Smart analysis & planning* is the analysis of the large amounts and varieties of data gathered in the smart sensing & monitoring phase so these could be used for farm management. The data will be processed to obtain useful management information in terms of schedules and advices for orchard operations and post-harvest processes. Smart systems that can analyse large amounts and varieties of data and combine them with all kinds of external data (e.g. weather information or satellite data) are emerging. *Smart control* is the application of high-tech systems to perform the schedules and advices that are created in the smart planning & analysis phase. Possibilities to mechanize and automate orchard operations based on the schedules and advices are increasing. However, still many orchard operations are carried out manually. Technical aids such as smartphones with specific apps and on-board computers on tractors with site-specific instructions can already support the farmer and are still improved with the time. According to Ossevoort et al. (2016), wearables such as smart watches and glasses (such as Google Glass) are promising for smart control.

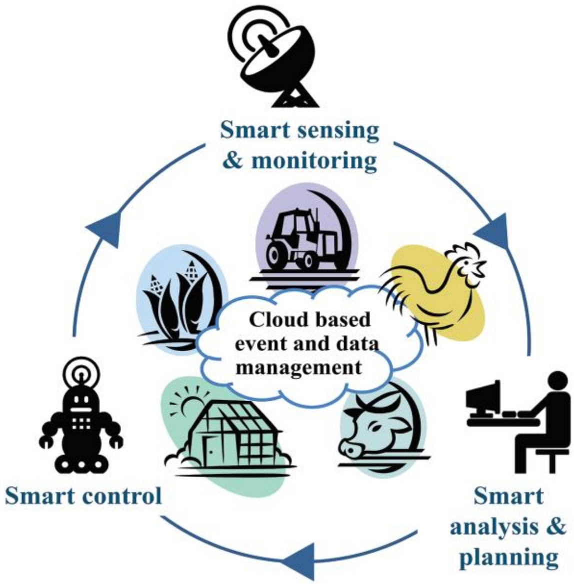

Figure 4 Generic sense-model-act cycle enhanced by cloud-based event management that underpins smart farming. Source: Wolfert et al., 2014

Currently, orchard operations are being applied uniform to each tree in the orchard (Kruize et al., 2018; Li et al., 2018; Pflanz, Gebbers & Zude, 2016). For spraying, for example, this means a part of the applied pesticide is wasted and the environment is unnecessarily polluted (Li et al., 2018) and for thinning this means that some trees will be “over-thinned” while others will be “under-thinned” (Pflanz et al., 2016). When a different treatment for each row or even tree is used, efficiency could be increased. Currently, trials are conducted with precision root pruning, spraying and thinning in the orchard (NPPL, 2020a, b). In the future, precision farming could be applied to more orchard operations which will lead to more sustainability, less need of manual labour and higher yield (Kruize et al., 2018).

Root pruning can be applied more precise using drone images of leaf volume and grow vigour (NPPL, 2020a). These images are used to develop a task card which can be used to control the pruning task with the Fendt-tractor and GPS. The task card is created on the computer and read into the system on the tractor. The system on the tractor is connected to the root pruner. Based on the task card, the root pruner automatically prunes fast growing trees with lots of leaves and growth and skips trees with less leaves and growth. The same task card can be used to precisely apply fertilizer. More fertilizer can be applied to trees with less leaves and growth while trees with much leaves and strong growth can be skipped. The weed control sprayer can be used to spray water with dissolved fertilizer. Another possibility for precision fertilizing is providing the compost spreader with GPS.

Precision *spraying* could be applied using a sprayer with a laser scanning sensor, multi-variable control system and a composite automation unit to modify spraying solution and air volume to match tree canopy structure measured by the sensors (Li et al., 2018). In the Netherlands, an orchard sprayer equipped with GPS, sensors and adjustable nozzles was developed (NPPL, 2020b). The sprayer can scan the leaves and branches of a tree and is able to adjust the fluid delivery rate of the nozzles to this measurement. The sprayer is connected with the registration program “Agromanager” so it can transfer the obtained data from its sprays and the measured leaf mass to the cloud. The fruit farmer can see this information on his computer or smart phone.

Precision *thinning* could be applied using either mechanical or chemical thinning. Mechanical precision thinning is operated with a mechanical thinning unit that is equipped with a sensor for identifying the flower density and a mobile geographic information system that can determine the optimum thinning intensity (Pflanz et al., 2016). Chemical precision thinning can be applied using scanners or drones to count blossom. The drone-based counting can be used to either develop a task card which can be used to control the spraying task or as input for an on-board decision support system (van Dalfsen, de Hoog, de Jong & van de Zande, 2019). To create the task card, the farmer must create classes in the computer system and indicate how each class should be treated (NPPL, 2020c). Based on the task card, the sprayer automatically controls the trees that should or should not be sprayed. In the future the amount of liquid can also be adapted to each tree.

Besides the precise applications that can currently be applied in fruit farming, several other possibilities for precision farming are gaining perspective for the future (Ossevoort et al., 2016). It is already possible to measure leaf discoloration, identify dying branches and measure the fruit size and colour before harvesting. Soil sensors can measure the moisture status and the nitrate content of the soil. By using RFID chips on bins, sorting information can be traced back to tree level. By the use of sensors, detailed, tree-specific information can also directly be collected during harvesting. The sensors can be read remotely. In this way, management information can be conducted, and orchard operations can be adapted to this information. For example, leaf discoloration is an indication for rust mite and dying branches are an indication for fruit tree cancer. Measurements of the number of fruits on the tree, the size and colour of the fruit can be used for harvest forecasts and estimating labour needs for harvesting. Fertilization and irrigation can be planned based on soil moisture and nitrate information.

To summarize, future technological applications in fruit farming that are before or in the introduction phase of the Product Life Cycle are robots for harvesting, in-field sorting and pruning, and technologies for precision fruit farming.

3.3 Conclusion

In this section the sub-research question “*What are the new technological applications in fruit farming?*” was answered. Many technological applications in fruit farming are available. Technologies can be applied to support or take over manual labour for harvesting, pruning and thinning or for the optimisation of orchard operations to increase yields, reduce inputs and lower environmental impact. However, full automation and precision fruit farming are barely applied yet because these technologies are hardly suitable for the current complex and variable orchard environment. Also, these applications are expensive and do not yet have the required speed of operation to be competitive to human labour. With changes in tree architectures and improvements of several machine parts, it is very promising that orchard operations will be automated, and precision farming will be widely applied in the near future.

4 Work

In this chapter, the changes in work on Dutch fruit farms because of the new technological applications described in chapter 3 will be discussed. To determine the change in work, the following factors determined by the Sociaal-Economische Raad (2019) will be used: the nature and organization of work (section 4.1), the quality of work (section 4.2), the scope of work (section 4.3) and the distribution of work (section 4.4). By describing the changes in the nature and organization, quality, scope and distribution of work, the sub-research question "*How do new technological applications change work on Dutch top fruit farms?*" will be answered in the concluding section.

4.1 The nature and organization of work

The technological applications as described in chapter 3 have an influence on the nature and organization of work. The nature and organization of work implies changes in production and work processes and organisational adjustments that need to be made in order to imply the technologies (SER, 2019). These changes and adjustments can arise as the application of new technologies can create new business- and revenue models, which require change in the way of working. In the following paragraphs first the influence on the nature of work in fruit farming will be presented, followed by a description of the organizational adjustments.

4.1.1 The nature of work

In this section, the change in the nature of work in fruit farming is analysed as the change in work that is executed on fruit farms in order to produce fruit. New technologies can change the traditional method of production in fruit farming in several ways (Schmeitz & van Wijk, 2016). First, orchard operations will be more supported, and some will even become autonomous. New machines in fruit farming can support the *harvesting, pruning, thinning* and other orchard activities and robots for *harvesting* and *pruning* can partly or fully take over manual tasks. The first will make work more efficient while the second will change the way of work from manual to handling and monitoring robots.

Second, farming will become smarter and data-driven (Schmeitz & van Wijk, 2016). The connected high-tech sensing technology as used for precision fruit farming changes 'management by gut feeling' into 'management by facts' (Sundmaeker et al., 2016). For example, the use of sensors will enable fruit farmers to very accurately predict the volume and quality of supply by processing data which is monitored very precisely (Schmeitz & van Wijk, 2016). Hereby, the fruit farmer is able to predict the harvest and is able to change from the traditional supply-oriented, cost price driven production, to a data-driven approach in which demand and supply are matched. In the long-term, farm equipment will even become autonomous, self-adaptive systems that are able to operate, decide and even learn without on-site or remote human intervention (Sundmaeker et al., 2016).

Finally, there will be a new way of collaboration in the chain (Schmeitz & van Wijk, 2016). The new technological applications will change supply chains in value networks. In a value network, parts, products and machines are fully integrated in the supply chain. Collaboration is important in value networks since individual market players need to shift from an individual approach towards collaboration, in which data through the chain is shared.

To summarize, due to technologization, production processes in fruit farming will change to autonomous, smart, data-driven processes that can be remotely controlled and are fully integrated in the supply chain.

4.1.2 The organisation of work

In this section, the change in the organization of work is analysed as the organizational adjustments that need to be made by the fruit farm in order to imply the new technologies. Before the changes in the nature of work that were mentioned in paragraph 4.1.1 will occur in fruit farming, some organisational adjustments need to be made (Schmeitz & van Wijk, 2016). Automation and precision fruit farming are currently only used to a limited extent in fruit farming (Chapter 3). Important conditions are that tree training systems are suitable for technological applications and that ICT systems are set up in such a way that they support the required flexibility, integration and autonomy (He & Schupp, 2018; Ossevoort et al., 2016). Harvest assistant platforms, picking trains, mechanical pruners and thinners and tractor mounted machines are developed to operate in the current orchard structure. However, for automation of the picking and pruning task the orchard structure needs to change from three-dimensional to one- or two-dimensional trees (Bogue, 2020; Robinson, Hoying, Sazo, DeMarree & Dominguez, 2013). Detection and identification are much easier in these type of tree structures (He & Schupp, 2018). The three-dimensional orchard structure is currently the most used tree structure in Dutch fruit orchards and will not change on the short term because trees in an orchard last for 20 to 25 years (Robinson et al., 2013).

To be able to apply precision fruit farming, a so-called Sensing & Control platform is needed to make data from new technologies usable (Carrez, 2013). A Sensing & Control platform is a platform that can store, process and combine sensor- and machine data with other data and exchange this data with other systems (Kruize et al., 2018). Besides this, the platform can transform management orders into machine instructions and direct the execution of these instructions. However, a Sensing & Control platform is not yet available for Dutch fruit farming. Ossevoort et al. (2016) are presenting a possible design for a Sensing & Control platform in their report. An information standard is crucial in an information architecture to be able to exchange information with different partners in the supply chain (Ossevoort et al., 2016; Schmeitz & van Wijk, 2016). Apart from the necessity of standards for exchanging information, standards also reduce the risk of errors (Schmeitz & van Wijk, 2016).

If the tree training system and the ICT system are meeting the standards that are needed for the application of a new technology, the final decision to apply the technology is a decision that must be taken by the farmer. Considerations to fully, partly or not to make use of new technological applications include the speed and quality with which the technological application can take over or support manual tasks and the investment costs of the technological application (Zhang et al., 2016a). Robotic systems need to perform tasks at a speed comparable to a human and the cost of acquiring, operating and maintaining the technology must be compensated by the benefit when using the technique (Bogue, 2019; Sundmaeker et al., 2016).

To summarize, adjustments in the organisation of work that needs to be made in order to imply the new technologies are that current tree training systems and ICT systems in the organization must be suitable for the new technological applications. Besides this, farmers must want to apply the new technology.

4.2 The quality of work

The changes in the nature and organisation of work have an impact on the quality of work. The quality of work implies the change in working conditions and labour relations (SER, 2019). The change in working conditions concerns the change of an employee's workload which is determined by the physical, social and psychological climate in which work is carried out. Due to technologization, physically demanding, dangerous, dirty and/or boring work will be less done by people (UWV, 2017). This leaves room for more varied and less strenuous work at which greater demands are made on creativity and social skills (SER, 2016). The change in labour relations concerns the change in the relationship between the employer and the employee (SER, 2019). The use of new technologies can create new (flexible) forms of work which can have an impact on this relationship due to the independence of time and place and the use of digital resources (SER, 2016).

New technological applications are also changing working conditions for fruit farming. Manual *harvesting* has always been physically demanding and highly repetitive (Silwal et al., 2017). Due to physical positions that must be taken for picking, heavy lifting and repetitive hand actions employees may get occupational injuries (Silwal et al., 2017; Zhang et al., 2016a). Also, employees are exposed to fall hazards from standing on ladders while picking, and from climbing up and down ladders. Mechanisation of parts of the picking process have decreased the physical constraints of employees (Zhang et al., 2016a). When picking platforms or picking trains are used, employees only have to manually detach the apples while activities such as moving ladders, climbing ladders, carrying a bucket or pulling plucking sleds are eliminated.

Pruning is still a manual task that requires humans to perform arduous work under harsh weather conditions (Tabb & Medeiros, 2017). As with harvesting, the activity can result in falls, lacerations, slips, head/eye injuries, strain to shoulder/back, and repetitive motion injuries (He & Schupp, 2018). Using pneumatically or battery-powered shears for pruning makes the task less fatiguing than when using manual loppers (Byass, Richardson, Shipway & Shipway, 1967). When using a platform instead of ladders for pruning more convenience have been experienced when performing the task (Heijerman-Peppelman et al., 2010). Mechanisation of other orchard operations has made performing these tasks easier. For example, for *planting* a trencher can be used to dig a trench eliminating the need to manually drill posts and planting holes (Heijerman-Peppelman et al., 2010).

When automating the *harvesting* and *pruning* activities, the physical constraints mentioned in the above paragraphs will be eliminated. Besides the improvement of the physical climate, the social and psychological climate of the employee improves as well as greater demands are made on the creativity and social skills of the employee when making use of automation and precision fruit farming. The demand of skills will be further elaborated in section 4.4. The labour relations in fruit farming on the other hand will not change as the biggest part of the employment in the horticultural sectors already consists of flexible labour (Boon, 2012). Therefore, this will not have an impact on the quality of the work.

To summarize, the quality of work will improve due to technologization. Working conditions will improve as physical activities such as harvesting, pruning and planting are becoming more convenient due to mechanization and semi-automation. Full automation of the harvesting and pruning activity will even eliminate physical constraints and creates room for the use of other skills which also has a positive impact on the working conditions.

4.3 The scope of work

The change in the nature and organization of work does not only have an impact on the quality of work, but also affects the scope of work. The scope of work implies the increase or decrease in the number of jobs (SER, 2019). Two effects regarding the scope of work are distinguished in the literature. The first effect is the *destruction effect* which implicates that technologies substitute capital for labour (Schwab, 2016). In contrary, the *capitalization effect* implicates that technologies cause an increase in the demand for new goods and services which leads to the creation of new occupations, businesses and even industries. This is also referred to as the compensation theory (Piva & Vivarelli, 2018). Several recent studies are presenting concerns about unemployment due to technological change. An example is the study of Frey and

Osborne (2017) in which they claimed that 47% of US jobs are at risk of being automated. However, the extent to which jobs are destroyed and created differs per sector (SER, 2019). According to Ter Weel (2018) there are three effects determining the increase or decrease in the amount of jobs. The first effect corresponds to the *destruction effect,* implicating that manual tasks will be replaced by technology which causes a decrease in the number of jobs. The second effect is part of the *destruction effect* implicating that the use of technology leads to higher productivity which causes a decrease in required labour. The third effect, being the *capitalization effect*, is that new jobs can become available due to the use of technology.

The *destruction effect* due to higher productivity occurs in fruit farming since employment for harvesting, thinning and pruning has been reduced due to mechanization of these tasks (Robinson et al., 2013). For *harvesting*, labour efficiency could be increased by 15% to 60% when using a harvest platform (Baugher et al. 2009; Robinson & Sazo 2013; Robinson et al. 2013; Zhang et al. 2016a, b). When using a picking train, efficiency could be increased since the bins do not have to be placed in and removed from the orchard (Heijerman-Peppelman et al., 2010). Hand *thinning* can be reduced when using a mechanical thinner (Schupp et al., 2008; Veal et al., 2011). However, the degree to which hand thinning can be reduced varies per machine. For example, when using a string thinner hand thinning can be reduced with 31%. For *pruning*, higher rates of work can be sustained when using pneumatically or battery-powered shears and a platform can be used to increase efficiency (Byass, 1967; Heijerman-Peppelman et al., 2010).

Automation of tasks can create a *destruction effect* due to the replacement of manual tasks by robots. *Harvesting* is the only manual task that can currently be partly or fully automized (section 3.2). Bulk harvesters require only one worker to drive the harvest machine (Zhang et al., 2016a). Robotic harvesters operate fully automatic and do not need workers to get involved in the picking process. The robotic apple harvester of Abundant Robotics can even replace seven to ten people since it is able to pick one apple every second (Bogue, 2020). Automatic *pruning* needs to be further developed since the runtimes are yet too high to be adequate for taking over manual labour (Tabb & Medeiros, 2017). When applying precision fruit farming, the amount of time needed to collect information about the trees in the orchard is limited since sensors and cameras are taking over this task (Ossevoort et al., 2016). Besides this, the information can be automatically registered resulting in labour savings for registration and quality assurance of 25% (Ossevoort et al., 2016). Information can be shared more easily (resulting in fewer errors and corrections, among others) and there is less need to control and correct data since automation increases the reliability of the data.

Regarding the *capitalization effect* of new jobs coming available, jobs can arise for the development and maintenance of technologies (UWV. 2017). In fruit farming, this effect occurs temporarily for precision fruit farming as this technique is still in development. Currently, a precise application costs a farmer more work than a uniform application. This is because a task card still needs to be manually created as explained in section 3.2. Currently, the raw data that becomes available from the sensors or cameras need to be processed into useful management information on the computer before the farmer can use the information to apply precision fruit farming. Besides the rise in work due to data processing, more time is required for precise application since the speed of application is currently lower than with uniform applying (NPPL, 2020a). For example, with root pruning the tractor can usually drive 4 to 4.5 km/h, but when using automatic precision, the tractor can only drive 1.6 km/h. With further development of precise application, the processing of data can possibly be automated, and higher speed can be gained.

To summarize, the scope of work has slightly decreased with mechanization and semi-automation of orchard processes due to higher productivity and will sharply decrease with the full automation of harvesting and the application of precision fruit farming. When fully automating the harvesting activity the scope of work decreases with seven to ten people per robot. The scope of work is also reduced by the limited time needed to collect and register information. There will be a temporarily increase in work for information processing and precise application, however, these tasks will probably be eliminated and accelerated when the technology is further developed.

4.4 The distribution of work

Next to the impact on the quality and scope of work, the nature and organisation of work can impact the distribution of work. The distribution of work implies the distribution of the amount and sort of jobs among lower and higher educated workers (SER, 2019). Two perspectives towards changes in skills originating from technological change are presented in the literature (Waschull, Bokhorst & Wortmann, 2017). The first perspective is *de-skilling*, also referred to as the degradation of work or polarization of skills approach, implicating that jobs become simpler and lower skills are required. The de-skilling perspective emerged during the first industrial revolution when mechanization replaced skilled labour. The de-skilling perspective was also applicable in the 1970's when the computers were introduced in the production environment. The second perspective is *upskilling*, implicating that higher skills are required for jobs since simple and routine jobs are automated. The automation of simple and routine jobs is referred to as *routine biased technological change,* which implies that as a result of technological applications there is less demand for lower educated people since tasks that these people operate are more suitable for automation (SER, 2019). The higher skills required on the other hand is referred to as *skill biased technological change*, implying that new technological developments will mainly benefit higher educated people as their jobs are more often complementary to technological innovations (SER, 2019).

Manual labour in fruit orchards in the Netherlands is semi-skilled work which is currently mostly done by people from Central and Eastern European countries (UWV, 2017). Due to mechanization, digitalization and the use of robots for automation, more and more routine tasks are disappearing (UWV, 2017). As described in section 4.3, also in fruit farming routine tasks are increasingly disappearing. This is in line with the concept of *routine biased technological change*. The concept of *skill biased technological* change is also presented in fruit farming as the use of robots and machines is causing a shift towards tasks that require a higher level of training and education (UWV, 2017). Users should have certain digital skills when technological applications such as robots and precision machines in fruit farming are used (Sundmaeker et al., 2016). Therefore, the required level of competence of employees shifts upwards as they need to be able to control these robots and machines and use computer programs (UWV, 2017). Employees must become more technical oriented and are required to have more problem-solving skills and analytical skills to interpret data (UWV, 2017). Besides these, social skills such as communication, teamwork and responsibility are becoming more important. From the farmer, some additional skills such as creativity, speed and flexibility are also required (Schmeitz & van Wijk, 2016). Creativity is needed to come up with new business models that can possibly emerge due to technological applications. The concept of 'the big eat the small' has been changed to 'the fast eat the slow', making speed an important skill. Finally, personal flexibility is important to be able to accept changes.

To summarize, there will be more work for higher educated people and less for lower educated people as routine tasks are disappearing and tasks requiring a higher level of training and education arise. The required level of competence of employees shifts upwards because they need to have problem-solving, analytical and social skills. In addition to these skills, creativity, speed and flexibility are becoming important skills for farmers.

4.5 Conclusion

In this section the sub-research question "*How do new technological applications change work on Dutch top fruit farms?*" has been answered. It can be concluded that in recent years the quality of work has sharply increased because machines can support or even take over physically demanding, dangerous, dirty and/or boring manual tasks. However, the amount of work and the requested competences have remained about the same. In contrast with current technological applications, future technological applications will reduce the amount of manual labour required and can cause a new distribution of labour amongst higher and lower educated people. Since production processes in fruit farming are changing towards autonomous, smart, data-driven processes that can be remotely controlled and are fully integrated in the supply chain, routine tasks will disappear and make way for machine supporting and controlling tasks. These tasks require a higher level of competences of employees. However, conditions are that current tree training systems and ICT systems in the organization must be suitable for the new technological applications and that farmers do want to apply the new technology.

5 Conclusion and discussion

In this chapter, a conclusion and discussion on the research will be presented. In the first section, the conclusion is given, aiming at answering the main research question. After that, the research results, limitations of the research and recommendations for further research are discussed.

5.1 Conclusion

The new technological applications in fruit farming can be divided in technologies that are currently being applied and technologies that may be applied in the future. Current technological applications are in the growth, maturity or declining stage of the Product Life Cycle. Current technological applications are platforms and picking trains for harvesting, pneumatically or battery-powered shears for pruning, and mechanical and chemical thinners. Besides these technologies, various tractor mounted machines are used in fruit farming. Future technological applications are in the introduction phase of the Product Life Cycle, or still in development. Future technological applications are robots for harvesting, in-field sorting and pruning, and technologies for precision fruit farming.

Work on Dutch fruit farms will change in terms of nature and organisation, quality, scope and distribution due to technological applications. The nature of work will change to autonomous, smart, data-driven processes that can be remotely controlled and are fully integrated in the supply chain on the condition that current tree training systems and ICT systems in the organization must be suitable for the new technological applications and that farmers do want to apply the new technology. The quality of work will be increased as working conditions will be improved due to the application of new technologies. The scope of work will be decreased as technologies increase productivity and manual jobs will be taken over by machines. Finally, more work will be done by higher educated people rather than lower educated people since routine tasks are disappearing and the required level of competences shifts upwards.

The general research question of this research is **“What is the impact of new technological applications on work on Dutch top fruit farms?”**. The impact of new technological applications on work on Dutch fruit farms is determined by the speed and extent to which technologies will be adopted. Because the latest technologies currently still require high investments, a change in orchard structure and a suitable ICT system, work on the fruit farm will not change on the short-term. Also, a lot of technologies should be further developed in order to gain the perceived speed and quality comparable to humans. When the technology is further developed, it will comply with those requirements and become cheaper. In the meantime, fruit farmers will be able to introduce a new plant system on their fruit farm. Therefore, in the long-term, the impact of new technological applications on work on Dutch top fruit farms could be that the nature of work changes to autonomous, smart, data-driven processes that can be remotely controlled and are fully integrated in the supply chain. The quality of work will further rise while the scope of work decreases. Finally, there will be another division of labour between higher and lower educated people.

5.2 Discussion

Previous research has shown that technological applications will have an impact on work. This research further examined the impact of technological applications on work on Dutch top fruit farms. However, there are a few limitations for this research. First, this research is based on literature only while not all information is accessible and can be found in the literature. Not all articles in the database were accessible for students from the Wageningen University and there is a possibility that a new technological application is currently in development that have not yet been described in the literature. Since this study is fully based on literature, technologies that have not been written about in the literature or have been written about in articles to which there was no access were not included in the results of this study. Secondly, a non-systematic search method was used to find literature to answer the first sub-question. The use of a non-systematic search method results in a lower validity of the research results compared to a systematic search, because it is uncertain whether all technological applications have been identified in the research. However, it can be assumed that all significant technological applications have been identified given that the NFO database has been used and this organisation closely follows the developments in the sector. The third limitation is that some useful articles were gathered using the snowball effect. Snowballing leads to older articles and may give a biased view since authors mostly refer to the same kind of articles. However, authors of the articles found through snowballing were checked before usage to make sure that they are written by different authors.

Another limitation of the research is that the Product Life Cycle Theory was used to categorize the technological applications into current and future applications while this theory is originally intended for products and not for technologies. The Product Life Cycle Theory does not include factors such as technology adoption or integration of the technology in products or processes. Despite this disadvantage, the Product Life Cycle Theory is the best method to categorize technological applications since other life cycle theories that do take these factors into account, such as the Technology Life Cycle presented by Arthur D. Little (1981), are about technology in a broader sense.

The final limitation of the research is that it considered that the described technological applications will be applied in fruit farming. The question whether these technological innovations will be applied has been left out of consideration. This will depend on the changes required in the current farm structure, the quality and speed of the technological application and the cost thereof. Therefore, it should be considered that farmers can also choose not to apply the technology to their farm. In that case, there is no impact of the technological application on work. Further research will have to focus on the adoption of new technological applications in fruit farming to determine whether the impact on work will be applicable. Further research could also focus on whether the impact on work also holds for different countries and/or product groups. The results are now limited to Dutch top fruit farms but may hold for different kinds of fruits and/or fruit farms in other countries as well.

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Appendix I – Table of fruit farming operations

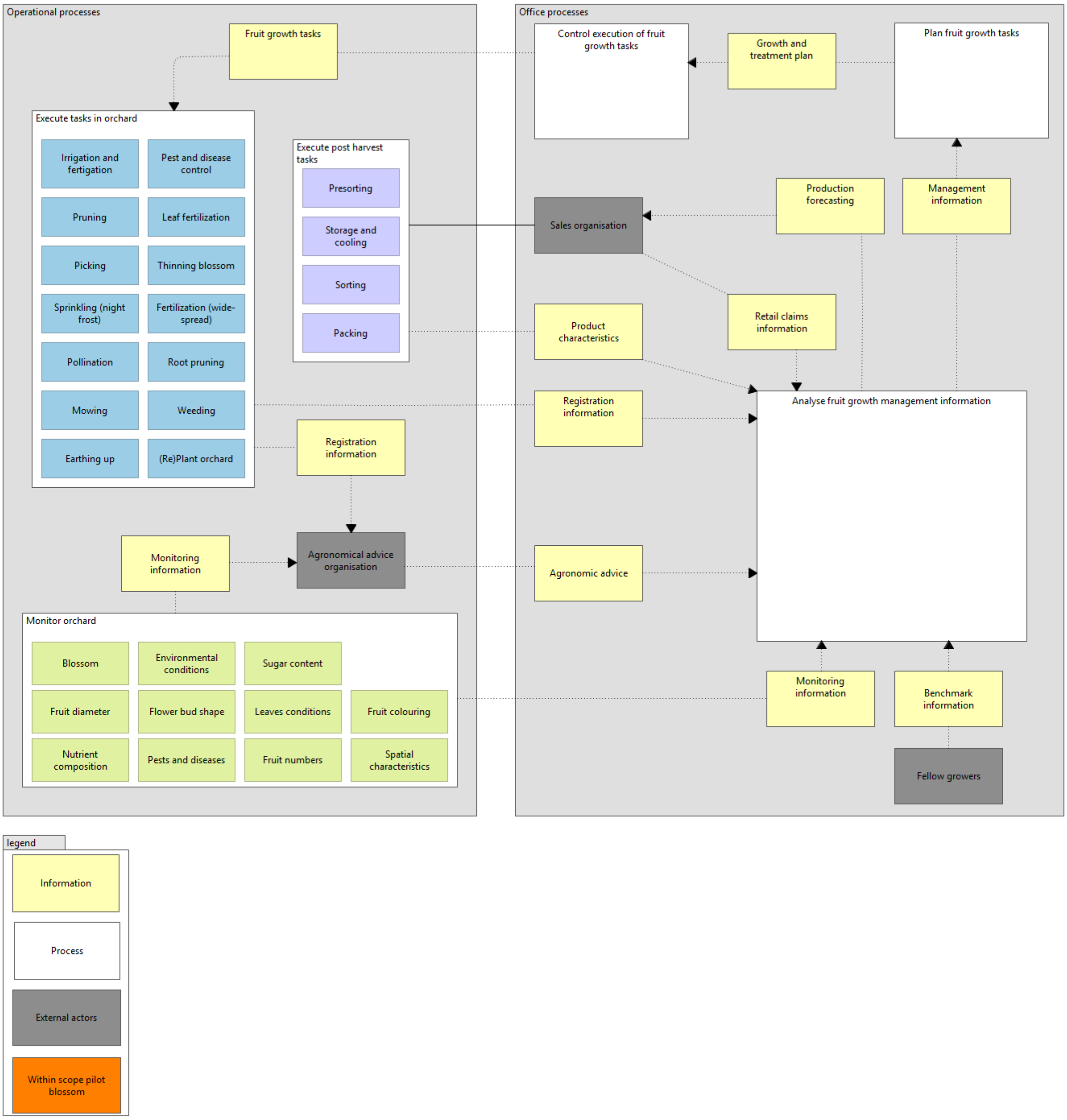

Figure 5 Reference model for fruit farming (Ossevoort et al., 2016)

Appendix II – Criteria to evaluate sources

Table 1 Criteria to evaluate sources (Source: Wageningen University & Research, n.d.)

Criteria	Questions
Suitability	☐ Is the content of the source relevant for your topic? Does it give the information you need? ☐ Is this source too elementary or basic, too technical or applied, too advanced, or just right for your needs? ☐ Is the publication in English or another language you can understand?
Authority	☐ Who wrote it? ☐ Does the author have expertise in this field? ☐ What kind of organisation is the author working for? And what is its reputation?
Purpose	☐ What is the purpose of the publication? Is it to inform, to sell a product, to give opinions, or to present research findings? ☐ What is the intended audience? Is it written for scientists, for professionals or for the general public?
Reference & source	☐ Can you check the accuracy of the information? ☐ Do the authors cite other work? Is there a reference list? ☐ What types of references have been used? Scientific or popular sources?
Type of source	☐ What type of document is it? Book, journal article, report, website, ...? ☐ Is the publication peer-reviewed? ☐ Does it reflect primary research or secondary research?
Currency	☐ When was the information published? ☐ Is it important to have up-to-date information?

Appendix III – Enlargement Figure 3

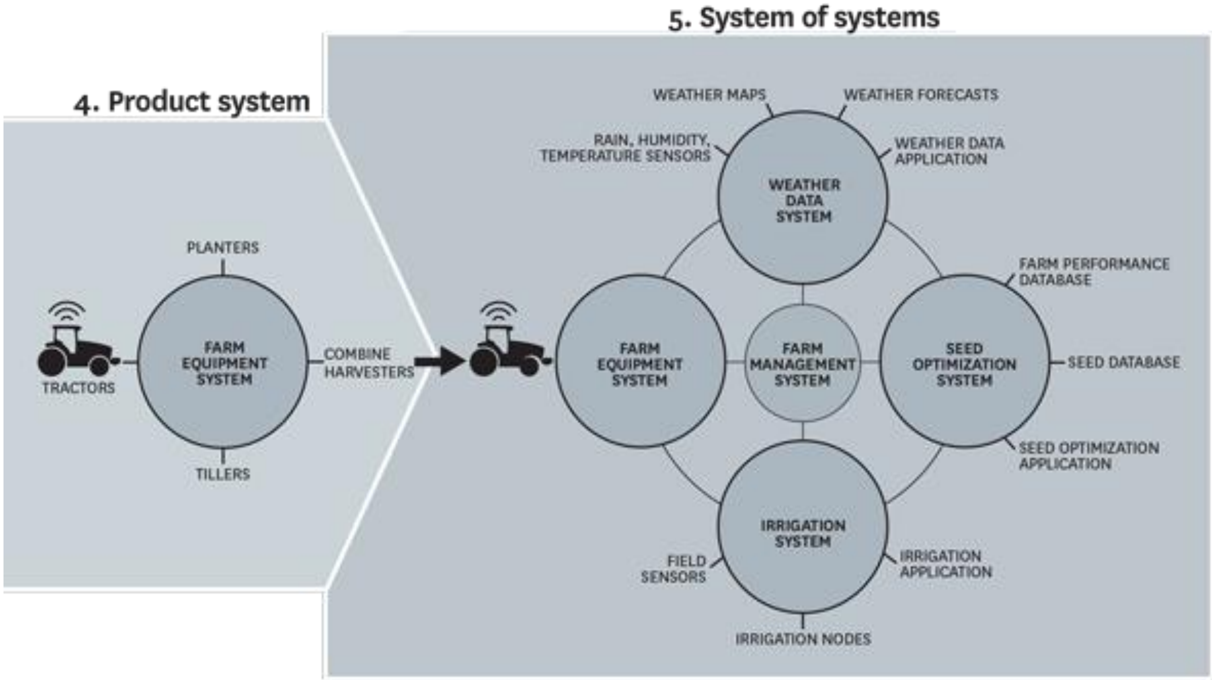

Figure 6 Enlargement Figure 3