The possibilities of water consumption reduction in Western Cape through precision agriculture

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Abstract

The Western Cape region of South Africa has faced a water crisis for the past few years, which suddenly reached acute levels earlier this year. There is an urgent need to find suitable, sustainable alternatives to the current methods of water management in the Western Cape region. We propose a mitigation strategy that uses precision agriculture to change the water management methods employed for agriculture, because this branch is extremely water-intensive and counts towards 60% of South Africa's water consumption. The various methods of precision agriculture and its accompanying socio-technical-economic benefits are described, followed by an elaboration of the various barriers towards the implementation of precision farming in South Africa. Finally we present the mitigation strategy for increasing the adoption of precision agriculture in these areas.

Introduction

Since 2015, the city of Cape Town, situated in Western Cape, South Africa, has experienced a lack of sufficient rainfall, which has turned into a large-scale drought crisis for over a year (City of Cape Town, 2017). The day that the city will run out of water, the so-called Day Zero, is slowly being pushed back by small rain showers, but is still a significant threat to the citizens of Cape Town (Sandhu, 2018). While the Cape Town drought crisis is a complex problem, it has a wide range of solutions and mitigation approaches, a major part of which can be found in the field of agriculture, since this branch is uses more than 60% of the water in South Africa (DWS, 2013) and the drought has an immediate impact on the agricultural food production. For example, the production of maize, one of the largest export products of South Africa, decreased by 24% between 2016 and 2017 due to the extreme droughts (South Africa Yearbook 2016/17, 2017). There is also a major industry revolving around vineyards, with production concentrated around Cape Town, and the harvest of this industry has seen the same problem: the national production of dried vine fruit and dried tree fruit decreased by almost 20% in one year because of the drought (South Africa Yearbook 2016/17, 2017). Since more that 45% of the agricultural export products of South Africa comes from the Western Cape, with a yearly added export value of R14 billion (€950 million), the economy depends heavily on the agriculture (Western Cape Government, 2018). Agriculture, and especially the production of cereals, is also important to feed the inhabitants of South Africa and to reduce the dependency on imported goods (Western Cape Government, 2017)

The crisis is nowhere near over, as scientists expect the frequency and the length of droughts to increase due to climate change (Ziervogel, 2010). Meanwhile, Cape Town has experienced a population growth of 38% over the last fifteen years, leading to a total of more than 4 million inhabitants (Statistics South Africa, 2011; Western Cape Government, 2016). Due to this increasing population, the water demand of Cape Town has more than tripled since the 1970s, which leads to a competition between water designated for farms and for the city (Callaway et al., 2009). Therefore, a stable and reliable food and water supply is needed to be able to manage this change for future years. The need arises for farmers in Western Cape to adjust their farming to a more resource-efficient and high-yield production.

A worldwide emerging strategy that can achieve this change is precision agriculture (PA). PA is described as measuring and observing the variances in the field and responding with a decision support system (Zhang, 2015). PA can help farmers increase profitability, optimize yield and quality, and reduce costs, with the use of spatial and temporal crop and soil data (e.g. Paustian & Theuvsen, 2017). This means that the technology has the potential to offer security for farmers even in more unstable weather conditions and the growing population of the city of Cape Town and surroundings. PA technologies can also help farmers to reach goals of sustainable intensification, which means to increase food production from existing farmland while minimizing the pressure on the environment (Lindblom et al., 2017).

Currently, PA is a slowly emerging technology spread over the world. The first forms of precision agriculture have entered the market in the 1990s (Lindblom et al., 2017). Precision agriculture comes in different shapes and sizes, personalized to the farm on which it is being used, and it evolves with the changing technologies of more advanced sensors and spatio-temporal software systems. In Germany, about one out of five farms already uses a form of PA (Kutter et al., 2011), particularly larger farms (Paustian & Theuvsen, 2017). Some farmers in South Africa are starting to conventional implement drip and sprinkler irrigation systems, which reduces evaporation, surface runoff and deep percolation depending on the farm's location (FAO & WWC, 2015). Furthermore, conventional drip or sprinkler systems gives farmers the chance to improve the timing and distribution uniformity of irrigation, which lead to a higher yield of crops per land area (FAO & WWC, 2015). However, farmers have shown some resistance against the implementation of sensors, partly because of financial reasons, but mostly because many farmers fail to see the benefit of PA above the sole use of farming experience (Lindblom et al., 2017). Nevertheless, with the right marketing techniques, mainly larger sized, educated, wealthy farmers are able to benefit from PA, as will be elaborated later in this paper. Farmers with a lot of hectares of land are more likely to implement the technologies, among other things, because due to the size, this land is harder to monitor without sensors (Paustian & Theuvsen, 2016). Rich farmers relatively have more access to the resources necessary to implement the technology, so the largest barrier is already overcome.

This research paper will further explore what the benefits are for farmers in the Western Cape to use precision agriculture and how it can be implemented. The aim of this paper is to discover the potential of precision agriculture to contribute to the solution to the Cape Town water crisis. Therefore, the research question states: How can PA be used to save water in the agricultural sector in South Africa? This question will be answered through literature research on this technology locally and globally. Different kinds of precision agriculture are presented and are discussed in the context of South Africa. Then, the barriers and facilitating factors of precision agriculture are discussed. Based on the technology and the barriers and facilitating factors, we will present a mitigation strategy supported by the literature research.

What is Precision Agriculture?

1. Artificial Intelligence in precision agriculture

Precision agriculture is based on measuring and observing the variances in the field and responding with a decision support system (DSS) (Zhang, 2015). This process is described by figure 1 (Zhang, 2015).

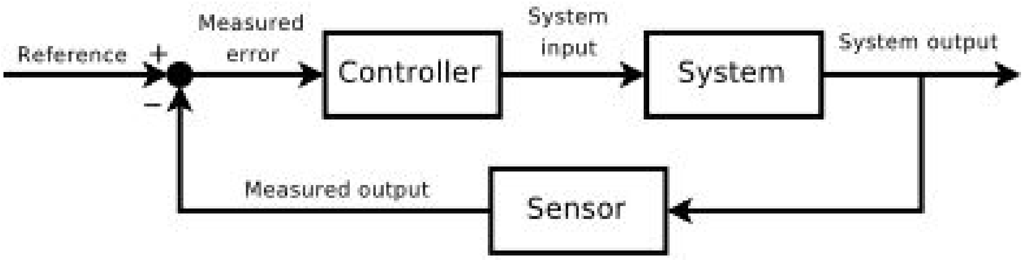

Figure 1: feedback schema that can be used for precision agriculture

In his model, there are variables, for example the moisture level, amount of nitrogen, the heaviness of the soil etc. The desired values for these variables are known. The goal is always to end up at approximately this desired level. A sensor system measures how far the real value is from the desired value. A control algorithm or artificial intelligence then calculates a way to reach that desired value and it either proposes to the farmer what to do, or it immediately takes action. There are always external influences, most notably the weather, that can cause the variable to still deviate from the desired value.

According to a very recent report by Energias Market Research, The Global Artificial Intelligence in Agriculture (AIA) Market is expected to grow significantly, driven by factors such as the rising adoption of information management systems, automated irrigation, deep learning techniques that increase crop productivity, and a general landscape pressure due to increasing global population, which consequently leads to an increasing consumption of agricultural products. Furthermore, the AIA market has found a niche in the domain of precision farming, in combination with the increasing adoption of smart sensors ("Global Artificial Intelligence Market - Industry Size Analysis Reports", 2018). Smart sensors like Parrot's Sequoia, which can be used to analyse sensors from the sky ("Parrot Sequoia", n.d.), or Kilomo Salama, that is similar to a connected weather station to reduce collateral damage due to weather changes ("About Kilimo Salama", 2010), are being implemented across the globe.

Most of the technologies pertaining to AIA fall under three main categories: predictive analytics (such as technologies that use Artificial Neural Networks), crop monitoring (using sensors and drones) and agricultural robotics (such as Aerobotics). These categories are described below.

1.1. Predictive Analytics

An Artificial Neural Network (ANN) is a massively parallel-distributed information processing system that has certain performance characteristics resembling biological neural networks of the human brain (Haykin, 1994).

ANNs have been used by researchers for rainfall-runoff modeling, streamflow prediction, ground-water modeling, water quality, water management, precipitation forecasting, time series analysis of various external influences on farm crops, reservoir operations, and other hydrologic applications. Utilizing an ANN, one study in the Netherlands developed an approach to predict daily water demands (Zhang, Watanabe & Yamada, 1994).

Although several studies indicate that ANNs have proven to be potentially useful tools in hydrology, their disadvantages should not be ignored, especially regarding data availability. The success of an ANN application depends both on the quality and the quantity of data available. This requirement cannot be easily met, as many hydrologic and agricultural records do not go back far enough. Quite often, the requisite data is not available and has to be generated by other means, such as another well-tested model. Even when long historic records are available, we are not certain that conditions remained homogeneous over this time span. Therefore, it is desirable to have data sets that are recorded over a system that is relatively stable and where human activities are predictable and not subject to sudden changes in pattern. Representing temporal variations is often achieved by including past inputs/ outputs as current inputs. However, it is not immediately clear how far back one must go in the past to include temporal effects (Govindaraju, Rao, Leib, Najjar, Gupta & Hjelmfelt Jr, 1999).

1.2. Crop monitoring using sensors

The crop monitoring system can use remote sensing or real time sense-and-apply (RTSA) (Zhang, 2015). If remote sensing is used, it is called georemote precision agriculture (Zhang, 2015), where data from satellites and drones is used to analyse the fields. An example of georemote precision agriculture is offered by SkySquirrel Technologies Inc. who bring drone and AI technology to vineyards, which are one of the more water-intensive crops the Cape Water region. They currently have a product under trial that helps farmers make informed irrigation and cover crop management decisions, directing water resources only where and when they are needed, while minimizing the ecological footprint of their vineyard. This helps farmers to improve their crop yield and to reduce costs. Users pre-program the drone's route and once deployed the device will leverage computer vision to record images which will be used for analysis using AI. ("VineView - Water Index Mapping | Water Stress Analysis", n.d.).

RTSA uses sensors in the soil or on the tractor to take measurements and it immediately makes a decision what to do with it. For example, the Yara N-sensor measures the wavelengths that the plants reflects and calculates the nitrogen absorption, see figure 2.

Figure 2: The Yara n-sensor (DLG, 2015)

It then immediately changes the amount of fertilizer to reflect the plants' needs. This decreases the amount of fertilizer needed in total and prevents the over- and under-supply of fertilizers, which improves the homogeneity and quality of the crops (Lindblom et al., 2017).

A combination of georemote sensing and RTSA is a soil scan as used by all the farmers in the precision agriculture project in the Netherlands (Proeftuin precisielandbouw, 2018). They measure the heaviness of the soil before planting any crops. This data is analyzed by a company, and it gives the farmers maps they can use in a later stage on the field for variable application of fertilizer or herbicides (Akkerweb.eu, n.d.; NPPL, 2018).

A Colorado based company called aWhere uses machine learning algorithms in connection with satellites and takes data from more than 7 billion points scattered across the globe to predict weather and climate trends, from which they analyze crop sustainability and evaluate farms for the presence of diseases and pests. ("Agronomic Data Products | aWhere", n.d.).

1.3. Agricultural robotics

A very recent example of agricultural robotics and predictive analysis is Aerobotics, a startup based in Cape Town, which uses on-demand drone technology and satellite imagery to help farmers manage their fields on a plant-by-plant basis, therefore reducing costs and resource use and improving farming efficiency. They have a cloud-based data analytics platform that helps farmers interpret the data using 2 years worth of historical records. The drones can detect whether a plant is receiving too little or too much water. The drones aim to highlight problem areas on farms with crop health maps and moisture index maps to reduce water usage and irrigate more precisely, as well as track crop performance across seasons ("Aerobotics - Clarity from above", n.d.).

2. Other big players in the market

Microsoft's FarmBeats program looks into building several unique solutions to solve soil-condition problems using low-cost sensors, drones, and vision and machine learning algorithms. They address the problems that currently prevent the large-scale adoption of AI technologies in the agricultural sector, such as the lack of electrical power or Internet connectivity in rural areas, and the knowledge gap of farmers who are typically not technology savvy ("FarmBeats: AI & IoT for Agriculture - Microsoft Research", 2015)

Other key players operating in the global artificial intelligence in agriculture market are John Deere, Iteris, Agworld, Trimble, Farmlogs, AGCO, Cropx, Prospera, Resson, IBM, Frambot, Tule Technologies, Granular, Gamaya, Hortau, Pycno, Agrosmart, Grownetics, and Raven Industries among others ("Global Artificial Intelligence Market - Industry Size Analysis Reports", 2018).

3. Effects of Precision Agriculture

PA can make the lives of many farmers much easier by monitoring and providing information on tasks. It has many benefits for a farm to switch to some form of precision farming. However, experiments in the past have shown that the conventional benefits of this drip and sprinkler irrigation technology can cause farmers to increase their plot sizes by an average factor of 2.5 times, which will lead to a total increase of the water use (Raz, 2014). Besides that, the use of the drip and sprinkler irrigation systems can decrease runoff, which can affect neighboring farm and increase their water use (Humphreys et al., 2010; Ahmad et al., 2014).

Next to potential water savings, precision agriculture can save farmers time, costs, and materials by using very specific navigation systems, such as GPS and LBS, for their fertilizer machines (Auernhammer, 2001). Since crops can be more specifically fertilized to what is needed, in less trips, and more adequate coordination, it is likely that the yield increases and the energy cost decreases (Auernhammer, 2001). These benefits also reflect positively on the natural environment. However, the technology is expensive, and therefore, it is not beneficial for every farmer.

In Denmark, researchers investigated the results of implementing site-specific weed management (Jensen, 2012). They found herbicide savings of 54% in wheat (Timmermann et al., 2001) and between 20% and 90% herbicide reductions (depending on the cultivar) by detecting weed infestation (Timmermann et al., 2003). The researchers Gutjahr and Gerhards (2010) found savings for herbicide against weeds of circa 20% for winter rapeseed. For sugar beet this was between 46% and 57% savings of herbicides. In maize, the herbicide savings were between 6% and 46%, depending on the type of weed. This shows that this specific type of precision farming has a massive impact on the total costs for farmers on herbicide (Jensen, 2012).

Barriers and Facilitating Factors of using Precision Agriculture

Most of the research of the barriers of precision agriculture is done for farmers in Europe or Northern America, and not South Africa or even Africa in general. One of the possible reasons is that PA is more common in Europe, for example up to 10-30% of the farmers in Germany have used PA(Kutter et al., 2011). Because of the lack of research in

South Africa, this section of this paper will focus on farmers in the Western Cape region with greater financial means, as these have the resources to purchase the technology, and are thus expected to have similar barriers as farmers in Europe and Northern America.

According to a literature review done by Pierpaoli et al. (2013), the following model can be used for the attitude of farmers to adopt precision agriculture, based on the Technology Acceptance Model (TAM). TAM is based on the theory of planned behavior, which argues that attitude, subjective norms and perceived behavioral control lead to an intention to perform an action and lead to certain behavior (Baumeister & Bushman, 2014). Pierpaoli et al. describe the factors that influence the attitude, as part of three groups: Competitive and contingent, socio-demographic, and financial factors

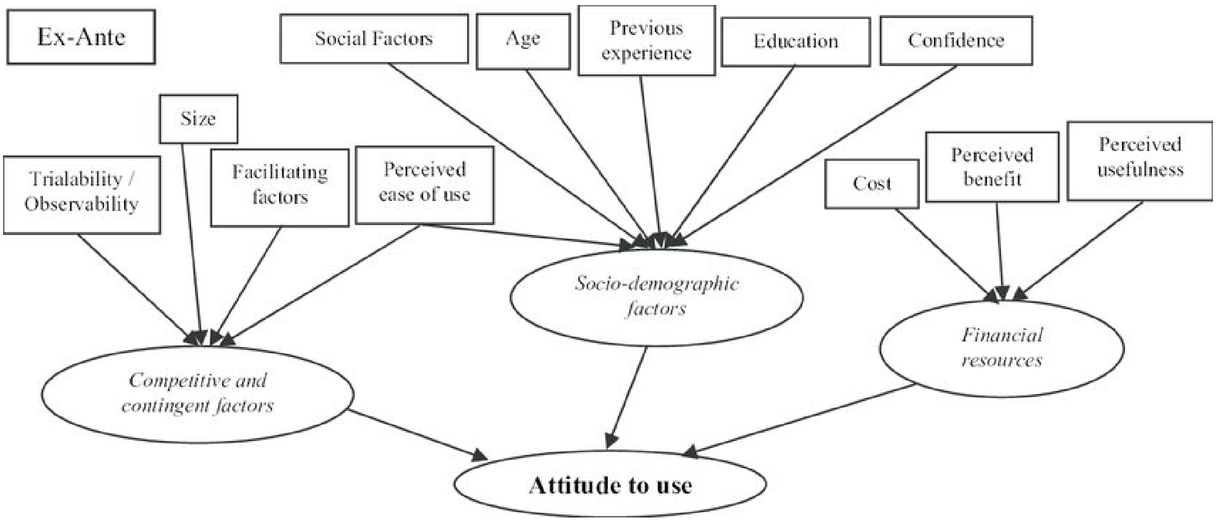

Figure 3: Factors influencing the attitude towards precision agriculture (Pierpaoli, 2015)

All these factors are explained and elaborated in the next part of this research. Possible solutions for factors that negatively influence the attitude of farmers are mentioned in the discussion.

1. Competitive and Contingent Factors

According to the model set up by Pierpauli et al., the competitive and contingent factors are farm size, facilitating factors, trialability and observability, and perceived ease of use.

1.1 Farm size

In various studies, it is found that larger farms are more likely to have precision agriculture (Paustian & Theuvsen, 2016; Pierpauli et al., 2013; European Commission, 2014; Larson et al., 2008). Various reasons are mentioned, such as the fact that larger farms are generally more focused on maximising their profits and the initial costs are relatively smaller and easier to earn back (European Commission, 2014). We therefore propose to focus on large farms in Western Cape. It is difficult to give an overarching definition for large farms, because that depends on the produced goods: fruit farms and vineyards are smaller than farms producing maize (Greenberg, 2015). We therefore define a large farm as a farm that is larger than at least 80% of the other farms in the same category.

1.2. Facilitating factors

Facilitating factors, such as support services and demonstrations are positive for the attitude towards PA, because it promotes how easy the technology is to use (Pierpaoli et al., 2013; Larson et al., 2008).

Precision agriculture technology advises a farmer to take action based on models made by data from sensors, drones or satellites. According to Lindblom et al. (2016), this advice can be overly rationalistic and therefore can be contradictory to the farmer's beliefs and empirical experiences. In the end, the final decision is made by the farmer or the farmer's advisor. Therefore, the device should provide the information which complements the experiences of the farmer. In this way, the decision making process is more transparent (Lindblom et al., 2016).

One of the important facilitating factors is that farmers are involved in the design of the precision agriculture technology to fit their needs. At the moment, farmers do not feel involved in the development of PA (Lindblom et al., 2016; Ljung & Källstrom, 2013). Since every farm has its own specific needs that researchers may be unaware of, a designed product might not exactly fulfill the needs of farmers (Ljung & Källstrom, 2013). Farmers therefore do not put as much trust in the advice of the model less and are less likely to apply it (Jakku & Thorburn, 2010). Lindblom et al. therefore propose on the one hand to involve the farmers in the design process, and on the other hand to improve the accessibility of the data to the farmers (2016). During the design process, it is important to stress that the researchers and designers can learn from the farmers and vice versa (Jakku & Thorburn, 2010).

When a farmer uses different technologies on his farm, tractors can be full of screens and tablets (lindblom et al, 2016). There is need for a system that can combine all these technologies to make it easier to comprehend and have a better overview (European Commision, 2014). However, these standards do not yet exist, and therefore the different systems are not yet compatible. This study done on behalf of the European Parliament has also found that more independent evidence is needed to convince farmers that the technology is useful.

1.3. Trialability/observability

The possibility of a trial period increases the chances of a farmer adopting PA (Larson et al., 2008). This is closely related to perceived ease of use and previous experience with precision agriculture. If it is possible to try out a new technology for a while, farmers find the technology easier to use, or at least expect the technology to be easier to use (Pierpaoli et al., 2012).

Observability is very important in the adoption of precision agriculture (Lindblom et al., 2017, Eastwood et al., 2012). Farmers are not likely to implement a technology if the effects are not visible quickly. Precision Agriculture technologies that solve a very visible problem and have immediate effects, such as steering assisting technologies are more widely accepted than for example site specific herbicide distribution (Lindblom et al., 2017; Holland et al., 2013). Once again, the solution that Lindblom et al. (2017) propose to increase the visibility of the effects of precision agriculture is to include farmers in the design process.

1.4 Perceived Ease of Use

A farmer that believes that the precision agriculture technology is complex or challenging to use is less likely to implement it on their farms (Aubert et al., 2012; Pierpaoli et al., 2013). Aubert et al. found four factors that influence the perception of the ease of use of PA technology (2012), namely knowledge of precision agriculture, compatibility with other technology, the quality of the support and the knowledge of the employees. According to Lindblom et al. (2016), farmers need to know that a learning process is needed to learn how to use PA technology and that the technology will get easier to use after a while. Local experts are needed to give an initial introduction to the technology in order to increase adoption (Aubert et al., 2016; Pierpaoli et al., 2013). As these experts are scarce, it is important on large farms that the employer and the employees already have more knowledge of the technology (Kitchen et al., 2002).

2. Socio-demographic factors

The socio-demographic factors that are discussed below are age, social factors, previous experience with PA, education, and confidence.

2.1. Age

Researchers have conflicting findings of the effect of age on the adoption attitude towards precision agriculture: According to some research, young farmers are more likely to implement PA (e.g. Larsson et al., 2008; Walton et al., 2008), although this was not always a significant effect (Paustian & Theuvsen, 2016). Paustian & Theuvsen therefore propose to use experience as a farmer as a factor influencing PA adoption instead of age. They have found that farmers in Germany with less than 5 years or between 16 and 20 years of experience are most likely to be willing to adopt precision agriculture (Paustian & Theuvsen, 2016). This could have many reasons, such as the fact that inexperienced farmers can have gained knowledge of precision agriculture during their studies and are more used to new technology in general. Also, these inexperienced farmers still have a long time ahead, so they could possibly benefit from their precision agriculture for many years (Paustian & Theuvsen, 2016). More experienced farmers (16-20 years) are more highly educated in Germany and that could be a reason that they are more likely to adopt PA (Paustian & Theuvsen, 2016). For South Africa, it could therefore be important to promote and market PA to a young and educated target group.

2.2. Social Factors

Social factors are here defined as “the context in which people live their daily lives” (Gifford & Nilsson, 2014). Examples of such are religion, ethnicity, culture, social class, norms, and values.

There has been little to no research on the effects of social factors on the attitude towards precision agriculture. There are two main reasons to use precision agriculture: to increase crop production and quality, and to reduce the waste of resources (European commission, 2014). Farmers that are more environmentally conscious and think protecting the environment is part of their responsibility can choose for PA, such as some of the farmers in the Proeftuin precisielandbouw project in the Netherlands (2018).

2.3. Previous Experience with Precision Agriculture

People that do not have a lot of experience with computer systems in general and Precision Agriculture systems in particular are less inclined to switch from conventional farming to precision agriculture (Lindblom et al., 2017).This factor is also closely related to Perceived Ease of Use and Confidence. People that have less experience with a technology, perceive it to be more difficult to use (Pierpaoli et al., 2013) and are not confident that they can learn how to use the technology. Possible ways to get acquainted with the technology are (free) trials. For example, South Africa based Aerobotics offers a free 7 day trial to reach more farmers that have less experience (Aerobotics - Clarity from above, n.d.). Another possible solution for this factor is to include more and better guidance, before and after the purchase of precision agriculture technology (Pierpaoli et al., 2013).

2.4. Education

All the found research agrees that higher levels of education have a positive effect on the attitude of precision agriculture and higher educated farmers are also more likely to have precision farming technology on their farms (e.g. Paxton et al., 2010;Aubert et al., 2012; Larson et al., 2007). Possible explanations are that higher educated farmers find it easier to learn to use a new technology (Schimmelpfenning & Ebel, 2011), and have experience with precision agriculture at schools and other education (Paustian & Theuvsen, 2016).

2.5.Confidence

Confidence is here defined as “the attitude of having the ability to learn and use the technology” (Adrian et al., 2005 and Tohidyan Far & Rezaei-Moghaddam, 2017). The confidence to use a technology positively influences the user’s perceived ease of use. Adrian et al. (2005) found that farmers who were more confident were more likely to adopt the technology. In Iran, it was also found that farmers that showed more confidence were more likely to adopt precision agriculture (Tohidyan Far & Rezaei-Moghaddam, 2017). Apart from this Tohidyan Far and Rezaei-Moghaddam, there is not a lot of research that takes confidence into account as being a barrier or facilitating factor for the intention to adopt PA, although it is recognized as part of the technology acceptance model (Rezaei-Moghaddam & Salehi, 2010)

3. Financial resources

3.1. Costs and benefits

The main reason farmers from various countries in Europe mention to not adopt PA is that the financial costs are too high (Kutter et al., 2011; Department for Environment, Food and Rural Affairs, 2013). However, in a study in the United Kingdom, it was also found that 78% of the farmers that decided to use PA, have chosen it to reduce costs (Department for Environment, Food and rural Affairs, 2013). Other research has shown that the effect of income as a barrier to adopting PA has decreased in the period 2004-2013 (Holland et al., 2013) or was found to be insignificant (Larson et al., 2007).

According to the European Parliament, there needs to be more independent research in the real profitability of PA in order to convince people to use it (European Commision, 2014).

If used correctly on large farms, precision farming leads to less financial costs on the long term (e.g. Jensen et al., 2012), although incorrect implementation can lead to more environmental pollution and increased financial costs (Lindblom et al., 2017; Aubert et al., 2012).

3.2.Perceived usefulness

Farmers do not always perceive the PA technology to be useful. Even if there is considerable evidence that precision agriculture has a positive effect on crop yield and profits, farmers do not necessarily use the technology more (Lindblom et al., 2017). Farmers do not know if the benefits weigh up against the costs (Aubert et al., 2012). Some farmers also believe that their land is not suitable for PA and therefore do not use the technology (Department for Environment Food and Rural Affairs, 2013).

The perceived usefulness is influenced by many factors that overlap with the perceived ease of use. For example, the compatibility of the PA technology with current technologies in the tractor or around the farm also strongly influences the perceived usefulness (Lindblom et al., 2016, Aubert et al., 2012). Research done in Europe suggests that technologies that have quick and visible results are more likely to be adapted (European Commision, 2014). Examples of these are autosteering systems that lead to less driving on tractors.

Improving the perceived usefulness cannot only be solved by giving farmers data of the economic benefits (Aubert et al., 2012) or by giving them evidence that the technology works (Lindblom et al., 2017). However, in the Netherlands, it was found that the larger group of farmers will follow if the first adopters are convinced by using PA (European Commission, 2014).

Potential of Precision Agriculture to mitigate the Cape Town Water Crisis

Many of the sophisticated technologies discussed in the previous sections share many barriers to wide-scale use, one of which is the financial costs. While they are arguably highly effective, they are not yet affordable on a large scale. Switching to higher-value precision technology systems will require significant investment into operation and maintenance costs, in excess of those required when using traditional, surface irrigation methods. The higher investment costs could place some farmers at greater financial risk and limit their responsiveness to changes in the amount or timing of irrigation water supplies, as might occur with climate change or with increasing competition for water in agriculture and other sectors. For these reasons, often the expected farm-level adoption rates and aggregate outcomes of programmes that promote the use of higher technology irrigation systems are not realized (Van der Kooij et al., 2013; Burnham et al., 2014).

Hence as mentioned before, the proposed early adopters should be farmers with bigger agricultural yields and cropland, who can afford to buy into or invest in the technology (e.g. Paustian & Theuvsen, 2016; Daberkow and McBride, 2003; Roberts et al., 2004; Reichardt et al., 2009; Lambert et al., 2014). Simultaneously, it is important to educate new or young farmers if in order to usher in a generation of farmers that is more environmentally-conscious and oriented towards saving resources. This change can be brought about by introducing and teaching some of these technologies in schools, for example (Paustian & Theuvsen, 2017). Since rural areas are remote and often do not have easy access to information, it is imperative for the wide-scale adoption of new technology to be accompanied by instruction on how to install and use the technology (Aubert et al., 2012). For instance, the South African Irrigation institute offers trainings in irrigation technologies, GPS and irrigation Management ("SABI", n.d.). It also compares a lot of different irrigation systems, and provides information which kind of irrigation system a farmer should use for different kinds of soils, water and landscapes.

The access to information can be further improved, as mentioned earlier, via co-creation - involving farmers in the design process of solutions and new prototypes is a low-cost and efficient long-term solution to ensure that the real needs of the farmers are met. The wheel of co-creating in agriculture is already turning - for example, through programs such as Grainsense ("Co-creation on the field with farmers", n.d.).

Introducing sophisticated technology in rural areas as a form of public infrastructure without direct user costs would make it more affordable (Cloete, n.d.). By decreasing the voluntariness of the project and improving regulations, farmers are more likely to start using precision agriculture techniques (Aubert et al., 2012). An important aspect is also to make the technology under consideration, the standard technology being used in the nearby region, so as to make it compatible with other existing technologies and improve the chances of adoption (Aubert et al., 2012).

It is also important to keep in mind the disconnect that farmers face regarding irrigation practices, on whether to focus on conserving water or to aim for a higher crop-yield and increased production (Ørum et al., 2010; Benouniche et al., 2014). Policy-makers that promote the use of precision agriculture techniques, must consider this farm-level perspective and economic rationale regarding irrigation technology choices (Vico and Porporato, 2011; Finger and Lehmann, 2012; Heumesser et al., 2012).

Since the most likely adopters of PA are either farmers with quite some experience, or farmers who are just starting with their careers and still have many years of work ahead of them (as elaborated in earlier sections), it seems natural to focus promotional efforts on this target group. Focussing on farmers with much more experience, has the added benefit that it is likely to increase the perceived usefulness of other groups of farmers as well. One the other hand, younger farmers today may have received more education and therefore have more confidence in not just the capability of PA, but also in their ability to use PA to their benefit.

Lastly, offering trial runs of different kinds of technology to give an impression of the benefits of PA, provides the chance of reaching out to many more potential adopters. This can also be done, very conveniently, but setting up 'demonstration farms' ("NRS: Chapter 553 - Demonstration Farms And Plots", n.d.). Demonstration farms are primarily farms that focus on trying new agricultural techniques, without as much emphasis on economic gains. Such farms have been set up in countries across the world, including African countries like Ghana ("MoFA establishes demonstration farms in districts", n.d.), Kenya (Mbugua, 2017) and Nigeria ("Notore, Kaduna government partner to harness agribusiness opportunities", n.d.). Demonstration farms are viable as public infrastructure for farmers, and would address multiple aspects of the problem, like education, experience, ease of use and confidence.

Conclusion

This paper the water crisis of the Cape Water region and its relationship with, as well as influence on, the agriculture sector of the region. The paper discusses the potential socio-technical and technical solutions and new developments that exist in the agricultural sector that could be used to mitigate the effects of the water crisis. The paper also discusses the various barriers that prevent wide-scale implementation of the solutions, and finally proposes a mitigation plan to address these barriers with a focus on a specific target group using the concept of 'precision agriculture' or PA.

PA can help decreasing the the water usage in the agricultural sector by measuring and observing the variances in the field and responding with a decision support system, which results in the optimal water usage and crop production. This saves water in comparison to the current situation, since currently (without PA) farmers often use more water than necessary. Since nearly all technical advancements are not affordable to subsistence farmers, the target group for the mitigation effort was chosen to be big farmers in the Cape Water region who could afford the technology or service being offered, to analyse and reduce on-farm water usage. These first users also serve as an example for other farmers. This analysis and reduction comes through the use of conventional drip and sprinkler systems combined with artificial intelligence algorithms, sensors, predictive analysis, crop monitoring and agricultural robotics. The farmers who are more inclined to adopt PA tend to have large farms focussed on maximising yield, and are generally higher educated than the average farmer in the region; they als often show some degree of concern for sustainability, or have some prior experience with PA, and are either quite experienced in their field, or quite young and confident of trying new technology.

The adoption of PA could be significantly aided by reducing the costs using agriculture-promoting policies, involving farmers in the co-design process of new technology, setting standards for the integration of different forms of PA technology or for the integration of PA with existing technologies, and targeted promotion towards a select group of early adopters. Much of this can be done through the establishment of demonstration farms in the Cape Water area, thereby not only addressing multiple barriers simultaneously, but also alleviating some of the economic stress and laying emphasis on sustainability. This form of mitigation would hopefully aid the agriculture sector of the Cape Water system while retaining the involvement and experience of farmers, and moving towards food and water security in the future.

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