ICT in the agricultural sector, towards more sustainability?

A focus on Precision Agriculture

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1. Introduction

1.1. **Context for a sustainable agricultural food production**

Food is a basic need for living and therefore agriculture is one of the oldest human activities, but the old agricultural methods have largely disappeared in the Global West. They have made room for mechanisation and innovation, consequently leading to more intensive practises. However, from an environmental viewpoint there are voices that advocate for a more sustainable agricultural food production. Broadly, these demands and changes can be summarised in three major developments:

The first development comprises the degradation of water and soil as the result of over fertilisation and the use of pesticides. Many scholars have agreed that ''modern agriculture has created substantial harmful effects on air, soil, water and biodiversity'' (Kimbrell 2002; Maynard and Nault 2005; Miller and Hackett 2008 in Hiranandani, 2009, p. 764). Continuing this procedure will have serious consequences for the ecosystems and future generations. Therefore, the Director General of the Food and Agricultural Organisation advocated for a paradigm shift in attitudes towards agriculture. This must be done by the decrease of agricultural inputs that harm ecosystems, finally resulting in a more sustainable agricultural sector (United Nations, 2014).

The projections that describe a worldwide population growth can be seen as the second development regarding a sustainable agriculture. This development will emphasise a raising need to increase the agricultural food production (Kaloxylos et al., 2012). It is estimated that by the year 2050 the world population will reach the number of nine billion. According to the Food and Agricultural Organisation (2009) food supplies will face major challenges over a period of 40 years. Within the literature, the percentages of predicted necessity of food increase vary somewhere between fifty to hundred percent (Tilman et al., 2002; Lamb & DiLorenzo, 2014).

Thirdly, there is a change in the societal discourse on agricultural practices. This can be demonstrated by the following phrases: ''As consumers have prospered, they have become much more discerning and judgemental about the quality and wholesomeness of their food and the treatment of animals and nature in its production" (Lowe et al., 2010, p.288). As a consequence "the ethics of intensive farming have been called into question" (Lowe et al., op. cit.). These ideas can partly be reduced to the ideology of environmentalism. Environmentalists emphasise the importance of ecologic values and argue for a transition towards an environmental-friendly, sustainable food production.

Given de outlining of these three developments, the agricultural sector is challenged to seek new approaches and techniques that provide a more sustainable future. In this context, a more sustainable future refers to a sufficient food supply while minimising the harming effect on ecosystems - both in the short and long term - as well as taking into account the social desires regarding agriculture. There are many different agricultural methods that can facilitate sustainability. Because this bachelor thesis will only focus on an agricultural method that uses Information and Communication Technologies (ICTs) as a mean to pursue a sustainable agriculture, it is not relevant to explain all types of sustainable methods. The one that is relevant, Precision Agriculture, will be introduced in the next paragraph.

1.2. **Research topic and question**

The transition towards a more sustainable food production with a minimum harm for the environment while at the same time satisfying societal desires regarding intensive farming, requires changes in the whole food production chain. Since the contemporary food chain is complex, fragmented and comprises many different actors, it is beyond the topic and length of this bachelor thesis to look at the whole chain. Therefore, the thesis will only focus on the agricultural food producers, the farmers.

Technology has always played a crucial role in agricultural developments, and ever since it is a manner that attempts to pursue efficiency. According Van Henten and Groot Koerkamp (2006) the next technological step in agriculture is the incorporation of intelligence. To a great extent human intelligence can make good management decisions, but when it gets more complex, errors may occur. Intelligent technological systems that can make complex management decisions and carry out complex operations are the solution here. Also, these systems can incorporate sustainability through the fine tuning of seeding, soil conditioning, weeding, spraying and harvesting. Precision Agriculture is an agricultural method that meets this intelligence together with sustainability.

Precision Agriculture can be described as a method that ''allows for the management of spatial and temporal variability within a field, reduction of costs, improvement of yield quantity and quality and reduction of environmental impacts'' (Reichardt and Jürgens, 2008 in: Kutter et al., 2009, p. 2). Input decisions on fertilizers, seeds or pesticides can be facilitated by means of computer-based decision-support systems'' (Kutter, cit. op.). Although it might seem that Precision Agriculture is mainly applicable to arable farming due to its large scale operations, it can also be suitable for dairy farmers. In order to feed their animals and fertilize their fields with fertiliser produced by their livestock, dairy farmers have to grow grass and crops such as corn, beetroot and potatoes. But in another manner, dairy farmers can also apply precision agriculture. In this context it means ''the use of technologies to measure physiological, behavioural and production indicators on individual animals to improve management strategies and farm performance' (Bewley, J. 2009). The objectives are to maximise the potential of individual animals, a reduction of medication by preventive health measures and an early detection of diseases.

According Aubert et al. (2012) the emergence of Precision Agriculture has led to a paradigm shift in agricultural practices because it considers the field or livestock ''as a heterogeneous entity that allows for selective treatment instead of a homogenous entity that requires indiscriminate care'' (p. 510). It applies a selective treatment that can result in a decrease of contaminants. Therefore, it is a more sustainable agricultural practice in comparison with conventional agricultural practices.

This thesis will focus on the role of Information and Communication Technologies (ICTs) in the farmers' decision-making and operation. In this context the goal is to facilitate in a more sustainable agricultural practise, based upon the Precision Agriculture.

The research question will be:
To what extent do farmers based upon their ICTs, make decisions that apply an in time and place diversified strategy for their fields and/or livestock and by doing so facilitate a more sustainable agriculture?

Sub questions that aim to help answering this research question are:
- *To what extent are ICTs taking part in the farmers' practices and in decision-making?*
- *How do farmers value sustainability?*

It should be mentioned that, although there is quite a lot of Precision Agriculture related literature on the developing world, the thesis will focus on the Global West as the geographical context. To be able to answer the research question, an empirical research was conducted. Survey questionnaires were carried out by farmers living in three different provinces in the Netherlands (see figure 1). The respondents had to answer different questions about their farm, ICT use, valuation of sustainability and operational decision-making. The results will be illustrated and explained in Chapter 4 and 5.

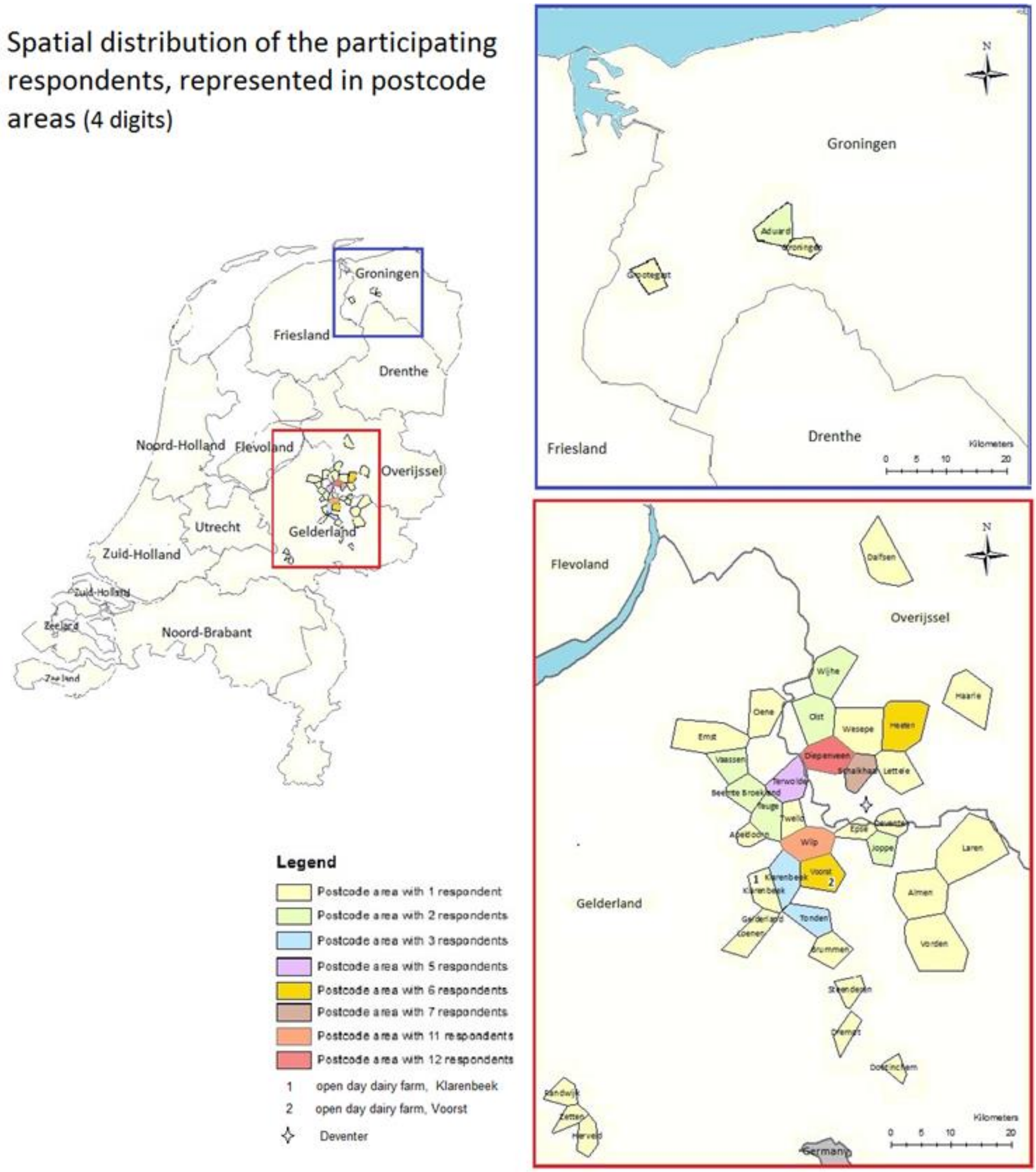

Figure 1. Postcode areas (4 digit) and postcode of respondents in the survey questionnaires (own edit, 2014)

2. Theoretical framework

2.1. **Sustainable agriculture**

2.1.1. Defining sustainability and the concept of sustainable agriculture

Sustainability is often defined as ‘’development that meets the needs of the present without compromising the ability of future generations to meet their own needs’’ (World Commission on Environment and Development (WCED), 1987, p. 8). This contains two key elements: the concept of human needs and ‘’the idea of limitations imposed by the state of technology and social organizations’’ (WCED, 1987, p. 8). It advocates for a progressive transformation of society and economy. This process is dependent on the costs-benefits distribution and the access to resources.

Sustainable agriculture lacks an unambiguous definition. According to Perlas (1995) and Schaller (1993) it rather is a value- and believe system that is applied to agricultural practises. Referring to the sustainability definition by the WCED (2009), the so-called ‘needs’ here are ‘’current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered’’ (Tilman et al., 2002, p. 671). Agricultural practised in this manner, can be defined as sustainable.

2.1.2. Uniformity versus diversification strategies

Since the second half of the twentieth century, agriculture has undergone a major shift on global scale. Its focus is on increasing productivity by genetic uniformity within crops, often resulting in a monoculture that enhances possibilities for agricultural mechanisation (Flinckh, 2008). These crops require, in comparison with more traditional practices of agriculture, greater inputs of fossil-fuel energy, synthetic pesticides, water and fertilizers (Picone and Van Tassel, 2002). According to Swart (2014), this has partly led to an undesirable legacy. This includes pest resistance and new pests, degradation of water and soil, a lower groundwater level and the loss of agricultural biodiversity.

Resistance to pests (for the field) or medication (for livestock) can be a problem for farmers, because it develops within a few years. According Tilman et al. (2002) the occurrence of new resistance is caused by making insufficient use of spatial or temporal variety and crop rotation. Flinckh (2008) agrees, but he notes that in modern agriculture many are still convinced that ‘’diversity would be too difficult and expensive ’’ (p.399).

2.2. Information and Communication Technologies in agriculture

2.2.1 Information and Communication Technologies in agriculture

Information is playing a key role in our lives and so it becomes more and more important in agricultural practices. According to Laliwala et al. (2006) there are within Information and Communication Technologies (ICTs) many information sources that benefit the agricultural sector. These ICTs include e.g. public databases such as the weather forecast and market information, but also sensor technology related information obtained from geo-referenced remote-sensing. Geo-referenced remote sensing can, for example, support variable rate applications by indicating which places in the field require a high or lower rate of fertiliser. The information that is obtained of these ICTs can make agricultural processes and decision-making more efficient (Arroqui et al., 2012) and more sustainable than conventional methods.

However, due to the ability to collect an enormous amount of data, farmers often face difficulties analysing and interpreting data. It is a time-consuming process, which farmers may not always be able or willing to invest. However, the biggest obstacles in succeeding the translation of the flow of information into agricultural efficiency is found in the farmers' acknowledgement of the relevance and importance of the gathered data (Brook, 1988; Kay and Edwards, 1999; Stafford, 2000; Thysen, 2000). To succeed, a systematically way of thinking is required (Huirne et al., 1993). In the next paragraph a systematic agricultural decision-making model will be explained.

2.2.2 A systematic approach to agricultural decision-making

Fountas et al. (2006) describes decision-making as one of the core activities of agricultural management. Farmers have to make precise decisions on their production on a daily basis. Agricultural decision-making is based upon a cognitive system of practical knowledge and learning together with intuition (Kaloxylos, 2012). Intuition is often useful in generating plans and in responding to urgent or rapid changing circumstances (Suter, 1992). Here, intuition can be defined as a complex result of farmers' personal experiences as well as site-specific experiences. Especially small farmers who own little formal knowledge, base their decisions mainly on intuition.

To get an overview of different components of the decision-making process, Fountas et al. (2006) have developed a decision-making model around information-intensive agricultural practices. It is a descriptive bottom-up (participatory) approach that aims ''to capture the links between the different factors starting from data collecting, transformation of data to information, and then to decision'' (p. 196). It should be mentioned that it is a model, so it focusses on a section of agriculture and is not applicable for all farmers.

Shortly, this model describes a process by which collected data will be transferred from a machines computer to a desktop computer. Raw data can be stored in the database. In the next step of the information flow (the data processing) errors in data can be identified and corrected and then will be transformed in a format that is applicable in a decision-support system. These decision-support systems include computational algorithms (e.g. charts, tables, spreadsheets, GIS, statistically calculated weather simulations and crop modelling software) that provide information which can be interpreted and operationalised by the decision-maker (the farmer).

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2.3 **Precision Agriculture as an inspiration**

2.3.1 Precision Agriculture as a sustainable agricultural practice

Briefly, Precision agriculture can be summarised as the ‘‘management of spatial and temporal variability at a sub-field level to improve economic returns and reduce environmental impact’’ (Fountas et al., 2006, p.193). Decisions are based on a wide range of information sources and therefore adequate analyse is required. Ultimate aim is ‘‘to increase the number of (correct) decisions per unit area land per unit of time with associated net benefits’’ (McBratney et al., 2005).

2.3.2 Precision Agriculture ICTs

Aubert et al. (2012) divide the ICTs of Precision Agriculture into “methods of gathering data and analysing spatial variability at the sub-field level” (p. 511) (e.g. GPS, GIS, crop scouting, remote sensing systems, yield monitors) and computer controlled devices that allocate the required agricultural inputs on the field (e.g. navigation systems directing machines move across the field, variable rate applications devices). The computational devices for livestock include among others yield recording and milk sampling. By monitoring the individual development of animals, their potential and health can be optimised.

2.3.3 Implementing Precision Agriculture as an agricultural practice

Adopting a new kind of (technical) approach in agricultural production does not only require something of personal characteristics such as ability to change - both on the level of intelligence and finance - but also willingness to do so. The latter is often in conjunction with a certain vision or ideal for the future. Also, a cost-benefit analyse will be often made before the implementation and investment in a different agricultural practice.

2.4. **Conceptual model**

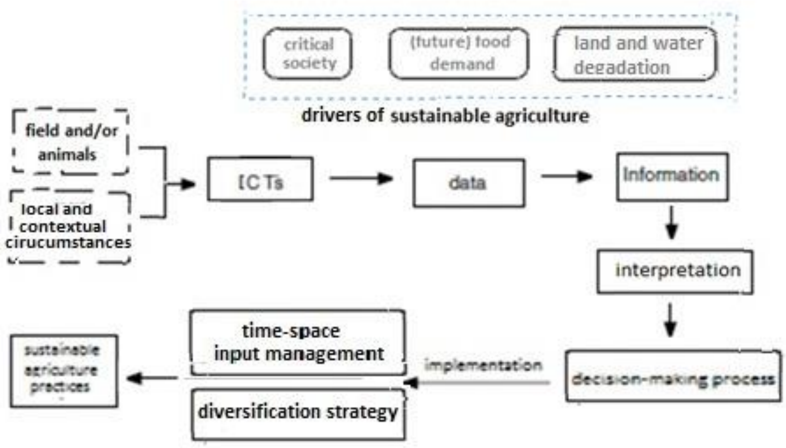

Figure 2 This conceptual model demonstrates how the concept of sustainable agriculture can transform into actual sustainable agricultural practices and is inspired upon the Precision Agriculture (own, 2014).

2.4.1. Explanation of the conceptual model

Sustainable agriculture is roughly driven by three components: 'land (soil) and water degradation' caused by, amongst others things, overfertilisation and the use of pesticides; judgemental and conscious attitude of consumers towards agricultural practices ('a critical society'); and a rising 'future food demand' due to population growth. Both 'field and/or animal characteristics' and 'local and contextual circumstances' (e.g. type of soil, grown crops, amount of milk from cow, level of groundwater, rainfall or drought) can be observed by Precision Agricultural ICTs. This observation results into data that can be transformed into information (operation) for the farmer. Then, he or she must interpret this information and then makes a decision for the land or livestock. These decision-making process consists of different components (e.g. knowledge, intuition, financial motives, a cost-benefit analyse and the sustainability motive etc). After the process of deciding what to do, the decisions will be implemented on the field or livestock and theoretically results into a sustainable agricultural practice.

3. Methodology

3.1 **Method**

The research question is focused on farmers' use of ICT in their practices in the context of sustainability. The questionnaire will be discussing the following topics: farmers personal and business characteristics, ICT use, data collection, features that are considered important in the light of sustainability and agricultural decision-making. Questionnaire surveys (see Appendix) can be useful method in obtaining peoples characteristics, attitudes or opinions and behavior (McLafferty, 2010). Also, it can obtain relatively quick and easy information.

The questionnaire surveys has been designed both on paper and online (surveymonkey.com). An accompanying letter was added to explain the objective and content of the research to the respondents. The online version of the survey questionnaire was send to farmers and others in a relevant working group or board. IBM SPSS 6 was used to analyze the results of the empirical research.

Not all information obtained by the survey questionnaire appeared to be useful in answering the research question. For example, one of the questions submitted to the respondents was about which type of fertiliser they used for their field. A rough distinction was made between organic and chemical fertiliser. However, literature proved that the outcome is irrelevant for this thesis. It said the following: Although the (excessive) use of chemical fertilisers is inconsistent with a sustainable agricultural method, it ''is unclear whether the 'slow release' of nutrients from organic compost or green manures can be adequately controlled to match crop demand with nutrient supply to increase nitrogen-use efficiency in intensive crop production systems'' (Tilman et al., 2002, p. 673).

3.2. **Data collection**

In total there were 95 respondents. Although not everyone responded to every question, I have not omitted cases before starting the analysis. Instead, given the chosen statistical tests the missing cases were determined and left out.

At an open day of a farm, I could approach and question many respondents in a relatively short amount of time. Therefore, I contacted two farmers who were going to have an open day and got their permission to bring my survey questionnaire. The two open days were both situated in the province of Gelderland, in Klarenbeek and in Voorst (see figure 1). Although these places are about 10 kilometres apart, there were enough new visitors to approach with my survey questionnaire. At the first open day, visitors from distant locations (Betuwe, countryside of Groningen) attended and responded to the survey questionnaire. In addition to the open days, I visited about 20 farmers at their businesses near Deventer (province of Overijssel). An online version of the survey questionnaire was send to farmers and others in a relevant working group or board. This resulted in a dozen respondents.

According LEI (2013) the Dutch agricultural sector is composed of 17,99% arable farming, 13,23% horticulture, 53,48% dairy farming, 3,47% mixed farming, 8,03% pig and/or poultry farming and 2,47% other types of agricultural business such as vineyards. In the sample these percentages differ somewhat. Most respondents were dairy farmers (88,4%) followed by a few arable farmers and mixed operators (both 4,2%) and even fewer contractors (2,1%) and horticulture (1,1%). Since both open days I attended were one a dairy farm, it seems a logic consequence that most visitors that responded my survey questionnaire were dairy farmers as well. This has led to a higher amount of dairy farmers in the sample than is known in the population.

3.3 **Ethic issues**

3.3.1. Using ICT to ensure a sustainable agriculture?!

There can different obstacles perceived if farmers attempt to pursue an in time place diversified input strategy by means of ICT. According to Swart (2014), a sustainable agricultural sector together with technology should take into account the following: recognition of the social and ecological functions of local farming systems, focus on locally grown products or as he refers to as local 'needs', and the re-evaluation of the worth of indigenous knowledge. Also, Swart emphasises the functioning of the societal layer behind any technology. Introducing a new technology may be considered as a sort of societal experiment and people may have different worldviews with respect to nature, technology, and culture. Something else that might be relevant was already described in 1987 by the World Commission on Environment and Development (WCED). This is the possibility to meet limitation caused by the state of technology and the organisation of society, while pursuing a sustainable agriculture.

3.3.2. Ethics in conducting the questionnaire surveys

During the drafting of the questions it was important to take into account the respondents' privacy, so there were no question regarding financial income etc. By adding an additional letter to the survey questionnaires, respondents were explained that I would treat their information strictly confidential and only for scientifically purposes. Also, respondents had the opportunity to fill in their e-mail address to be kept informed with the result and conclusion of this thesis.

Chapter 4. Results

Before moving on to the results, attention should be drawn to the structure of this chapter. Each paragraph describes relevant results for the given sub question. In the chapter 5 these results will be further discussed and explained with literature from the theoretical framework.

4.1. **To what extent is ICT taking part in the farmers' practices and in decision-making?**

To be able to answer this sub question, there must be investigated if farmers make use of ICTs in their practices. The farmers in the sample do make use of ICTs in their work activities. Table 1 will clarify which types of ICTs they use. Respondents could give multiple answers, since they can make use of more than one type of ICT. This resulted in a total of 219 ICT applications for the 94 valid cases. Only 3 out of the 94 respondents (3,2%) stated that they did not use any of the given types of ICT.

type of ICT	Frequency	%
Sampling (milk, soil etc.)	77	26,3
public databases (weather, market information)	73	25,0
rapporting/ recording	53	18,2
computational input rate devices	25	8,6
milking robot	21	7,2
graphs, charts, spreadsheets, simulation models	20	6,8
robotics, other than a milking robot	13	4,5
sensor technology	6	2,1
none of the given options	3	1,0
Other	1	0,3
	292	

***Table 1**. Different types of ICTs and its frequency of use, according a sample of 94 farmers*

Wondering to what extent ICTs are playing a role in the decisions for the farmers method concerning the amount of inputs and an in time and place specific appliance, the answer options have been categorised into three categories:

- I base my decision partly on ICT and partial on my own decisions without any form of ICT ('partial ICT')
- I do not base my decisions on any form of ICT ('no ICT')
- I base my decisions fully on ICT ('only ICT')

The distribution of the results are demonstrated in table 2

	Observed N	%
Partial ICT	26	27,37
No ICT	15	15,79
Only ICT	54	56,84
Total	95	100

***Table 2**. ICT use in decision making concerning the amount of agricultural inputs and their in time and place specific appliance*

As shown in table 2, almost 85% (27,37% + 56,84%) of the respondents in the sample based their decisions for input management and a diversification strategy on ICTs. Since the question in the survey questionnaire is specifically asking about input and diversification, there is no similar data available in the literature or in the Dutch statics. This makes it not possible to apply a statistical test that compares the distribution of the sample with the Dutch agricultural distribution.

4.2. **How do farmers value sustainability?**

This sub question will focus on the valuation of sustainability in general and the farmers' valuation of sustainability concerning his or her working operations.

Within the concept of sustainability, a distinction is made between the environment and future. The latter is not only referring to the business successor, but also to a sustainable future for mankind. This is made clear in the explanation of the question concerned. As in table 3 is demonstrated, for both variables over 70% of respondents valuated sustainability as important.

	sustainable environment		sustainable future	
valuation	frequency	%	frequency	%
not important	2	2,15	2	2,11
neutral	13	13,98	9	9,47
important	69	74,19	69	72,63
very important	9	9,68	15	15,79
	93	100	95	100

Table 3. *The valuation of sustainability in general*

	regarding the environment					regarding the future				
	not important	neutral	important	very important		important	neutral	important	very important	
uniformity	1	8	26	1	36	0	6	28	2	36
diversification	0	1	6	3	10	0	0	4	5	9
combination	1	3	33	5	42	0	2	33	8	43
	2	12	65	9	88	0	8	65	15	88

Table 4. *The valuation of sustainability, and aspiration for uniformity or diversity within the agricultural method*

However, when you compare the valuation of sustainability with the farmers own operation regarding sustainable management, it is shown that relatively few farmers (11,4% regarding the environment and 10,2% regarding a sustainable future) aspire diversity (table 4). Most respondents aim at uniformity (40,9%) or a combination of diversity and uniformity (47,7% for an environmental sustainable viewpoint and 48,9% regarding a sustainable future).

The Pearson Chi square test demonstrates that my sample will give no insight in any correlation between on one hand the purpose of pursuing uniformity, diversification or a combination of both regarding their field or within their livestock and on the other hand respondents valuation of environmental sustainability. The level of significance is 15,2%, where it should be less than 5% to be significant for any association. The sample includes 88 valid cases, which comprises 92.6% of the total sample size. This test unfortunately could not be done for sustainability regarding the future. The reason for this is that the distribution of expected counts is for 50% of the cells less than five, where it should be a maximum of 20% of the cells. This percentage does not change enough after merging some of the categories.

		frequency	valid %
valid	place and time	10	20,4
	amount	36	73,5
	both	3	6,1
	total	49	100
missing		46	
total		95	

Table 5. *the valuation of investing in machinery that contain sustainable computational input devices*

The respondents was asked to what extent they have invested in machinery that contain sustainable computational input devices. This involves the investment in machinery that monitors an in time and place diversity (in order to apply a diversification strategy) as well as the investment in machinery that monitors the rate of inputs. 49 out of 95 respondents indicated to invest in at least one of these types of machinery (see table 5). The missing cases here are the respondents who did not invest in this kind of machinery. 73,5% of the valid response indicates an investment in the monitoring of the amount of inputs opposed to 20,4% that invests in in the monitoring of a place and time diversified input strategy.

Chapter 5. Conclusion

5.1 **Discussion and conclusion.**

This bachelor thesis attempted to discover the facilitating role of Information and Communication Technologies (ICTs) in farmers' decisions and work operations towards a more sustainable agriculture. This has led to the focus on the Precision Agriculture.

It turned out to be quite difficult to make statements about an population with inferential statistics, due to a lack of significance or the lack of data to compare with the sample. However, an attempt is made to apply descriptive data.

Almost all of the respondents in the sample (96,8%) use one or more types of ICT in their practices. The most used types are sampling (26,3%), public databases (25%) and reporting/recording (18,2%) (see also table 1). This can simply be explained by the mechanisation and innovation within the modern agriculture of the Global West. It seems almost unthinkable that a farmer does not use any technologic or computational device. However, when it comes to decision-making, the rate of ICTs usage is slightly lower (84,2%). It should be noted that this score is only giving information about decision-making that relates to input management and a time and place monitoring of field and/or livestock. This implies that the outcome of the use of ICTs in agricultural decision-making can be very different when other criteria are measured.

In the agricultural operations only 3,2% of the respondents did not use any of the given types of ICT opposed to 15,8% in decision-making (again: my survey questionnaire only provides insight into input strategies and a time and place monitoring). 27,4% of the respondents stated to base their decisions only partly on ITCs and partly on their own decisions. This seems to be in line with Van Henten and Groot Koerkamp (2006), who argue that to a great extent human intelligence can make good management decisions. Kaloxylos (2012) agrees, as he describes agricultural decision-making as a process that is based upon a cognitive system of practical knowledge and learning (experience) together with is intuition. But, as decisions are getting more complex human-made decisions may face errors (Van Henten and Groot Koerkamp, 2006). Computational decision-support systems may be the solution against these errors. This can be an logic explanation why many farmers yet (partly or completely) base their decisions on ICTs.

The results of the respondents' valuation of sustainability demonstrate that most farmers value sustainability as important (over 70%). This applies to both a sustainable agriculture related environment (e.g. minimising environmental harm) as well as a sustainable agriculture related future (e.g. food production). Only few did consider sustainability as not important (around 2%). Thus it seems contradictory that when it comes to a sustainable operation in terms of aspiring diversification within the field and/ or livestock, only few mention to do so (10-11%). A logic explanation for this is that many farmers are still convinced that ''diversity would be too difficult and expensive'' (Flinck, 2008, p.399).

Little adoption of a diversification strategy is also shown in the amount of respondents that stated to invest in machinery that monitors an in time and place diversity within the field and/or livestock, and machinery that monitor input rates.

All this leads to the research question: *To what extent do farmers based upon their ICTs, make decisions that apply an in time and place diversified strategy for their fields and/or livestock and by doing so, facilitate a more sustainable agriculture*?

Upon the discussed results above, there are no significant statements that can be made. However, an attempt is made to apply descriptive statistics. This demonstrated that to a high extent the participating farmers use ICTs in their operational work. In decision-making this rate appeared to be lower, due to the use of self-made decisions without interference of a computer that supported or managed their decisions. Between word and deed regarding a sustainable input management or the investment in sustainable agricultural related machinery a mismatch is demonstrated. Participants mentioned to value sustainability as high, but their actual operations did not demonstrate this. Therefore, I would conclude that even if the use of diversification strategy related ICTs in their practices or agricultural support systems that can facilitate sustainability is high, this does not automatically lead to a more sustainable practice.

5.2. **Refection**

In hindsight, given the different levels of measurement it was not always easy to answer the research question. Often a combinations of variables did not fit into a statistical test, the results had no valid outcome or the was nog significant result. Another point of improvement in similar future work is asking the right questions which provide all the information to answer the research question instead of asking a lot of question that are not all effective in obtaining this information. A more personal struggle was maintaining a clear overview in my thought instead of a paying a lot of attention to irrelevant details, resulting in the postposing of important assets of the thesis. Connected to this, next time I have to keep in mind that it is not always worth to make a research topic or question too complex.

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Appendix I (in Dutch): Survey Questionnaire

Enquete: begeleidende brief en vragen

Geachte,

In het kader van mijn studie Sociale Geografie en Planologie aan de Rijksuniversiteit Groningen doe ik een onderzoek naar de rol die ICT kan spelen bij het realiseren van een duurzame landbouwproductie, geïnspireerd op de precisielandbouw. Precisielandbouw is het toepassen van ICT op zo'n manier dat bemesting en gewasbescherming en tot op zekere hoogte ook water en voedsel precies op de plek komen waar zij nodig zijn en er niets wordt verspilt. Ook benadrukt de precisielandbouw juist de voordelen die te behalen zijn uit verschillen in bodem, gewassoorten en de verschillen binnen de veestapel in plaats van het nastreven van veel mogelijk gelijkheid of eenheid. Er kleven ook nadelen aan precisielandbouw. Doordat het toch wel een high-tech manier van landbouwvoering is, is de vertaalslag van ICT data naar de praktijk soms lastig. Dit vergt het een investering, niet alleen financieel maar ook op het gebied van tijd, de omgang met deze ICT (welllicht omscholing), persoonlijke kennis etc.

Ik zou graag door het stellen van enkele vragen een aantal van de hierboven genoemde aspecten wat concreter voor ogen willen krijgen. Hiervoor heb ik uw hulp nodig! Uiteraard ga ik vertrouwelijk met uw antwoorden om. Ik zal de resultaten verwerken in een statistische analyse waarin wordt gezocht naar onderlinge verbanden tussen de uitkomsten en er wordt gekeken of er opvallende zaken zijn. Dit is alleen voor wetenschappelijke doeleinden. Eventueel kan ik u hier na afloop van op de hoogte houden. Gelieve dan aan het einde van de enquête uw mailadres te noteren.

Alvast dank!

Met vriendelijke groeten,
Nienke Harmelink

Studente Sociale Geografie en Planologie
Rijksuniversiteit Groningen

(begeleidend docent: prof. dr. Strijker)

Vraag 1. <u>Bedrijfskenmerken.</u>

a. Geslacht
   - ☐ Man
   - ☐ Vrouw

b. Wat is uw leeftijd?
   - ☐ 20-35
   - ☐ 36-50
   - ☐ 51-65
   - ☐ 66 of ouder

c. Postcode: …………… ………..

d. Wat is uw hoogst genoten opleidingsniveau?
   - ☐ Lager
   - ☐ Middelbaar
   - ☐ Hoger
   - ☐ Universitair

e. Wat voor type bedrijf heeft u overwegend? *(meerdere antwoorden mogelijk)*
   - ☐ Melkveehouderij
   - ☐ Akkerbouw
   - ☐ Gemengd bedrijf
   - ☐ Glas- en tuinbouw
   - ☐ Loonwerkbedrijf

f. De volgende werkwijze is voor u van toepassing:
   - ☐ gangbare methode
   - ☐ biologisch

g. Ik maak gebruik van (er zijn meerdere antwoorden mogelijk)
   - ☐ Kunstmatige gewasbescherming
   - ☐ Biologische gewasbescherming
   - ☐ kunstmatige bemesting
   - ☐ biologische bemesting
   - ☐ Geen van bovenstaande

h. Hoeveel hectare land heeft u momenteel in gebruik? (eigendom, pacht/ huur etc)
   - ☐ <30 ha
   - ☐ 30-50 ha
   - ☐ 51-100 ha
   - ☐ > 101 ha

i. Hoeveel (melk)vee heeft u momenteel?
   - ☐ geen
   - ☐ Minder dan 50
   - ☐ 50-100
   - ☐ 101-150
   - ☐ 151-250
   - ☐ Meer dan 250

j. Wat voor type internet heeft u:
   - ☐ Glasvezel
   - ☐ ADSL
   - ☐ Kabel
   - ☐ Anders, namelijk……………………………………………….

Vraag 2. Bedrijfsvoering.

Duurzaamheid is een breed te interpreteren begrip. Eén van de definities is: 'het voorzien in de wensen van huidige en toekomstige generaties, rekening houdend met een gezond leven en de werking van ecosystemen'.

a. Hoe belangrijk acht u duurzaamheid in uw bedrijfsvoering ten aanzien van het milieu:
- ☐ Niet belangrijk
- ☐ Niet belangrijk, niet onbelangrijk
- ☐ Belangrijk
- ☐ Zeer belangrijk

b. Hoe belangrijk acht u duurzaamheid in uw bedrijfsvoering ten aanzien van de toekomstige generaties (niet enkel bedrijfopvolging, maar ook voor de samenleving)
- ☐ Niet belangrijk
- ☐ Niet belangrijk, niet onbelangrijk
- ☐ Belangrijk
- ☐ Zeer belangrijk

c. Bij mijn werkzaamheden…. *(meerdere antwoorden mogelijk)*
- ☐ maak ik gebruik van duurzame energie (zon, wind etc.)
- ☐ investeer ik het gebruik van machines (eigendom dan wel loonbedrijf) die het inputgebruik inzichtelijk maken
- ☐ investeer ik in het gebruik van machines (eigendom dan wel loonbedrijf) die monitoren welke activiteiten op een locatie hebben plaatsgevonden (bijv. gewasverslag, perceelkaarten, irrigatiemonitoring).
- ☐ Is duurzaamheid iets wat op de laatste plek komt.
- ☐ Geen van bovenstaande antwoorden is van toepassing.

d. Wat ik nastreef is..
- ☐ zoveel mogelijk gelijkheid binnen mijn bedrijf (gewassen, bodem en/of vee)
- ☐ het behouden van variatie tussen planten dan wel gewassen, bodemtypen en/of dieren
- ☐ een combinatie van bovenstaande.

Vraag 3. Precisielandbouw.

Precisielandbouw is kort gezegd het selectief behandelen van verschillen van het land en/of het vee. Door met ICT te monitoren wat deze verschillen zijn en hoe zij zich over tijd en ruimte gedragen, kan worden vastgesteld welke inputs (water, voedsel, bemesting, bestrijdingsmiddelen etc) waar en wanneer nodig zijn. Juist door gebruik te maken van de diversiteit die aanwezig is en hier effectief op in te spelen, kan de benodigde input precies daar waar nodig worden geïmplementeerd. Hiermee kan de winst worden verhoogd en de impact op de natuur en omgeving worden geminimaliseerd.

a. Precisielandbouw..
- ☐ heeft mijn aandacht gewekt
- ☐ interesseert mij niet heel erg
- ☐ ik heb er te weinig kennis van om te kunnen zeggen of het mijn wel/niet interesseert.

b. Welke is voor u van toepassing? *(er zijn meerdere antwoorden mogelijk)*
- ☐ Ik doe zelf aan precisielandbouw.
  Zoja, hoe? ……………………………………………………………………………………………………
  ……...........
- ☐ In mijn directe omgeving (bedrijven in de regio, familie en kennissen) wordt aan precisielandbouw gedaan.

Zie de volgende pagina voor het vervolg van de antwoordmogelijkheden

- ☐ Ik heb wel eens een bedrijf dat aan precisielandbouw doet (bijv. tijdens een open dag) of voorlichting over precisielandbouw bezocht.
- ☐ Geen van bovenstaande opties is van toepassing.

c. Welke van de volgende uitspraken is voor u van toepassing? *(meerdere antwoorden mogelijk)*

Ik maak in bij mijn werkzaamheden op het bedrijf gebruik van…

- ☐ publieke databases (weersverwachting, globale marktenprijzen van (grond)stoffen als gewasbescherming etc)
- ☐ sensor technologie (bijv. remote sensors om gewas- en bodemeigenschappen te meten).
- ☐ een melkrobot
- ☐ robotsering anders dan een melkrobot (bijv. robot voor weefselkweek in glastuinbouw)
- ☐ computergestuurde apparaten die benodigde agrarische inputs aan de juiste locatie of het juiste dier toekennen (bijv. navigatiesystemen die de een tractor op het land aansturen; variabele waarde-toekenningsapparaten etc).
- ☐ grafieken, tabellen, spreadsheets, simulatiemodellen (over het weer, gewasbeplanting etc) om zodoende te kunnen zien welke beslissingen ik dien te maken voor mijn bedrijf
- ☐ monsters (bodem, dier, melk etc.) om inzichtelijk te krijgen waar variatie aanwezig is
- ☐ verslagen van gewassen en/of vee, zodat inzichtelijk waar sterkte en zwaktes liggen om hier in de toekomst op ingespeeld kan worden.
- ☐ Anders, namelijk……………………………………………………………………………………………………...
- ☐ Geen van bovenstaande antwoorden is van toepassing *(vervolg s.v.p. uw beantwoording vanaf vraag 4b)*

Vraag 4. <u>Interpreteren van informatie en besluitvorming.</u>

Deze subvragen proberen inzichtelijk te krijgen hoe het proces van informatie aflezen en/of interpreteren naar het maken van concrete beslissingen voor uw inputmanagement van bemesting en gewasbescherming verloopt.

a. Interpreteren van computerberekeningen (spreadsheets, modellen, simulaties etc) vind ik…

- ☐ Lastig
- ☐ Niet lastig, niet eenvoudig
- ☐ Eenvoudig

Evt. toelichten: ……….

- ☐ Niet van toepassing

Ik baseer mijn keuze voor de mijn werkwijze aangaande de <u>hoeveelheid</u> bemesting en gewasbescherming op: *(meerdere antwoorden mogelijk)*

- ☐ De berekeningen van een computermodel, computersimulatie of dergelijke maken voor mij inzichtelijk welke scenario's of keuzes het beste zijn
- ☐ Ik maak na het inzien van de informatie die (de in vraag 3c benoemde) ICT mij verstrekt eigenhandig een simulatie, berekening of dergelijke voor mijn strategie
- ☐ Ik baseer mijn werkwijze op informatie die de veevoervertegenwoordiger/ bedrijfsbegeleider mij verstrekt

- ☐ softwareberekeningen afkomstig van bedrijfsbegeleiding/veevoervertegenwoordiger
- ☐ Ik baseer mijn keuze op eigen verzameld materiaal, dus zonder gebruik te maken van ICT

b. Ik baseer mijn keuze voor de mijn werkwijze aangaande de timing en locatiekeuze van bemesting en gewasbescherming op: *(meerdere antwoorden mogelijk)*

- ☐ De berekeningen van een computermodel, computersimulatie of dergelijke maken voor mij inzichtelijk welke scenario's of keuzes het beste zijn
- ☐ Ik maak na het inzien van de informatie die (de in vraag 3c benoemde) ICT mij verstrekt eigenhandig een simulatie, berekening of dergelijke voor mijn strategie
- ☐ Ik baseer mijn werkwijze op informatie die de veevoervertegenwoordiger/ bedrijfsbegeleider mij verstrekt
- ☐ softwareberekeningen afkomstig van bedrijfsbegeleiding/veevoervertegenwoordiger
- ☐ Ik baseer mijn keuze op eigen verzameld materiaal, dus zonder gebruik te maken van ICT

c. De keuze van het gebruik van mijn van bemesting en gewasbescherming baseer ik op ..

- ☐ ICT data *(meerdere antwoorden mogelijk)*
- ☐ Bedrijfsbegeleiding/ veevoervertegenwoordiger
- ☐ Eigen kennis
- ☐ Intuïtief
- ☐ Eigen ervaringen
- ☐ Eerdere besluiten
- ☐ Ervaringen van anderen
- ☐ Aanbevelingen van anderen
- ☐ Mijn financiën
- ☐ Een kosten-baten analyse
- ☐ Anders, namelijk ……………………………………………………………………………………………………

Evt. toelichten: ………

………

d. Indien meerdere antwoorden bij vraag 4d, welke van de volgende is (vaak) doorslaggevend voor uw keuze: *(hier dus maar één antwoord mogelijk)*

- ☐ Kennis (eigen)
- ☐ Intuïtief
- ☐ Ervaringen (eigen)
- ☐ Ervaringen (van anderen)
- ☐ Aanbevelingen van anderen
- ☐ Mijn financiën
- ☐ Een kosten-baten analyse
- ☐ Anders, namelijk……………………………………………………………………………………………………

Dank voor het invullen van de enquête!

En wilt u op de hoogte worden gehouden van de uitkomsten, vul dan hier uw emailadres in: ………………………………………………………………………………………………………