CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

Diploma Thesis Title:

ECONOMICS OF ON-FARM RESERVOIRS TO MANAGE RISK

This Diploma Thesis has been written and defended at the Cranfield University in UK under the Double Degree Agreement between the Czech University of Life Sciences Prague, and the Cranfield University. In accordance with the Double Degree Agreement, this Diploma Thesis is fully recognized as part of the MSc programme study at the Czech University of Life Sciences Prague.

Author: Markéta Chalupová

Diploma Thesis Supervisor: Dr. Tim Hess

CRANFIELD UNIVERSITY

MARKÉTA CHALUPOVÁ

ECONOMICS OF ON-FARM RESERVOIRS TO MANAGE RISK

SCHOOL OF ENERGY, ENVIRONMENT AND AGRIFOOD
Environmental Management For Business

MSc
Academic Year: 2014 - 2015

Supervisor: Dr Tim Hess
Co-supervisor: Prof. Keith Weatherhead
September 2015

CRANFIELD UNIVERSITY

SCHOOL OF ENERGY, ENVIRONMENT AND AGRIFOOD
Environmental Management For Business

MSc

Academic Year 2014 - 2015

MARKÉTA CHALUPOVÁ

Economics of on-farm resrvoirs to manage risk

Supervisor: Dr Tim Hess
Co-supervisor: Prof. Keith Weatherhead
September 2015

This thesis is submitted in partial fulfilment of the requirements for the degree of MSc

ABSTRACT

Especially in dry parts of England, the agricultural sector faces water scarcity due to increasing competition for, and pressure on water sources. To secure water for irrigation needs, farmers invest in on-farm reservoirs. During recent years, the interest of farmers regarding the investment of on-farm reservoirs has increased, particularly in potato and vegetable production where irrigation is vital.

The aim of this study is to determine behaviour of farmers in irrigation decision-making, through on-farm reservoirs to manage risk. Three objectives were set up to accomplish it: to determine the reasons why farmers decided to build a reservoir; to identify risks they think the reservoirs mitigate and what is their perception about reservoir itself; and lastly to find out how farmers make decisions about using water in reservoirs. Data for this research were collected through semi-structured interviews with potato farmers in England. Their answers served for comparison to previous models and discussion. The results conclude that farmers are aware of todays and future water scarcity which could threaten their production. Therefore, they implemented on-farm reservoirs to mitigate both economic and environmental risks related to the water scarcity. When deciding to irrigate, it was found farmers use water in a way to ensure high crop quality before high yield, ensuring their crops are saleable and thus securing the future of their business.

Keywords:

Water scarcity, Agriculture, Potato production, Decision-making, Irrigation

ACKNOWLEDGEMENTS

I would like to thank my supervisors Dr Tim Hess and Prof. Keith Weatherhead for their guidance, support and useful advice they provided during this project.

I would like to thank Dolores Rey Vicario, Rocío Ballesteros González and Heather Woodfield for their help, valuable comments and advice.

Also I would like to give many thanks to all farmers that participated in this research, without whom this project would not have been possible.

I would like to thank Rowan Davies for his moral support and love through this project he gave me.

Many thanks to all of my friends, especially Sanna Uolamo, Zsófia Ujvári, Petra Valjentová and Magdaléna Pincová who supported me during all year at Cranfield University.

Lastly, I would like to thank my mum, dad and sister for their loving support as well as financial help, which was essential to my studies at Cranfield University.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

CAMS	Catchment Abstraction Management Strategies
DEFRA	Department for Environment, Food & Rural Affairs
EA	Environmental Agency
EPA	Environmental Protection Agency
HoF	Hands-off flow
RDPE	Rural Development Programme for England
RPA	Rural Payment Agency
SMD	Soil Moisture Deficit

1 INTRODUCTION

Agriculture substantially contributes to competition for, and pressure on water resources, which has environmental implications (Mauser & Schneider, 2008) & (Buratto & D'Alpaos, 2015). Environmental impacts can include a loss of biodiversity, habitats, water resources and water quality (Hoffman et al., 2007). Research carried out for this report is focused on England and Wales.

Some crops need supplemental irrigation to ensure high yields and quality, which are required by market (Knox et al., 2010). Water for irrigation is abstracted from different sources, such as surface (rivers, streams and lakes), groundwater or reservoirs (FAO, 2015). Currently more than half of potato and vegetable production is located in areas where catchments are classified by the Environment Agency (2008) as over-abstracted. Nevertheless, more water for irrigation is likely to be required. This is due to climate change and population growth.

Predicted climate changes promise drier summers, extreme events and wet winters. The summer precipitation is projected to reduce between 10 and 15 % in Eastern, Central and South England by 2050, which will reduce flow rates in the rivers. Especially potato production is very vulnerable to these climate changes and will likely be put at risk (Knox et al., 2010). Water scarcity has negative impact on tuber yield and quality loss (FAO, 2012). Moreover, population is projected to increase by 15 %, which will cause more pressure on water sources due to higher demand for water (Patel & Morris, 2012). Therefore, new investments and technologies in more efficient irrigation systems are needed (Knox et al., 2008) & (Knox et al., 2011). Implementation of reservoirs on farms could mitigate risks related to water scarcity caused by climate changes and higher water demand due to population growth (Patel & Morris, 2012). On-farm reservoirs can supply water for irrigation when abstraction licences are not obtainable or they are restricted and thus secure high quality and yield crops. Moreover they can mitigate impacts on the environment (Weatherhead et al., 2008).

1.1 Aim and objectives

This research was carried out in cooperation with potato farmers and growers under Greenvale AP in England, specifically located in the West Midlands and Eastern England.

The aim is to determine behaviour of farmers in irrigation decision-making through on-farm reservoirs to manage risk. The findings will serve for feedback into water resource agent-based models and also DEFRA policy to design the support reservoir building differently. To reach this aim, the following objectives were set up:

- To determine the reasons why farmers decided to build a reservoir.
- To identify risks they think the reservoirs mitigate and what is their perception about reservoir itself.
- To find out how farmers make decisions about using water in reservoirs.

1.2 Thesis structure

This chapter gave a background to the issue about increasing pressure on water resources and why it is important to manage water sources more efficiently. Aim and objectives were set up. The following chapters will discuss:

- Chapter 2: A review of previous studies for deeper understanding of the issue.
- Chapter 3: Methodology and techniques that have been used for data collection and analysis.
- Chapter 4: Presentation of obtained results.
- Chapter 5: Discussion of results and comparison to previous studies.

2 LITERATURE REVIEW

2.1 Irrigation in agriculture in England and Wales

The majority of agriculture crops in England and Wales are rainfed, which results in relatively small need of irrigation. Even in a dry year, the irrigated land accounts for 5 % (Hess et al., 2011). The water used for irrigation is abstracted from different sources, such as groundwater or surface (river, stream or canal) (Weatherhead et al., 1997a) & (Patel & Morris, 2012). If more than 20 m^3 is abstracted a day, an abstraction licence is needed (Environment Agency, 2014). Across all sectors in England and Wales, agriculture constitutes only 1% of licenced abstractions (DEFRA, 2011c). Even if it does not account for a significant share, the main problem is that the water is abstracted in very dry sites during very dry months and years (Hess et al., 2011). This causes a pressure on water resources (DEFRA, 2011c) and may harm the environment (Environment Agency, 2013). Therefore, it is important to control the amount of water abstracted, when and where via this licencing system (Environment Agency, 2013).

2.1.1 Irrigation of Potatoes in UK

Even if potatoes are planted only on 2 % of total croppable area in UK (DEFRA, 2015a), still they constitute the most irrigated crop (54 %)[1] (DEFRA, 2011b), occupying 46 % of the total irrigated area[2] (Hess et al., 2011). This high demand for water is to ensure high yields and quality that helps meet criteria required by market (Buckley et al., 2012). Its irrigation mitigates presence of some diseases, pests or disorders, which decrease the quality of harvested potatoes and thus their value on the market. For example, irrigation can reduce presence of common scab, which presents major financial loss in potato production (Carli et al., 2014). However, this high water consumption causes negative impacts on water sources, such as water scarcity. For example, East England, which is the highest potato producer in the UK (29 %), is contributing

[1] Water use for irrigation in England and Wales.
[2] Data focused on irrigated area in England.

by 56 % to water scarcity. It results above all in a pressure on the aquatic environment (Hess et al., 2015).

Moreover, agriculture will face future challenges in water supply, such as demographic change, lifestyle, increasing demand for food and climate change, which will cause stress on water supply (DEFRA, 2011c).

2.2 Future challenges in water supply

Demographic change is one of the challenges in water supply. Population in England is projected to grow by around 10 million by 2035 (DEFRA, 2011a). This will cause higher demand both for domestic use and food production. Demand for potatoes depends largely on the economic and social situation, and is predicted to increase in the region of 25 to 80% by 2050 (Knox et al., 2011). It will contribute to higher pressure on water availability, above all in Eastern England and South England, where population growth is most predicted (Eurostat, 2015) & (ONS, 2011) and most irrigated crops are grown (Hess et al., 2015).

Moreover, with respect of long term, climate change may cause even greater impact on water availability than the demographic change (DEFRA, 2011a). Predicted higher temperatures in Eastern England will cause droughts (UK Government, 2012), which will have negative impact on yields (DEFRA, 2007) and thus putting agri-food industry at risk, which contributes £3 bn/year to the region's rural economy (Knox et al., 2009).

2.3 Water supply in agriculture sector

It is obvious that well-managed water supply is necessary. Usually, when it is dry and farmers need water to irrigate their crops, they take water during summer via direct abstraction (75 %)[3] (Weatherhead et al., 2014). To be allowed to abstract more than 20 m^3 of water a day it is obligatory to obtain an abstraction licence. However, summer abstraction licences may not be reliable

[3] It is a share of total direct abstractions. Winter abstraction accounts for 25 % (Weatherhead et al., 2014).

and secure. In case that surface flows fall below a specified level, the abstraction licences become constrained for certain period, due to hands-off flow (HoF) restrictions (Environment Agency, 2013). HoF restrictions regulated by Environmental Agency (EA) prevent over abstractions and their impacts on the environment. However, stopped abstraction may constitute less amount of water for irrigation and thus cause to farmers both losses in yields and lower quality of crops (Buckley et al., 2012). A manner, how to adapt to climate changes and prevent these inconveniences, may be implementation of on-farm reservoirs together with efficient water management (Tasker, 2007).

2.4 On-farm reservoirs

On-farm reservoirs are usually winter storages of water, which are later used for irrigation in summer. It means, that during winter (October – March), when the flows are high, the reservoirs are filled by water from surface or groundwater sources. Later in summer, the stored water is pumped to the area where irrigation needed. This method avoids the unreliable direct summer abstractions and risks related to it. As well, the winter abstractions are reliable and cheaper (Weatherhead et al., 2014).

2.4.1 Optimal size of on-farm reservoirs

On-farm reservoir implementation can be a very costly investment (Weatherhead et al., 2008). Therefore, it is important to think about its construction wisely, such as its size. Construction of too large reservoir might be very expensive, but on the other hand, too small reservoir could restrict future water demand and thus irrigation options (Weatherhead, 1997b). However, a large reservoir could be shared with neighbouring farms and thus reduce costs. Another option is to sell redundant water and get some additional profit from it (Weatherhead et al., 2008) or save the water for next year (Weatherhead, 1997b).

2.4.2 Financing and support for on-farm reservoirs

Farmers can apply for a grant to fund on-farm reservoirs construction or to improve their irrigation system on farm. Watherhead et.al. (1997) state that the

majority of recent reservoirs have been part-funded by RDPE and predecessor schemes[4]. Currently the grants are paid by Rural Payment Agency (RPA)[5] and can cover up 40 % of the total costs (DEFRA, 2015b) To apply for the grant, applicant has to provide specific documents, such as proof of tenancy, accounts for the applicant business, permission from local authority and environmental consents (DEFRA, 2015c).

2.4.3 Benefits and mitigated risks by on-farm reservoirs

One of the main benefits of on-farm reservoirs is improving the water security. Because of securing water supply, the reservoirs also reduce risks, which benefit farmers and also other stakeholders. Risks might be financial or environmental. Table 1 discusses the financial risks that on-farm reservoirs mitigate for farmers, whilst Table 2 shows financial and environmental risks impacting other stakeholders.

Table 1 Reduced financial risks to farmers by on-farm reservoirs

Reduced financial risks		Source
Yield and quality of crops	Due to uncertain summer direct abstraction, water supply for irrigation may not be sufficient. Not fully irrigated fields may not provide sufficient yield and quality.	(Weatherhead et al., 1997a)
Contract loss with supermarkets	In case of potatoes, over 30 % of its production is grown for nation's supermarkets. The contracts with them exactly determine quantity and quality that need to be provided. If the growers cannot provide that agreed amount and quality due to water scarcity, they might lose their important purchasers.	(Hess et al., 2011; Patel & Morris, 2012)
Flood regulation	Floods could devalue crops and put farmers' profit in danger.	(Weatherhead et al., 2014; Robinson, 2011)

[4] Part of DEFRA.
[5] Part of DEFRA.

Table 2 Reduced risks to different stakeholders

Type of risk	Risk	Stakeholder	Risk in detail	Source
Financial	Water scarcity for other abstractors	Industries	If farmers use summer direct abstractions, they may indirectly reduce water supply for other non-agriculture users, which could threaten their business activity and profit.	(Weatherhead et al., 2014)
Financial/ Environmental	Flood regulation	Industries/ Households	On-farm reservoirs may provide flood storage and thus mitigate flood risk.	(Weatherhead et al., 2014)
Environmental	Impacts on various species	Environment	Summer direct abstractions contribute to falling flow, which harms aquatic environment.	(Suffolk Coast and Heaths AONB, 2010)

In addition, on-farm reservoirs provide a new environment for different species such as birds, mammals or insects. Also new visitors can appreciate on-farm reservoirs as a place to visit, which could support local recreation (Hoffman et al., 2007).

2.4.4 Weaknesses of on-farm irrigation

As well as benefits, on-farm reservoirs also have some weaknesses that can represent additional costs for farmers. These are such as evaporation losses, losses related to dead storage, costs related to regular inspections of civil engineers or higher energy consumption.

As on-farm reservoirs are uncovered water storages, the evaporation losses are present and thus decrease high water use efficiency in irrigation (Martínez-Granados et al., 2011). Weatherhead et.al. (1997) states that annually 600 mm of water might be lost due to evaporation. This number is even higher if reservoir is located in a windy site. However, the evaporation lost can be partly replaced by rainfall.

It is necessary to leave certain amount of water in the reservoirs at all times (called dead storage). The left water in the reservoir is supposed to sustain fish

life in the reservoir but also protect the reservoir itself to avoid cracking, clay drying or damage from sun and wind. However, as the stored water cannot be used fully for irrigation, it presents some additional costs to the farmers (Weatherhead et al., 1997a).

To ensure the reservoirs safety, reservoirs greater than 25,000 m^3 fall into The Reservoirs Act 1975, which requires constant observations by owner and also qualified civil engineers (Environment Agency, 2010). Furthermore, at least once per 10 years it is necessary to carry on a detailed inspection by Supervising Engineer. These observations and inspections can be time consuming and also bring additional costs. However, they prevent serious failures of reservoirs, such as erosions or overtopping (Environment Agency, 2010).

In addition, the operating costs of reservoir storage are much higher than direct abstractions in summer, even though water abstractions in winter are much lower than those in summer (Weatherhead et al., 2014). The costs are increased because of higher energy consumption (through double pumping) (Weatherhead et al., 2014).

2.4.5 Water use from on-farm reservoir and other water sources

Pocock (2015) states that farmers consider the water source reliability in irrigation decision-making. He set up an order of different water sources according to their reliability. As first water source should be used from a full (more than 95 % of water) reservoir, since the abstracted water can be replaced by rain. Later, low reliability surface water, medium reliability surface water, high reliability surface water, groundwater, stored water in reservoir, and at least public water system water should be used, respectively.

However, in a dry season it might happen that there will not be enough water to irrigate all crops. Therefore, Pocock (2015) assumes that it is important to decide what crops to irrigate and what crops to abandon according to their profitability.

Pocock's assumptions both in water source order and prioritization were not based on what farmers said but on cost-benefit analysis and rational thinking. Therefore, it might be fundamental to explore the difference between the models and real behaviour of farmers in irrigation decision-making.

3 METHODOLOGY

This chapter aims to describe methods and techniques that have been used in order to meet the objectives of this research.

3.1 Methods and data collection

To reach a deeper understanding of farmers' behaviour, *what do they think, what do they do, how and why*, a qualitative analysis in the form of a semi-structured interview was utilised. Semi-structured interviews are based on a set of prepared questions and topics in advance, which are covered during the interviews with respondents (Klandermans & Staggenborg, 2002). The questions are open and thus allow improvisation and scope to create new questions. Therefore, it is possible to elicit specific kinds of information (Wengraf, 2001).

The semi-structured interviews between researcher and respondents were partly communicated in person and partly on phone. Face-to-face interviews offered fewer limitations on types and length of questionnaire over telephone interviews. At the same time they allowed better contact between each other and ensure that the asked questions were not misunderstood (Frey & Oishi, 1995). On the other hand, interviews held on telephone provided speed of data collection. In case of ambiguity during the data collection, the respondents were additionally emailed or telephoned to clarify their statements.

3.2 Procedure of data collection

In order to get results of this research, several steps were taken. These are shown in Figure 1 and explained in the next sub-chapters.

Figure 1 Research methodology

3.2.1 Secondary data collection

To set up a questionnaire, literature was reviewed and used as a base of the questionnaire. Secondary data were partly used from model *"Water Abstraction Reform: On-farm Reservoir Modelling"* by Pocock (2015) and other studies mentioned in Chapter 2. Further supportive literature used in the questionnaire was mentioned in the second chapter of this study.

3.2.2 Questionnaire

Questionnaire (APPENDIX A) was composed of three sections: introductory statement, farm characteristics and main questionnaire with crucial questions (Figure 2). Introductory statement described the survey, its aim and why the respondents' cooperation is important. After their approval in participation, the researcher passed to the second section concerning about farm characteristics. This section intended to obtain basic data about the farm, such as what crops they grow, what water sources they use and how many reservoirs and what type they have.

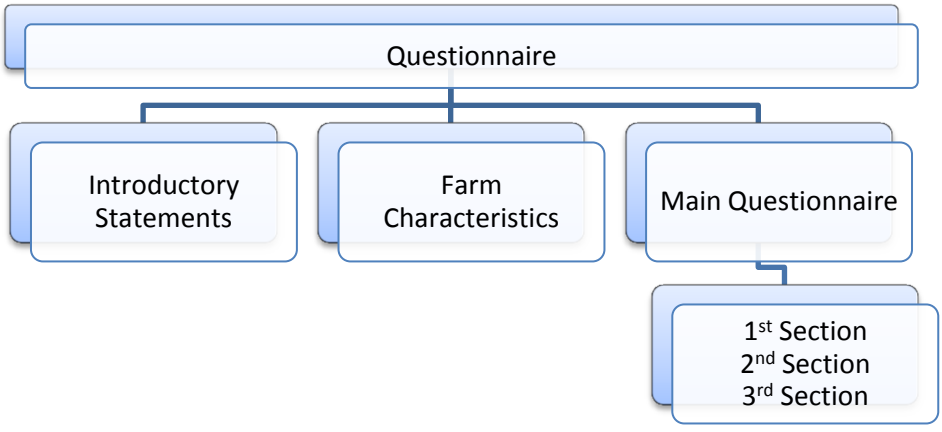

Figure 2 Questionnaire composition

3.2.3 Main questionnaire

The third section of the interview fluently followed the previous parts. The main questionnaire was divided into three sections according to three named objectives.

The first section was focusing on the reasons why farmers built a reservoir and why that particular size; if because of their today's needs of water or if they considered water scarcity in the future and therefore preferred to spend more money on bigger reservoir to secure water supply. The concluding question of this section was if their reservoir was funded. In case it was not, the aim was to find out what were the barriers or difficulties to obtain funding were. This information might serve as feedback for policy makers.

The second section of the questionnaire aimed to obtain farmers' perception about their reservoirs. The questions were set up in way to explore, what benefits or disadvantages the farmers think the reservoir brings. Also if they consider any risks that the reservoir helps them to mitigate.

The last section was based on assumptions used from mentioned model by Pocock (2015) other studies. The aim of this section was to compare the findings of this research to the findings from models, which were mainly based on rational thinking or cost-benefit analysis.

3.2.4 Selected participants

Participants were Greenvale AP potatoes and vegetable growers having at least one on-farm reservoir. Their location was in West Midlands and Eastern England (Figure 3). In total, 5 farmers were interviewed for this research.

Figure 3: Locations of Interviewed farmers

3.2.5 Interviews

Following approval by the Ethics Committee at Cranfield University, a questionnaire was used during interviews with farmers in July and August in 2015. In the case of interviewing them face-to-face, initially, they were contacted by phone in order to arrange a meeting to interview them later in person. By phone they were familiarised with the research. If they agreed to participate, the date of interview was set up. The interview was mainly conducted on the fields or in farmers' office.

In case of interviews held by phone, farmers were called and introduced to the research. If they agreed to participate in this research, they were interviewed at a time convenient for them. The average time of interviewing was 12 minutes.

3.3 Data collection and data analysis

During each interview, data was written down. In case not everything was caught on the paper, the researcher repeatedly listened to recorded interviews to catch missing relevant data. This also helped to make sure that no data was lost. The collected data were subsequently gathered and summarised in a spreadsheet together with responses of other respondents. It enabled clear summary of all reached answers for later analysis. Similar answers were grouped and categorized. The results are presented in Chapter 4 and described and compared to previous studies in Chapter 5.

4 RESULTS

This chapter shows outputs of semi-structured interviews described in the previous chapter. First, participated farm characteristics are defined and then answers of farmers are arranged in the order of the objectives.

4.1 Farm characteristics

Second part of the questionnaire obtained characteristics about the farms that participated in this research. All farms grow potatoes on different area. The areas rank between 70-283 ha. Beside the potatoes, most of the farmers also grow other crops, such as carrots, onions, leaks, salads, wheat or oilseed rape. Each farm possesses a different number of on-farm reservoirs. Table 3 shows that the amount of on-farm reservoirs is corresponding to the cropped area. It means larger cropped area is irrigated by higher amount of on-farm reservoirs, with the exception of Farmer 2. Farmer 2 grows on 283 ha but possesses 8 on-farm reservoirs. This is due to the fact, he grow crops on rented fields. Rented fields are often far away from each other and each of them needs access to water. Therefore all of 8 on-farm reservoirs, which are rented as well, are used for irrigation. On-farm reservoirs are unlined or lined depending on soil properties.

All farmers said that they fully irrigate all potatoes crops and also other crops they grow. Except Farmer 4, who grows wheat and oilseed rape.

Farmer	Potatoes on area (ha)	Other crops on area (ha)	Amount of on-farm reservoirs	Unlined or lined reservoir	Total capacity (m^3)
1.	100	105	3	unlined	113,692
2.	283	-	8	lined	-
3.	160	960	7	unlined	650,078
4.	70	360	1	unlined	30,000
5.	200	293	7	lined	320,000

Table 3 Farm characteristics (in 2015)

To fulfil on-farm reservoir by water, each farmer uses different water sources depending on the geographic conditions and abstraction licence. Farmer 3 and Farmer 4, both have winter abstraction licences to abstract water from a surface source; Farmer 1 has an annual abstraction licence and abstracts water both from surface and groundwater source. Farmer 5 uses only a summer abstraction licence abstracting water from both sources. Farmer 3 refills between 10-15 % of his reservoirs by harvesting water. Farmer 2 did not know this information

All of the farmers sell their potatoes to pre-pack sector. Farmer 3, Farmer 4 and Farmer 5 sell the potatoes as well to processing sector and Farmer 2 for seeds (Table 4).

Table 4 Sectors to which potatoes are sold (in 2015)

Farmer	Pre-pack	Processing	Seeds
1.	100 %	-	-
2.	82 %	-	18 %
3.	31 %	69 %	-
4.	60 %	40 %	-
5.	95 %	5 %	-

4.2 Reasons for reservoir construction

The main reason, why farmers decided to build a reservoir/reservoirs, was to secure their water availability and its volume and also to irrigate more fields to be able to grow high value crops on those fields. They supported this statement with answers, such as:

"By borehole we could not irrigate all fields, so then we would be forced to plant arable crops there, which would not be that profitable. And because of quality - we have very sandy soil and we would not be able to produce high quality crops without irrigation. With irrigation we can produce high value crops on more area." (Farmer 3)

"Then I could not grow potatoes because they need water. There is no groundwater source and my abstraction licence could be stopped when water for irrigation needed. Therefore to build a reservoir was the solution." (Farmer 4)

"Because we can only harvest the water slowly from our abstraction licences and when we need to irrigate, we need to irrigate quickly. So we harvest water slowly all summer long and then we need to pump the water quickly. Without a reservoir, we would have water to irrigate but, but we would have not be able to run two machine on a system at one time. But because of putting water to reservoirs we can run up 4 machines at one time. The reservoirs are good for availability of amount of water." (Farmer 5)

4.2.1 Size of reservoir

Farmers stated that when deciding to build a reservoir, they had thought about future water scarcity. Therefore, they built a larger reservoir for future higher demand for water. However, Farmer 1 and Farmer 4 mentioned that now they do not think the size will be enough for next years and Farmer 1 said, that the size of his reservoir is not large enough even today. This is due to the dead storage, which is partly caused by breeding fish in the reservoirs. The area of land available for their construction also limited the size of the reservoirs.

4.2.2 Grants

Not one of the farmers used a grant from the government. One of the reasons was that grants were not available at that time (in 2007) when constructing the reservoir (Farmer 4). Farmer 1 and Farmer 5 mentioned that they did not apply for grants because they found them very complicated and bureaucratic. Farmer 5 answered to a question *"Why did not you apply for grant?"* as follows:

"Because we wanted to get on with it, there were so many hoops to jump through, so many forms to fill in, so many delays, we built them with our own money and they were bought and paid for before the grant would even have come through."

Farmer 2 did not know the answer to this question.

4.3 Potential for risk mitigation – Farmers' perspective

4.3.1 Mitigated risks

All of the farmers agreed that on-farm reservoirs mitigate risks, both economic and environmental. The most common stated risk was water un-availability, when rainfall is low in a dry year and abstraction licence is stopped. When this risk is mitigated, other risks are mitigated as well, such as poor quality of potatoes or low yields. If potatoes are not irrigated enough they have got small size of tubers and common scab on their skin, of which neither is required by market. Potatoes then become unsalable, farmers lose money and people's jobs are put at risk.

Farmer 3 and Farmer 4 having winter abstractions mentioned that on-farm reservoirs decrease environmental damage, which would happen by abstracting water in summer when flows are likely to be low. Farmer 4 stated that on-farm reservoirs also decrease flooding in downstream areas from what he has experienced.

4.3.2 Benefits

All farmers stated that on-farm reservoirs bring many benefits. Having water available in the reservoirs makes them control the water better and irrigate their crops when they need. This fact brings them economic benefits, such as high crop quality and high yields. Also breeding fish in the reservoirs creates additional financial benefit.

Farmers also mentioned that on-farm reservoirs benefit the environment. Farmer 3 and Farmer 4, which switched from summer abstractions to winter abstractions, stated that it has lower impacts on the environment, because they abstract water when flows are higher. Other benefit is the diverse wildlife in and around the reservoir, such as fish, birds and insects.

Farmer 1 and Farmer 3 believe that the reservoirs also provide a social benefit in terms of having an area for people to enjoy a nice walk around the reservoir. In the long term it might be interesting and beneficial for tourism/recreation.

4.3.3 Disadvantages

The on-farm reservoirs also bring certain disadvantages to the farmers. The most common were loss of land where the reservoir sits (Farmer 1 and 5), dead storage of water (Farmer 1 and 3), also construction and maintenance costs (Farmer 1, 2 and 5). Farmer 1 mentioned that he experienced water contamination as a result of human interference, which brought him extra costs and work.

4.4 Decision making process for irrigation by reservoir

Findings of this section focuses on water use for irrigation. First, it aimed to find out what farmers consider when deciding whether to irrigate or not. Second, how they use water from different sources for irrigation and lastly, what steps they take in irrigation decision-making in case they are running out of water.

4.4.1 Factors considered in irrigation decision-making

Farmers consider several factors before they decide whether to irrigate or not. All farmers mentioned, that they visit fields and look at the crops, soil type and soil moisture. All farmers, except Farmer 1, measure Soil Moisture Deficit (SMD). All farmers look at the crops' stage and needs, weather forecast and rainfalls. Farmer 2 uses software Soil Moisture Sensor and Farmer 5 Happy Irrigator which helps them in irrigation decision-making.

4.4.2 Water use in irrigation decision-making

The answers to questions, "*How do you decide from which source to irrigate?*" and *"Do you use water from those sources based on their reliability?*", among the farmers were fairly similar. Farmers answered, they prioritize water sources based on their location and not reliability. That means, they use the water source, which is closer to certain field. In many cases, they can use only on-farm reservoir, as they build it on fields, which did not have access to any other water source.

To find out, whether farmers avoid the situation of running out of water later in the season, they were asked *"Do you leave stored water in reservoir in the*

beginning of the season to have water for later in the case it is dry and not enough water is available?". Farmer 1 answered, *"yes, we do"* and the rest of the farmers responded "no". Two farmers supported their "no" as follows:

"*No. If we are not irrigating in the early season it is because of lack of water. We are irrigating for crop quality - scab control. This is most important. If you have scabs on your potatoes, there would be nothing and it would not matter how many you have. Therefore, it is important to irrigate in the early season during scab period. Then we concentrate on the yield*." (Farmer 4)

"We use water when we need, because we have learnt two things: because we have summer abstraction, it is not that we fulfil our reservoir in winter and empty in summer. When water is needed, water is needed. No prizes for having a full reservoir - the water earn money in crops, not sitting in the reservoir." (Farmer 5)

Afterwards, farmers were asked to describe their steps in irrigation decision-making, if the situation of running out of water happens. All of the farmers stated that they would prioritize those crops that are more profitable and abandon those with lower value. Some answers were as follows:

"I prioritize that crop that is more profitable. The contracts with clients are before season - January/February. Depending on what crop is more profitable, I put crops on the field to have water availability to that field." (Farmer 1)

"I would consider type of potatoes I grow. The seed potatoes do not need big size so they do not need too much water. I would stop watering them and use the water for the main crop. Priority to salad potatoes because they are smaller and the common scab would be on high percentage of skin finish." (Farmer 2)

"I would prioritize. I would stop irrigating that variety that is more resistant to droughts and use water for other variety that is less resistant." (Farmer 3)

5 DISCUSSION

Chapter 5 aims to discuss results obtained from this research and compare them to previous studies. Lastly, limitations of methodology and possible improvements are considered.

The results obtained from interviews with potato farmers accomplished all three set objectives:

1. To determine the reasons why farmers decided to build a reservoir.
2. To identify risks they think the reservoirs mitigate and what is their perception about reservoir itself.
3. To find out how farmers make decisions about using water in reservoirs.

The findings from the first and second objectives are closely related therefore they will be discussed together. The third objective is discussed last.

5.1 Reasons for on-farm reservoir construction

Building on-farm reservoirs to expand potato production

Farmers prefer growing high value crops instead of low value crops, as they earn more money from them. Also, the fact that the demand for potatoes exceeds the production (Morris et al., 2014) could reinforce the decision of farmers to expand their potato production. Therefore, farmers built a reservoir on the fields, which did not have any access to any water sources. Thus they have increased their potato production providing high quality and yields.

Building on-farm reservoirs to mitigate risks

Most of the farmers built on-farm reservoirs to mitigate risks. The most common mentioned risk was poor quality of their crops. This would happen if the farmers got restricted to abstract water during a dry season and thus they would not be able to irrigate their crops. It would lead to poor quality of potatoes and farmers' could potentially lose contracts with retailers, which require high quality. As this research shows, the retailers represent a significant share of potato purchasers

(73.6 %)[6]. Therefore the interviewed potato farmers had to improve their water supply. It makes them more competitive in the market compared to those farmers that do not have enough water for irrigation and cannot provide crop yield (t/ha) and high quality potatoes (£/t) due to water scarcity. Farmers with reservoirs get contracts with retailers easier and are able to sell their high quality crops. Hereby, they can continue with their potato production, which can spark a chain reaction giving benefits also to another stakeholders, such as farmers' employees, customers, local people and government. Table 5 points out political and economic benefits to different stakeholders, which can result from mitigating risks by using water from on-farm reservoir. It does not include economic benefits, which are directly related to on-farm reservoir construction itself (e.g. the benefit to the construction company).

[6] Pre-pack sector for retailers.

Table 5 Political and economic benefits to different stakeholders sparked by using on-farm reservoir

Benefit	Benefit in detail	Stakeholder	Contribution to the stakeholder
Political	Water availability and security	Farmer	Not restricted by law to abstract water. With water from reservoir they can irrigate their crops.
Economic	High crop quality	Farmer	Their crops are saleable.
		Customers	Customers get food in required quality.
		Workers at the farm	Because high quality crops are saleable, farms profit and thus job of workers is not put at risk.
	High yields	Farmer	Compliance with required amount of crops by the market.
		Customers	Higher supply of food for customers.
		Government	Profit from tax collection from farmer's profit and salaries of people working in the agri-food industry.
	Better control of water	Farmer	Farmers know how much water available they have and thus they can manage its use better.
	Breeding fish in the reservoirs	Farmer	Additional profit for the farmers from renting their reservoirs for breeding fish.
		Breeder	Expansion of breeding fish leading to potential higher profit.
		Customers	Higher supply of food for customers.
		Government	Profit from tax collection from renting, breeding fish and their sale.
	Winter abstraction instead of summer abstraction	Farmer	Lower abstraction fees.
		Industry	It helps for lower competition for water when water stress is likely to be in summer. Thus, more water remains for other industries using water for their business activities.
	Flood prevention	Farmer	Reservoir may prevent floods, which could destroy crops and make them unsalable.
		Local people	Households can be prevented from floods.
		Industry	Industries can be prevented from floods.
		Government	Costs are avoided related to prevented floods.

Regarding benefits, not all of them are applicable to all farmers. For example, not all farmers having an on-farm reservoir are abstracting water in winter, thus their abstraction licence fees are not cheaper. Also not all farmers introduce fish in the reservoirs, because it makes water cloudy (Weatherhead et al., 2008) and reduces the amount of water available for irrigation (Patel & Morris, 2012).

Another direct economic benefit to farmers is prevention from unpredicted floods. Farmer 4 said that he has already experienced this situation and using his reservoir he reduced flows in rivers and helped from the threat of floods. Floods would present damage to farming (Posthumus et al., 2009) and thus high financial losses to the farmers (Knox et al., 2010).

Farmers also mentioned that on-farm reservoirs mitigate risks to the environment (Table 6). It does not directly benefit the farmers, but the environment, which provide regulating services important for humans, farmers and industries. Thus, higher biodiversity in and around on farm reservoir can contribute to enhancement of water, air and soil regulation necessary also for agricultural production.

Also farmers stated that reservoirs provide nice surroundings for people to enjoy. It could attract tourists to visit, which could contribute to local communities providing small business such as vicinity or entertainment facilities. However, public access to reservoirs could bring certain difficulties to farmers, such as new infrastructure and thus another loss of land, health and safety problems and possible vandalism (Weatherhead et al., 2008).

Table 6 Environmental and social benefits provided by on-farm reservoirs

Benefit	Benefit in detail	Stakeholder	Contribution to the stakeholder
Environmental	Winter abstraction instead of summer abstraction	Environment	Summer abstractions are likely avoided and thus they do not contribute to over-abstractions. The flows in summer will stay higher, what is favourable for wildlife in the rivers, lakes and streams.
		Environment	Higher flows in summer dilute pollutants
	On-farm reservoirs create a new environment	Environment	Reservoirs create new environment for wildlife in and around reservoir, which were not present before, such as fish, insects, birds, mammals, etc.
		Environment	New flora in and around the reservoir
	Flood prevention	Environment	Habitat modification avoided
Social	New environment	Local people Farmer	Nice walk around the reservoir

Disadvantages of on-farm reservoirs from farmers' perspective

In comparison to the benefits, most of the farmers did not see many disadvantages related to on-farm reservoirs. Loss of land, impossibility of using all stored water and construction and maintenance costs, these were the most mentioned disadvantages of on-farm reservoirs from farmers' perspective. No one of the farmers considered evaporation losses as a disadvantage, even they will likely become greater due to climate changes (Hoffman et al., 2007).

Those farmers who have introduced fish in on-farm reservoirs considered the impossibility of using all stored water as the greatest problem. Farmers have to leave certain amount of water in the reservoir to provide sufficient amount of water for fish. Otherwise the water could be used for irrigation and satisfy the needs of crops. This fact could warn other farmers before deciding whether to breed fish in their reservoirs or not and first weigh consequences and benefits.

Lastly, farmers perceived the construction costs very high. Possibly, if grants were better accessible and cut farmers' costs by 40 % or more, farmers would not find it as a significant disadvantage.

5.2 Water use from on farm reservoir

Farmers use water sources based on their location. They usually have only one water source available to irrigate a certain field. Therefore, Pocock's (2015) model introducing prioritization of various water sources based on their reliability, could not be applicable. However, Farmer 1 mentioned that he grows the crops with highest yield potential on fields, which have the most reliable water source. Ensuring that the crops will be sufficiently irrigated and later provide required high quality and yields. This suggests farmers put high value crops on fields with reliable water sources to mitigate risk of water scarcity.

Each farmer fulfils his/her reservoir by different water sources in different seasons. Farmer 3, as only of the interviewed farmers, refills between 10-15 % of his reservoir by rainwater harvesting. Even the rain is unpredictable and the harvested volume is small, it is relatively possible to harvest water and refill the on-farm reservoir all year long. Farmers having only summer abstractions could consider rainwater harvesting integration in their irrigation system to collect water also during winter, when rainfalls are higher.

In terms of irrigation decision making, the majority of farmers said that they prefer a dry season. This is because farmers with on farm reservoirs will have secured water to irrigate their crops and thus will have full control over the amount of water they put on crops. When deciding whether to irrigate or not, farmers visit the fields and look at the crops considering their growth stage and the needs of each stage; soil type and soil moisture deficit (SMD); weather forecast and rainfalls is also considered. By calculating daily need of water they avoid waste of water and on the other hand they secure enough water for crops to be of high quality. To reinforce the high quality crops, most of the farmers use water in early stages of the crop taking the risk of running out of water later in the season, at the expense to have poor quantity. Low quality potatoes would not be saleable. In the case farmers run out of water in the end of the season, it

was found they generally decide to abandon some crops to ensure maximum quality of other crops and make them saleable. In case they grow different types of crops, they stop irrigating those with lower value. These findings support Pocock's (2015) model of prioritization.

5.2.1 Securing water for future needs

Farmers interviewed considered future demand for water, which is predicted to be larger than currently, when deciding to build a reservoir. They preferred to spend more money on larger reservoirs to prevent water scarcity for a longer period in the future. Currently, some of the farmers have redundant water in the reservoir, which can be stored for next season. It means that next season they abstract less water and save costs related to the abstractions. None of the farmers sell the redundant water to any other farmer or non-agricultural body. This might be due to the complexity of calculating the value of water at certain time or barriers in water trading in the UK.

5.2.2 Government grants

None of the interviewed farmers had applied for a grant to fund the construction of the reservoir, saying that the complexity of application discouraged them. Above all, the process of the application would have extended the time of construction of the on-farm reservoir. Which already takes between 2 and 3 years to be completed without grant applications (Weatherhead et al., 2008). Farmers preferred to finance their investment by themselves and thus secure their water supply sooner. The fact that the grant could cover up to 40 % of on-farm reservoir construction and farmers do not apply for it, raises the question if the present policy is successful and could benefit from changes.

5.3 Limitations of the methodology

During this research, some limitations of the methodology became apparent. First of all, a large sample of respondents was not carried out. Only 5 farmers participated in this research, as keeping attention of the respondents during harvest was difficult. Answers from a larger sample of farmers could have supported current stated answers further. Also they could come up with different statements enriching this research.

Moreover, the questionnaire was time limited meaning number of questions and depth of discussion was restricted. Farmers were under time pressure, therefore some questions were not asked during the interview. Also, during the period of interviewing respondents, new questions were thought of after interviews were carried out. Therefore, the previous respondents had to be contacted additionally by e-mail to complete missing questions. However, some of the questions were misunderstood and the answers could not be included in this research.

6 CONCLUSION

This research aimed to determine behaviour of farmers in irrigation decision-making through on-farm reservoirs to manage risk. The importance of the findings was to obtain a better understanding of how on-farm reservoirs improve the economics of farming. Also to find out if there are disadvantages of using on-farm reservoirs and in what situations these will occur, helping future farmers avoid these and maximising the benefits.

Overall conclusions from the data collected suggest farmers' behaviour and decision-making in irrigation is largely dominated on the aim to obtain the highest profits from growing crops. Farmers know requirements of the market, to which they adaptively respond. They incline to high value crops production rather than low value crops. To secure their production and sales, they undertake high costs related to loss of land and expensive investment in on-farm reservoir implementation. Their investments are planned for long term needs, which supposed to secure their businesses for now and for near future. By this change in water supply they satisfy high crop quality strictly required by market. Therefore now, dry seasons which would be harmful for their profit, are paradoxically profitable and make them competitive in the market.

Results of this study further support the results of similar studies researched. Which overall proves the implementation of on-farm reservoirs is beneficial for farmers growing high value crops. Finally, data collected is a useful resource for DEFRA as a comparison to Pocock's model and could be used in future for the structuring of grants and information packs to encourage farmers to build on-farm reservoirs.

7 REFERENCES

Carli, C. et al., 2014. Effect of different irrigation regimes on yield, water use efficiency and quality of potato (Solanum tuberosum L.) in the lowlands of Tashkent, Uzbekistan: A field and modeling perspective. *Field Crops Research*, 163, pp.90-99.

Buckley, D. et al., 2012. *Irrigation Best Practise - A Guide for Potato Growers*. [Online] Available at: http://www.ukia.org/pdfs/water%20management%20for%20potatoes.pdf [Accessed 3 June 2015].

Buratto, A. & D'Alpaos, C., 2015. Optimal sustainable use of drinking water sources and interactions between multiple providers. *Operations Research Letters*, 43(4), pp.389-95.

DEFRA, 2007. *Irrigation Best Practice: Water Management for Potatoes A Guide for Growers*. [Online] Available at: http://www.ukia.org/pdfs/A%20Water%20Management%20Toolkit%20for%20Field%20Crop%20Growers.pdf [Accessed 29 August 2015].

DEFRA, 2011c. *Future Water - The Government's Water Strategy for England*. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69346/pb13562-future-water-080204.pdf [Accessed 3 June 2015].

DEFRA, 2011a. *Water for Life*. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/228861/8230.pdf [Accessed 3 June 2015].

DEFRA, 2011b. *Water Usage in Agriculture and Horticulture Results from the Farm*. [Online] Available at: http://webarchive.nationalarchives.gov.uk/20130123162956/http:/www.defra.gov.uk/statistics/files/defra-stats-foodfarm-farmmanage-fbs-waterusage20110609.pdf [Accessed 25 August 2015].

DEFRA, 2015c. *How to apply for grants: Countryside Productivity*. [Online] Available at: https://www.gov.uk/guidance/how-to-apply-for-grants-countryside-productivity [Accessed 22 August 2015].

DEFRA, 2015a. *Agriculture in the United Kingdom 2014*. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/430411/auk-2014-28may15a.pdf [Accessed 3 June 2015].

DEFRA, 2015b. *Apply for water management grants - Detailed guidance*. [Online] Available at: https://www.gov.uk/apply-for-water-management-grants#after-applying [Accessed 22 August 2015].

Environment Agency, 2008. *Water resources in England and Wales - current state and future pressures*. [Online] Available at: http://webarchive.nationalarchives.gov.uk/20140328084622/http:/cdn.environment-agency.gov.uk/geho1208bpas-e-e.pdf [Accessed 24 July 2015].

Environment Agency, 2010. *The Owner's Guide to Reservoir Safety*. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/302050/owners_guide_to_reservoir_safety_English.pdf [Accessed 2 August 2015].

Environment Agency, 2013. *Managing Water Abstraction*. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297309/LIT_4892_20f775.pdf [Accessed 2 June 2015].

Environment Agency, 2014. *Abstracting water: A guide to getting your licence*. Environment Agency.

Epa.gov, 2015. *Natural Events And Disasters | Agriculture | US EPA*. [Online] Available at: http://www.epa.gov/agriculture/tned.html#floodplan [Accessed 1 September 2015].

Eurostat, 2015. *Database - Eurostat*. [Online] Available at: http://ec.europa.eu/eurostat/data/database?node_code=proj [Accessed 26 August 2015].

FAO, 2012. *Crop yield response to water*. [Online] Available at: http://www.fao.org/3/a-i2800e.pdf [Accessed 28 August 2015].

FAO, 2015. *2. WATER SOURCES AND WATER AVAILABILITY*. [Online] Available at: http://www.fao.org/docrep/u5835e/u5835e03.htm [Accessed 25 July 2015].

Frey, J.H. & Oishi, S.M., 1995. *How To Conduct Interviews by Telephone and in Person*. SAGE Publications.

Hess, T., Daccache & Lennard, A., 2015. Comparing local and global water scarcity information in determining the water scarcity footprint of potato cultivation in Great Britain. *Journal of Cleaner Production*, 87, pp.666-74.

Hess, T., Knox, J., Kay, M. & Weatherhead, K., 2011. Managing the Water Footprint of Irrigated Food Production in England and Wales. *Issues in Environmental Science and Technology*, 31, pp.78-92.

Hoffman, G.J. et al., 2007. *Design and Operation of Farm Irrigation Systems*. 2nd ed. ASABE.

Klandermans, B. & Staggenborg, S., 2002. *Methods of social movement research*. Minneapolis: University of Minnesota Press.

Knox, J.W., Daccache, A., Weatherhead, E.K. & Stalham, M., 2011. *Climate Change Impacts on the UK Potato Industry*. [Online] Agriculture and Horticulture Development Board Available at: http://www.potato.org.uk/sites/default/files/publication_upload/20113%20Climate%20Change%20R404%20Final%20R404.pdf [Accessed 5 July 2015].

Knox, J., Morris, J. & Hess, T., 2010. Identifying future risks to UK agricultural crop production. *Outlook on Agriculture*, 39(4), pp.249-56.

Knox, J.W., Weatherhead, E.K., Diaz, J.A.R. & Kay, M.G., 2009. Developing a strategy to improve irrigation efficiency in a temperate climate - A case study in England. *Outlook Agric.*, 38(4), pp.303-09.

Knox, J., Weatherhead, K. & Rodriguez-Diaz, J., 2008. *A fair share of water for agriculture: A strategy for irrigation in Eastern England*. [Online] Available at: http://www.ukia.org/pdfs/a%20fair%20share%20of%20water.pdf [Accessed 26 August 2015].

Martínez-Granados, D., Maestre-Valero, J.F., Calatrava, J. & Martínez-Alvarez, A., 2011. The Economic Impact of Water Evaporation Losses from Water Reservoirs in the Segura Basin, SE Spain. *Water Resour Manage* , 25(13), pp.3153-75.

Mauser, W. & Schneider, K., 2008. *Water resources: efficient, sustainable and equitable use*. London: Haus.

Morris, J. et al., 2014. Economics of Rainfed and Irrigated Potato Production in a Humid Environment. In Bournaris, T., Berbel, J., Manos, B. & Viaggi, D. *Economics of Water Management in Agriculture*. CRC Press. pp.71–97.

ONS, 2011. *Regional Profiles - Population and Migration - East of England*. [Online] Available at: http://www.ons.gov.uk/ons/dcp171780_301596.pdf [Accessed 25 August 2015].

Patel, A. & Morris, J., 2012. *The Costs of On-farm Reservoirs and Infrastructure*. Cranfield campus library catalogue; EBSCOhost.

Pocock, J., 2015. *Water Abstraction Reform: On-farm Reservoir Modelling*. NO PUBLISHED.

Posthumus, H. et al., 2009. Impacts of the summer 2007 floods on agriculture in England. *Journal of Flood Risk Management*, pp.182-89.

Robinson, E., 2011. Drought, flooding cut crops. *Delta Farm Press*, 68(24), pp.1-17.

Suffolk Coast and Heaths AONB, 2010. *Farm Reservoir Design Guide: A Guide to Good Planning and Design of Farm Reservoirs in the Suffolk Coast nad Heaths Area of Outstanding Natural Beauty*. [Online] Available at:

http://www.suffolkcoastandheaths.org/assets/Planning/SCH-Farm-Reservoir-leafletWEB.pdf [Accessed 3 June 2015].

Tasker, J., 2007. Champion needed to secure supply. *Farmers Weekly*, 147, p.18.

UK Government, 2012. *UK Climate Change Risk Assessment: Government Report*. [Online] TSO (The Stationery Office) Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69487/pb13698-climate-risk-assessment.pdf [Accessed 20 August 2015].

Weatherhead, K., 1997b. On-Farm Irrigation Needs And Reservoir Size. *Irrigation News*, 26, pp.9-12.

Weatherhead, K., Kay, M. & Knox, J., 2008. *Thinking about an irrigation reservoir? A guide to planning, designing, constructing and commissioning a water storage reservoir*. [Online] Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297089/gemi0408bnzp-e-e.pdf [Accessed 2 July 2015].

Weatherhead, K., Knox, J. & Morris, A.D.a.J., 2014. *Water for Agriculture: Collaborative Approaches and On-Farm Storage*. Cranfield CERES, EBSCOhost.

Weatherhead, E.K. et al., 1997a. *Irrigation Demand and On-farm Water Conservation in England and Wales*. Cranfield CERES, EBSCOhost.

Wengraf, T., 2001. *Qualitative Research Interviewing: Biographic Narrative and Semi-Structured Methods*. London: SAGE.

APPENDICES

Appendix A : Questionnaire Template

To whom it is concerned:

I am Markéta Chalupová, studying a master degree of Environmental management for business at Cranfield University. Currently, I am working on the final project dealing with the *Economics of on-farm reservoirs to manage risk*.

Its aim is to find out the real behaviour of farmers during the irrigation process and subsequently compare it to different models based on cost-benefit analysis.

I confirm that all information will be treated with strictest confidence and your name will not be used in any report, publication or presentation. Together with this questionnaire I send you a consent form to fulfil.

I would be very grateful for your participation in this survey and thus helping me to get final results.

Thank you very much.

Markéta Chalupová

The questionnaire consists of two main sections. The first section aims to get background information about the farm. The second section contains the crucial questions about irrigation and reservoirs.

1st Section: Farm Characteristics

Contact person	
Telephone or email	

Which crops do you grow? **(e.g. potatoes)**	**Land use per crop?** **(ha)**	**Is that crop irrigated? (yes/no)**	**Total area of that crop irrigated (ha)**

In terms of all POTATOES grown, how much area is used for each sector:	**On planted area (ha):**
Pre-pack	
Fresh bags	
Fresh chipping	
Processing	
Seeds	
Other ware	

Do you have any abstraction licence? Complete what applicable:

Abstraction licence	**Surface source (m3)**	**Groundwater source (m3)**
Summer		
Winter		
Annual		
Total abstracted (m3)		

Complete what applicable:

What type of reservoir do you have?	**How many reservoirs do you have of that type?**	**Total capacity (m3)**
Unlined		
Lined		
Total		

2nd Section:

1st Part:

The objective of this part is to explore the reasons why farmers decided to build a reservoir.

1. What was the reason to build a reservoir?

2. Why this size of reservoir?

3. Does this size comply your today's needs of water?

4. Is the size of reservoir bigger to prevent water scarcity in the future?

5. Did you use any grant from government to build the reservoir?

5. a) If not, why?

5. b) If yes – How much of the cost of the reservoir was granted (%)?

Any comments on this part of questionnaire:

2nd Part:
The purpose of the following questions is to find out the perceptions of farmers about reservoir itself.

1. Do you reduce some risks by having an on-farm reservoir?

1. a) If so, what risks? (the risks might be economic, environmental, political, social, etc.)

2. Does the reservoir give you any benefits?

2. a) If so, what benefits? (the benefits might be economic, environmental, political, social, etc.)

3. Does the reservoir bring you any disadvantages or risks?

3. a) What disadvantages or risks?

Any comments on this part of questionnaire:

3rd Part:

The objective is to find out how farmers use water sources.

1. How do you decide whether to irrigate or not? Please mention everything that you consider.

2. When deciding whether to irrigate or not, do you consider:	**Yes/No**
Calculating Soil Moisture Deficit on day-to-day basis	
Crop's needs and its stage	
Rainfall	
Weather forecast	

3. Do you calculate daily irrigation demand?

4. Do you consider risks that might occur if you do not irrigate?

4. a) Which risks?

5. How do you decide from which source to irrigate?

6. Do you use water from water sources based on their reliability?

7. If you have more than one water source available, in which order do you use them based on reliability?

First I use water from:

No.	Water source
	Low reliability surface water
	Stored water from full reservoir > 95 %
	High reliability surface water
	Ground water
	Stored water from reservoir < 95 % full
	Public water system
	Medium reliability surface water

Any comment on order of water sources:

8. In case your water is running out and crop reaches the End SMD limit, what would you do? How would you irrigate?

8. a) Do you consider profitability of each crop in this situation? Do you abandon any crop? Or do you split water among all crops evenly? Please comment.

Any comments on this part of questionnaire:

Thank you very much for your time and participation in this survey. If you have any questions or any comments, please do not hesitate to contact me on:

My phone: +44 7851 812394

or

Email: m.chalupova@cranfield.ac.uk

Appendix B : Data Collection

Questions	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5
What was the reason to build a reservoir?	The security of water We wanted a borehole, but it was not possible. So the only option to irrigate the necessary fields was to build a reservoir.	Water availability The soil is sandy and dries up quickly. Crops need lots of water to irrigate.	By borehole we could not irrigate all fields, so then we would be forced to plant arable crops there, which would not be that profitable. And because of quality - we have very sandy soil and we would not be able to produce high quality crops without irrigation. With irrigation we can produce high value crops on more area. Now we can farm more valuable crops on more areas of farm	Then I could not grow potatoes because they need water. There is no groundwater source and my abstraction licence could be stopped when water for irrigation needed. Therefore to build a reservoir was the solution.	Because we can only harvest the water slowly from our abstraction licences and when we need to irrigate, we need to irrigate quickly. So we harvest water slowly all summer long and then we need to pump the water quickly. Without a reservoir, we would have water to irrigate, but we would not be able to run two machine on a system at one time. But while putting water to reservoir we can run up to 4 machines at one time. Because of availability of volume of water
Why this size of reservoir?	This size is according to the size of land that was available for a reservoir construction.	Doesnt know	According to the size of land available.	Because it is enough.	To be able to harvest enough water for our irrigation needs.
Does this size comply your current needs of water?	Not anymore. When designing the reservoir construction, they added extra volume of the reservoir for higher demand in the future. But because we have to leave at least 25 % of water due to wildlife (fish) in the reservoir, we do not have enough water to satisfy our current need.	Yes	Yes	Yes	Yes
Is the size of reservoir bigger to prevent water scarcity in the future?	It was meant to do so. But explanation above.	Yes	Yes	No	Yes, it will be enough for next 20 years.
Did you use any grant from government to build the reservoir?	No	Doesnt know		No	Absolutely not
No - why?	To much red tape	Doesnt know		That time it was not available (2007)	Because we wanted to get on with it, there were so many hoops to jump through, so many forms to fill in, so many delays, we built them with our own money and they were baught and paid for before the grant would even have come through.

Figure 4 Appendix: Reasons for reservoir construction

Questions	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5
Do you reduce some risks by having an on-farm reservoir?	Having water when it is HoF. But in case of this farm, we do not have any problem with HoF. I think reservoir brings more risks than mitigates. (Mentioned in question about disavantages.)	Yes	Yes	Yes.	Yes
What risks? (economic, environmental, social)	-	Risk of low summer rainfall in dry year. If we did not have reservoirs, we would not be able to irrigate enough.	Quality (scab) (if there were scabs, we could not sell our potatoes and we could not grow them any more). We would have to grow arable crops which are not that profitable financial risks - we can sell our products	Yield and quality. Quality in terms of common scab. As we take the water from winter when flows are high, we would lessen the amount of flooding in downstream.	Economic - if we can not irrigate our crops, we lose our money. If we lose money, we put peoples jobs at risk. And by harvesting the water slowly from our sources, we are doing less environmental damage than if we suck them dry when the water sources are under pressure.
Does the reservoir give you any benefits?	Yes	Yes	Yes	Yes	Absolutely yes. Huge benefits.
What benefits? (economic, environmental, social)	Social - you can have a nice walk. For long term it might be nice for tourism/recreation. But it would mean another loss of land for infrastructure. Political - If you get restricted by law not to abstract water, you have water in your reservoir, which is yours and you can use it. No economic benefits.	Security of water supply. We can control the water better. Economic - High yields and high quality. Environmental - the water is abstracted when the flows are higher and it does not harm the summer flows, wich are usually very low.	Environmental - we get wildlife, tries, habitat, fish (carps). It is a nice place to have a walk. Financial - we let a breeder to breed carps in the reservoir - some additional financial profit	Yield and quality. We can control water better in the reservoir. We are not restricted by HoF, because we abstract water in winter and then it is ours. Above all it is better to have dry season and use water how much we need than having a wet year. We cannont control how much water is going to be on the field by rainfalls. And in the future we would not be probably allowed to abstract water. So if I have a reservoir, the water is mine and I can irrigate.	Mentioned above (reduced risks). Environmental - wildlife - birds, fish. Lots of wildlife living in grass growing along the banks
Does reservoir bring you any disadvantages?	Yes	No. Just capital costs in the begining.	Yes	No.	Yes
What disadvantages?	Reservoir increases risks with contamination by humans and birds. Reservoir brings financial disadvantages, such as: High energy requirement (double pumping) Loss of land where we could grow crops Civil engineering, seepage, leakage. Loss of 25 % of water because of wildlife in the reservoir.		We have to leave 10 % of water in reservoir that we cannot use for irrigation (because of fish in there)	Note: It was difficult to plan where to build the reservoir because of EA.	Loss of land where reservoir sits on (it is quite costly) It cost lots of money to built them and maintain In the future we will have to put another lining in.

Figure 5 Appendix: Farmers perception of reservoir

Questions	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5
How do you decide whether to irrigate or not?	By experience. I look at the soil and crop stage. I consider	We look at the soil and crop by digging. Rainfall, cropstage, weather forecast. I look at the soil type (if it is sand or clay and how much water it maintains) Soil Moisture Sensor (website - irriquest.net). It helps us to decide when to irrigate.	SMD when it goes between 20-25, we know when we need to irrigate	They measure water deficit in the Soil and another program.	We have scans on some fields that measure soil moisture deficit. As well as visiting the fields regulary to have a look, walk and see and we also run a Happy Irrigator SW, a management program which is like water balance sheet.
Make sure farmer covers:					
Soil Moisture Deficit on day-to-day basis	No	Yes	Yes	Yes	Yes
Crop`s needs and its stage	Yes	Yes	Yes	Yes	Yes
Rainfall	Yes	Yes	Yes	Yes	Yes
Weather forecast	Yes	Yes	Yes	Yes	Yes
Do you calculate daily irrigation demand?	Yes	Yes	Yes	Yes	Yes
Do you consider risks that might ocurr if you do not irrigate?	Yes	Yes	Yes	Yes	Yes
Which risks?	Poor quality	Potatoe common scab - it would effect the quality and size of potatoes. Both are requirements by Tesco and Yields	Common Scab	Common scab presence	Poor quality of potatoes because of common scab or poor yields.
How do you decide from which source to irrigate?	Based on location.	Depends on where the land is and what is the closest water source to the field. Different farm owners pull from different sources dependent on location.		We have only one water source.	We take water only from reservoir.
Do you use water from sources based on their reliability?	They are all reliable all.	No, based on location.		Not applicable	Not applicable
Do you leave stored water in reservoir in the beginning of the season to have water for later in case it is dry and not enough water available?	Yes			No. If we are not irrigating in the early season it is because of lack of water. We are irrigating for crop quality - scab control. This is most important. If you have scabs on your potatoes, there would be nothing and it would not matter how many you have. Therefore, it is important to irrigate in the early season during scab period. Then we concentrate on the yield.	We use water when we need, because we have learnt two things: because we have summer abstraction, it is not that we fulfil our reservoir in winter and empty in summer. When water is needed, water is needed. No prizes for having a full reservoir - the water earns money in crops, not sitting in the reservoir.
In case your water is running out and crop reaches the End SMD limit, what would you do? How would you irrigate?	I prioritize that crop that is more profitable. The contracts with clients are before season - January/February. Depending on what crop is more profitable, I put crops on the field to have water availability to that field.	I would consider type of potatoes I grow. The seed potatoes do not need big size so they do not need too much water. I would stop watering them and use the water for the main crop. Priority to salad potatoes because they are smaller and the common scab would be on high percentage of skin finish.	I would prioritize. I would stop irrigating that variety that is more resistant to droughts and use water for other variety that is less resistant.	We would irrigate that potatoes that had more yield potential.	We would just work out where the cost-benefit as water was greatest and use it on crops with the highest value.

Figure 6 Appendix: Irrigation decision making