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ASSESSING IRRIGATION TRENDS AND AGRICULTURAL WATER RESOURCE MANAGEMENT CONSTRAINTS IN MALTA

MASTER THESIS

Supervisor: doc. Ing. Martin Hanel, Ph.D.
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Assessing irrigation trends and agricultural water resource management constraints in Malta

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Objectives of thesis

Malta is among the most densely populated and most water scarce countries in the world. Low rainfall and a seasonal variable semi-arid Mediterranean climate does not allow for full recharge of the aquifers as they are being over abstracted and polluted by fertilisers. This study was based on collating published scientific evidence, farmer and stakeholder surveys on current water resource management conducted in Malta in June 2016 and modelling irrigation water demand for potatoes using a water balance model tool (WaSim). The differences in the estimates of the agricultural water usage are significant. There was a general disagreement among stakeholders about management of the water resources and over all water governance. Farmers and the public are not aware of the water shortages and farmers still think they have enough available water for irrigation. The problem with the water shortages should be tackled at the farm level to help farmers to understand the current situation and enable easier adaptation of farmers to the changing climate.

Methodology

This research was based on collating published scientific and industry evidences, gathering and analysing historical water use data, WaSim modelling and farmer and stakeholder surveys. In 2015, Cranfield University started a new research project with the Malta College for Arts, Science & Technology Research (MCAST) and Directorate of Agriculture – National Agricultural Research Centre to investigate options for Fostering Water Agriculture Research and Innovation in Malta (FOWARIM) funded under the EU Horizon 2020 under which is this research based. This research was awarded a grant by The Douglas Bomford Trust to enable the author to visit Malta for a two-week period to investigate the current water management issues, conduct farmer and stakeholder surveys and familiarize with the area.

The proposed extent of the thesis

40 pages of text and illustrations

Keywords

farmer, irrigation demand, potatoes, irrigation practices, stakeholder survey

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Recommended information sources

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Declaration

I hereby declare that the thesis titled "Assessing irrigation trends and agricultural water resource management constraints in Malta" is original work which I have completed independently under the direction of the supervisor. All the sources have been quoted and listed in References at the end of the thesis.

Prague, 17th April 2017 ___________________________

CRANFIELD UNIVERSITY

ZUZANA VLACILOVA

ASSESSING IRRIGATION TRENDS AND AGRICULTURAL WATER RESOURCE MANAGEMENT CONSTRAINTS IN MALTA

SCHOOL OF WATER, ENERGY AND ENVIRONMENT
Environmental Water Management

MSc Thesis
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ABSTRACT

Malta is among the most densely populated and most water scarce countries in the world. Low rainfall and a seasonal variable semi-arid Mediterranean climate does not allow for full recharge of the aquifers as they are being over abstracted and polluted by fertilisers. This study was based on collating published scientific evidence, farmer and stakeholder surveys on current water resource management conducted in Malta in June 2016 and modelling irrigation water demand for potatoes using a water balance model tool (WaSim). The differences in the estimates of the agricultural water usage are significant. There was a general disagreement among stakeholders about management of the water resources and over all water governance. Farmers and the public are not aware of the water shortages and farmers still think they have enough available water for irrigation. The problem with the water shortages should be tackled at the farm level to help farmers to understand the current situation and enable easier adaptation of farmers to the changing climate.

Keywords: farmer, irrigation demand, potatoes, irrigation practices, stakeholder survey

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LIST OF ABBREVIATIONS

ET_o	Reference evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
MCAST	Malta College of Arts Science and Technology
MWA	Malta Water Association
NSO	National Statistics Office
SEWCU	Sustainable Energy and Water Conservation Unit
UAA	Utilized Agricultural Area
WFD	Water Framework Directive

Assessing irrigation trends and agricultural water resource management constraints in Malta

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ABSTRACT

Malta is among the most densely populated and most water scarce countries in the world. Low rainfall and a seasonal variable semi-arid Mediterranean climate does not allow for full recharge of the aquifers as they are being over abstracted and polluted by fertilisers. This study was based on collating published scientific evidence, farmer and stakeholder surveys on current water resource management conducted in Malta in June 2016 and modelling irrigation water demand for potatoes using a water balance model tool (WaSim). The differences in the estimates of the agricultural water usage are significant. There was a general disagreement among stakeholders about management of the water resources and over all water governance. Farmers and the public are not aware of the water shortages and farmers still think they have enough available water for irrigation. The problem with the water shortages should be tackled at the farm level to help farmers to understand the current situation and enable easier adaptation of farmers to the changing climate.

Keywords: farmer, irrigation demand, potatoes, irrigation practices, stakeholder survey

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1 INTRODUCTION

The Maltese Archipelago is a small group of islands which consist of mainland Malta (246 km^2), Gozo (67 km^2) and Comino (1 km^2). With its location in the central Mediterranean region between Sicily (93 km) and Libya (300 km) Malta has a geographically strategic position, however it is not rich in natural resources. Nowadays, with a total population of 418,000 inhabitants, Malta is among the most densely populated countries in the world (United Nations, 2014). The major challenge for the country is to meet high and rapidly increasing demand for freshwater with an increasing population and very limited space. Low rainfall and a seasonal variable semi-arid climate makes Malta one of the most water stressed countries in the world with the lowest water resource index (40 m^3/year/capita) and one of the highest water competition index (24,800 inhabitants/hm^3/year) in the world (European Commission, 2010). The country is strongly dependent on groundwater resources and desalination plants as there are no exploitable surface waters. Groundwater aquifers recharge mainly from winter rainfall, however they are overexploited beyond sustainable levels due to high water demand and insufficient time to recharge. Malta also faces serious groundwater pollution of its sources as a result of agricultural pollution and over abstraction (FAO, 2006a).

Agriculture is the main consumer of fresh water resources in Malta. The agricultural sector used 52% of all available water resources in 2013 followed by households (32%), services (10%) and manufacturing and industrial activities (5%) (Tanti, 2015). Arable land using an external source of water for irrigation became more common due to higher demand for the good quality products, which had negatively affected the viability and sustainability of aquifers.

Malta’s water scarcity and pressure on the aquifers is well documented, however there is widespread ignorance about the choices, issues and the real nature of the problem (Roberts et al., 2015). Maltese water management vision in general is lacking the transparency and trust in the government’s ability to manage the water issues (Xerri et al., 2016). According to FAO (2006a) the Maltese water crises is partly due to lack of good governance. The main issues of governance nowadays are separated water and agriculture policies, fragmented decision-making and low awareness of the consequences of mismanagement of water resources (Zammit, 2016). Malta’s entry to the European Union brought more interest and engagement in environmental policies, however current pressure on the country is to fulfil all EU requirement, especially the Water Framework Directive (WFD) (Xerri et al., 2016). Malta also lacks advisory services for farmers, which can be a key towards sustainable agriculture (Swanson, 2008). A fundamental challenge for the Islands is to establish systems for efficient water governance that consider social, economic and environmental requirements which are adaptable to a changing climate (Bezzina and Scicluna Laiviera, 2016).

The main aim of this study was to undertake a baseline assessment of the environmental water resource impacts of agricultural development in Malta based on collating published scientific evidence and the author’s research in Malta. The objectives of this research were:

1. To examine published evidences on links between sustainable water resources and environment considering current irrigation and agricultural trends.
2. To conduct farmer and stakeholder surveys on the current trends of water resources, technology, stakeholder engagement and collaboration, and trends in water usage.
3. To model irrigation water needs for potatoes and to discuss differences in the estimation of agricultural irrigation demand in Malta.

In 2015, Cranfield University started a new research project with the Malta College for Arts, Science & Technology Research (MCAST) and Directorate of Agriculture - National Agricultural Research Centre to investigate options for Fostering Water Agriculture Research and Innovation in Malta (FOWARIM) funded under the EU Horizon 2020 under which is this research based.

2 METHODOLOGY

This research was based on collating published scientific and industry evidences, gathering and analysing historical water use data, WaSim modelling and farmer and stakeholder surveys.

2.1 Literature review of the impacts of water resources on the agricultural environment in Malta

The primary source of literature was the Agricultural Census reports of Malta's National Statistics Office (NSO) and FAO report of Water resources in Malta. Sciencedirect and Web of Science were used for the search of scientific articles. The key words used to search for the articles were: *agriculture, climate change, droughts, farmers, irrigation, rainfall, water governance, water resources and water shortages in Malta*. Additional sources were articles publish by the International Center for Advanced Mediterranean Agronomic Studies (CIHEAM) and Times of Malta local newspapers. A critical part of literature review was a visit to Malta where useful information and documents were obtained from stakeholders as a part of literature review.

2.2 Farmer and stakeholder surveys on trends of agricultural water resources and irrigation

Farmer and stakeholder surveys were conducted during the author's research visit to the Maltese Archipelago between the 7th and 21st of June 2016. The surveys were divided into two sections: General stakeholder questionnaire on agricultural water resources and Survey of farmers' perception on agricultural water consumption which can be found in Appendix A. These two surveys were grouped into four main themes: trends in water management, technology, stakeholder engagement and collaboration, and the future of the water resource management.

2.2.1 Farmer and stakeholder surveys development

The design of the farmer and stakeholder surveys were based on literature review and also discussed with the local contact in Malta. The criteria of the survey were chosen on the most discussed water issues and trends in the scientific literature, governmental reports and Maltese media. The key informants were identified with the help of the local contact as well as the author's effort to contact relevant stakeholders.

2.2.2 Survey of farmers' perception on agricultural water consumption

The farmer's survey was divided into two main sections including seven questions on current water resource management and future water resource management. The farmers' survey also includes farm introduction and description of the irrigation and water use. The interview with the farmer lasted approximately 15 minutes.

Farmers were interviewed in the Agricultural and Rural Payments Agency's Front Office and during the farmer's market in Ta'Qali. In total, 27 farmers were interviewed and the results from the farmer's survey can be found in section 3.2. The farmers' questionnaire was heavily modified during the author's stay in Malta due to language barrier, translation issues, and the lack of time farmers had to answer the questions. The farm locations of key informants which were interviewed can be found in Figure 2-2. The key informant farmers were found in the agricultural regions of Malta. Very limited number of farmers from Gozo were interviewed.

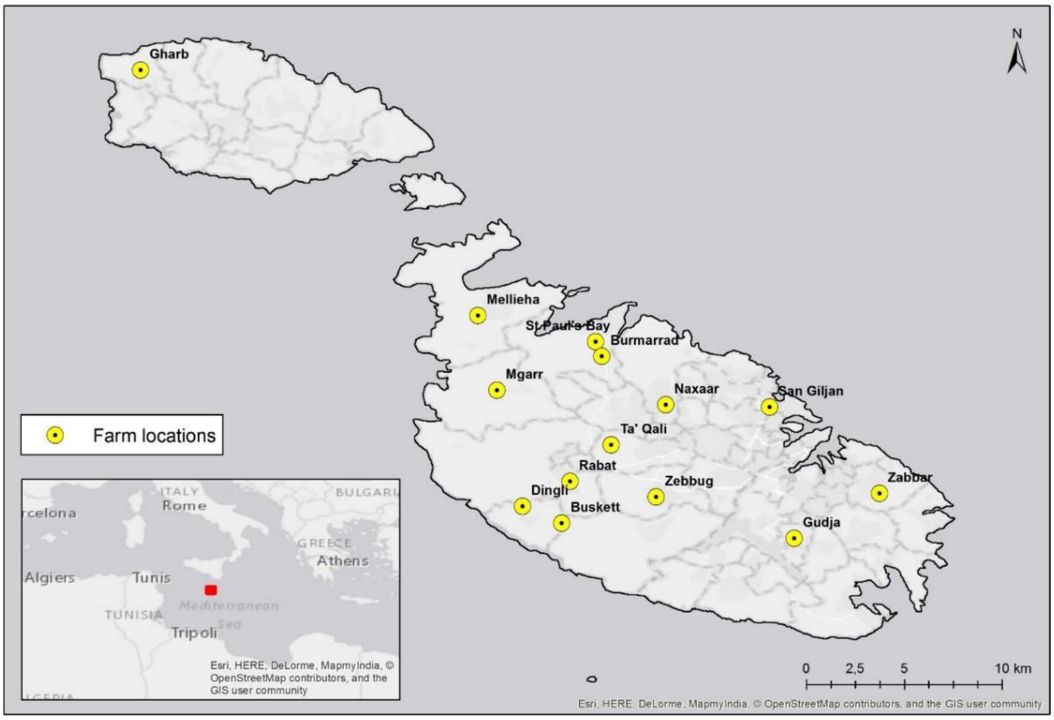

Figure 2-1 Key informant farm location distribution across the Maltese Archipelago.

2.2.3 General stakeholder questionnaire on agricultural water resources

The general stakeholder survey was divided into three main themes: water resources, technology and stakeholder engagement and collaboration. The interviewees who were invited to participate in the open stakeholder questionnaire can be found in Table 2-1. The interviews lasted approximately one hour and 30 minutes and usually held in the office of the informant.

Table 2-1 Summary of the key stakeholders invited to participate in the survey. General stakeholder questionnaire on agricultural water resources

Stakeholder	Description	Contact
Sustainable Energy and Water Conservation Unit (SEWCU)	Governmental agency responsible for designating and implementing national policies concerning use of water, energy and sustainable manners.	Michael Schembri, policy officer (Energy and Projects); Office of the Prime Minister
Malta College of Arts, Science and Technology (MCAST)	Undergraduate education and training institution.	Malcolm Borg, director of Institute of Applied Sciences – Centre for Agriculture, Aquatics and Animal husbandry FOWARIM project manager
Agricultural and Rural Payments Agency	Governmental agency responsible for the farmer's applications for the EU CAP subsidies	James Gauci, head office manager
Malta Water Association (MWA)	Non-governmental organization for better protection and conservation of Maltese water resources	Brian Restall, committee member, Dr Gordon Knox, co-founder and committee member
Qrendi Local Council	A rural village with a significant proportion of farmers.	David Schembri, mayor of Qrendi

2.3 Quantification of irrigation water demand of selected crops using modelling tool WaSim

The computer modelling tool WaSim uses a soil water balance for estimation of the daily soil water storage (Figure 2-3) (Hess and Counsel, 2000). Total annual irrigation requirements (mm) for potatoes for a growing season were determined using climate data from Luqa Metrological Office (35.85°N, 14.48°E, 91 m). Daily rainfall and reference evapotranspiration (ET_o) data for the 59-year period of 1956-2015 were examined to simulate the irrigation water needs for potatoes. Crop data and its irrigation area were adapted from NSO (2012). Soil texture determination was necessary for the modelling. Loamy sand texture was set as the prevailing throughout the island where potatoes are grown (FAO, 2006b; Farmer and stakeholder surveys, 2016; Lang, 1960). The timing of irrigation was set up to irrigate at fixed depletion of 30%[1] with the amount of the return to fixed deficit (mm). The detailed crop, climate, soil, irrigation schedule and model simulation schemes are shown in Appendix B. The model does not take into account contribution of the groundwater.

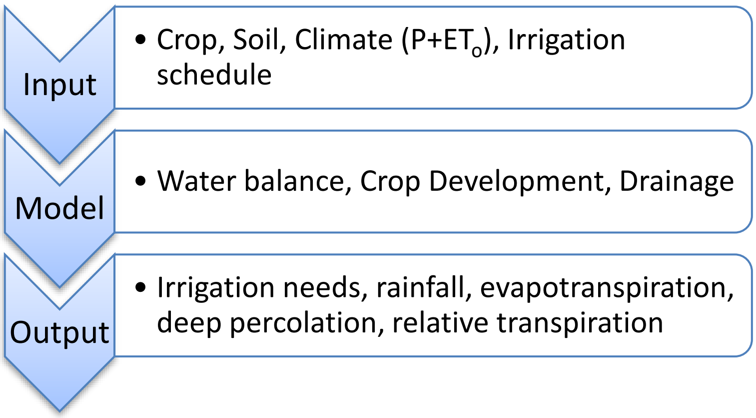

Figure 2-2 WaSim model processing scheme.

[1] 30% of available water was selected as an optimal depletion for not stressing the plant.

3 RESULTS AND DISCUSSION

3.1 An overview of agricultural water management and irrigation trends in Malta

Agricultural development of Malta is constrained by the geographical and natural characteristics of the country. The total agricultural area of the Archipelago was 12,940 ha, from which 88.5% (arable land 79.3%, permanent crops 10.9%, kitchen gardens 9.1%) accounted as utilised agricultural area (UAA) and 11.5% as other area in 2010 (NSO, 2012). The share of crops grown on arable land and permanent crops land are shown in Figure 3-1. In total, 12,529 holdings were recorded in 2010 and more than a half of these holdings utilised land smaller than 1 ha (NSO, 2012). Potatoes are the only agricultural product which is exported abroad, mainly to the Netherlands and Germany.

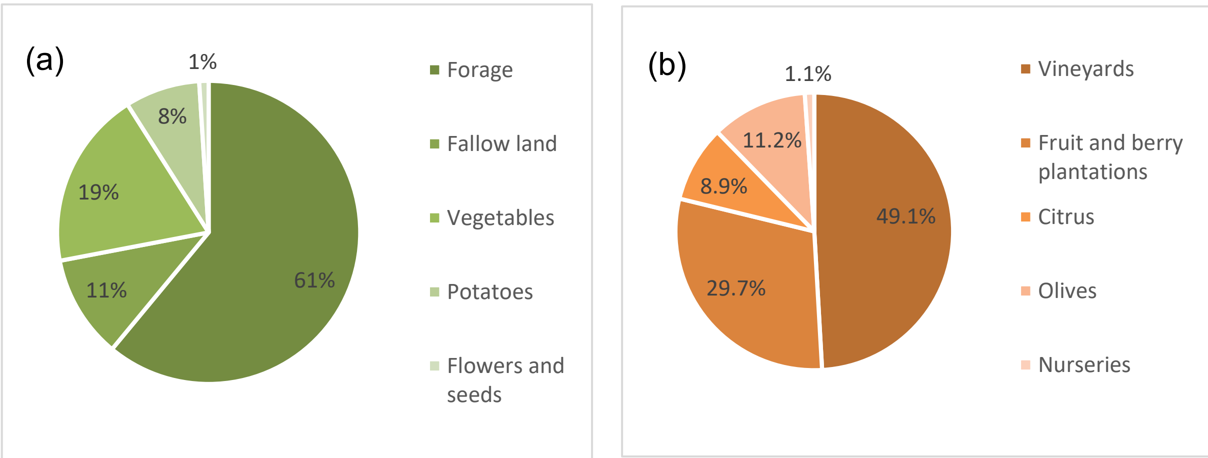

Figure 3-1 The share of the crops grown on arable land (a); the share of the crops grown as permanent crops (b).

3.1.1 Water resources in Malta

There are two main aquifers which are the only natural source of fresh water in Malta. The Main Sea-Level Aquifer is floating on the denser saline water at sea level in Coralline Limestone rock formation. Seawater intrusion to groundwater occurs when over-pumping the fresh water from this aquifer (Bakalowicz, Mangion, 2003). The Perched Aquifer consists of rainwater trapped in between the permeable Upper Coralline Limestone and the impermeable Blue Clay

(Attard, Azzopardi, 2005). The alternative sources of water are desalination plants. The first desalination plant was built in late 19th century and nowadays, there are four Reverse Osmosis (RO) desalination plants providing 57% of all potable water of the islands (NSO, 2012). In the near future Malta might become completely dependent on RO if the groundwater quality keeps deteriorating (Reitano, 2011). Another alternative source of water is second class water[2] which is used in agriculture, however the amount of this water is negligible.

3.1.2 Agriculture irrigation needs and future challenges in water resource management

There are significant restrictions in the productivity of Maltese agriculture due to the limited natural supply of water. The major agricultural issues nowadays are water scarcity, costs of the land, land fragmentation and high labour costs. Relatively low cost access to groundwater resulted in over abstractions which have led to degradation of the aquifers.

Agricultural contribution to national GDP stands at 1.9%, employs 1.7% of population (Trading Economics, 2016) and uses half of the fresh water supply of the islands. The aesthetical value of the Maltese countryside is strongly dependent on this sector but this and the contribution to the well-being of local people and tourists are currently unquantified.

The limited water resources give rise to significant restrictions on agricultural productivity. Effectively and efficiently managed water resources available for farmers are essential. With the increasing competitive market, irrigation becomes more important to increase the yields, product quality and farmer profit necessary to ensure food security and suitable economic return for farmers. Considering Malta's strategic location between Europe and Northern Africa, food security is essential and Maltese agriculture plays a very important role in the local food supply chain. There is also a higher demand for fresh good quality food with the development of tourism and an improvement in the quality of life in recent years.

[2] Re-utilized water from the waste water treatment plants.

There has been a significant increase (260%) in irrigated water use between the Census of Agriculture conducted in 1982 and that for 2001; in 2001 irrigated land was 14.9% out of all UAA (NSO, 2007). During the last Census of Agriculture in 2010, irrigated land accounted for 3,498 ha and increased to 36% of all UAA because of the increase of water availability and efficiency of water distribution due to the introduction of new technologies (Attard, Azzopardi, 2005). Irrigated land varies over the years depending on the weather conditions, some years are extremely dry and other are very wet. The most irrigated crops are vegetables (38.8%), potatoes (18%), private gardens (16.8%), vineyards (12.3%), fruit and berry plantations (6.5%) and others (Eurostat, 2012). The most common irrigation type is drip and sprinkler irrigation (Farmer and stakeholder surveys, 2016). The current estimate of the agricultural water usage was estimated to be 28 million m^3 as of the total usage was approximately 48 million m^3 in 2010 (NSO, 2012).

Irrigation water harvesting is an alternative source of water supply which can help to overcome rainwater shortages and droughts. Rainwater harvesting has been the only source of the water in the past and it has strong dependence on variable weather conditions limiting its reliability (Mangion, Sapiano, 2005). Rainwater is harvested into large above surface or underground reservoirs and used for supplementary irrigation.

Irrigation demand has its peak during the summer months when the rainfall is low. The summer crop is dependent on the available irrigation water (Attard et al., 2007). The value of production for total area of irrigated land is on average at least 3.5 times that from dry land farming (Attard, Azzopardi, 2005).

Irrigation practices and terracing in Malta were introduced by the Arabs during their reign over the islands in the 9th and 10th century and some of the words describing the nature of water are of Arabic origin and remain in Maltese language (Micallef et al., 2004). The Arabs also introduced the first water lifting devices for groundwater harvesting. The Knights of St. John designed the first public drainage system for the collection of sewage and introduced a law for the compulsory collection of rainwater (Sapiano et al., 2008). Increased population, the development of the islands and tourism industry during the 20th century resulted in the increase of water abstraction and the searching for other sources of water for irrigation and potable use.

Second class water from treated sewage effluent (TSE) was introduced in the 1970’s for irrigation purposes. The TSE can help to reduce gaps between water supply and water demand (Misra, Malhotra, 2011). The reuse of water for agricultural purposes has a great potential with large volumes of water which can be used. It is also a reliable and constant source of water which helps to reduce the amount of water extracted from the environment (Toze, 2006). There have been issues with the quality of the water in the past and nowadays. Some farmers are still very sceptical about the quality and final taste of their products watered by TSE. Second class water is only used by fields near the waste water treatment plants and this is due to a lack of infrastructure. During the low water season TSE is not needed and in the near future surface storage could be built to store such water (FAO, 2006). On the other hand, it is a constant source of water offering a reliable source for irrigation, especially during summer months when irrigation is at its peak (Mangion, Sapiano, 2005). By the end of 2016, total potential use of TSE will reach 7 million m^3 and should be available for irrigation purposes due to investments in further polishing of second class water and infrastructure to take this water to rural areas for use by farmers (Farmer and stakeholder surveys, 2016). The rest of the water is disposed into the sea.

3.2 Survey of farmers and stakeholders’ interviews

The main findings from farmer and stakeholders’ interviews were grouped into four main sections: trends in water management, technology, stakeholder engagement and collaboration and future water resource management under climate change. With regards to water issues, the different arguments were identified among all participatory stakeholders. The results from the farmers’ interviews are shown in Table 3-1 and discussed below.

3.2.1 Trends in water management

There is still a very traditional view on water resources in Malta, which is believed to be a private domain. Maltese farmers traditionally inherit their farming role after their parents and grandparents and they do not like any changes.

There was consensus on the water shortages among farmers, however in general they still think there are enough water resources. There are several sources of water in Malta. The most common sources of water used by farmers are boreholes, artesian wells, springs, private reservoirs, and rainwater harvesting. Usually, these sources are combined for providing water for irrigation purposes. In several cases, farmers do not collect water, which clearly shows that they are not aware of water shortages or interested in water savings due to financial or bureaucratic reasons. As the groundwater is free of charge, farmers are discouraged to collect rainwater and traditional ways of water savings are being forgotten.

There have been serious issues with water salinity and with high level of nutrients in groundwater. The whole country is designated as a Nitrate Vulnerable Zone (NVZ) under the EU Nitrates Directive which seeks to control and reduce the environmental damages.

Maltese farmers are not aware of how much water they use. Water for irrigation is used irregularly depending on crop type, irrigation practices, rainfall, soil moisture, wind conditions and the source and availability of water. From 27 farmers which were interviewed, only 4 of them tried to estimate their water usage. Due to the farmers' misunderstanding of the question a number of them answered by giving the number of minutes they irrigate a particular crop rather than the volume of water needed. This can lead to over-irrigation and higher evapotranspiration or underirrigation and low yields. Approximately 14 farmers would be willing to pay for water as an additional cost to energy bills and the cost of drilling their boreholes as they realise that water is precious. The rest of the farmers agreed they would rather stop farming as the water would make their farm's operation unaffordable.

3.2.2 Technology

Treated sewage effluent is a good alternative option for providing water for agriculture. However, there are lack of studies on TSE in Malta which limits decision making. 12 farmers reported that they would not use second class water as they are worried about the taste and quality of products irrigated with such water. The rest, 15 farmers, would be at least willing to try to irrigate with TSE if the water will be distributed for free. According to SEWCU, Malta recently innovated its water infrastructure, however there are still gaps mainly in distribution of TSE. It will be very challenging to convince and encourage farmers to use second class water in the future due to their bad past experiences where water quality was not suitable for irrigation purposes as well as the pricing of such water considering that groundwater abstraction is still free.

3.2.3 Stakeholder engagement and collaboration

In general, the public is largely unaware of the water crises in Malta and its dimensions (Roberts et al., 2015). There is a general disagreement between governmental and non-governmental organizations. The Malta Water Association (MWA) argued that the water resources are not well managed and there will be a possible collapse of the agricultural sector in the future due to water shortages. The solution outlined by the MWA is to have the agricultural sector use desalinated water only to allow the aquifers to naturally recover. Fresh water produced by RO would be very expensive as the energy costs are very high. The water charges do not reflect the actual cost of water and do not comply with the efficient use of water, which should be a priority for a water scarce country like Malta (Xerri et al., 2016). Additional source of energy such as solar energy for running RO could reduce water costs. Another alternative source of water should be considered in the case of oil spillage in the sea which could lead to interrupted supply of water. SEWCU argued that the water resources are well managed and lack of water can be substituted by second class water. On the other side there is a lack of infrastructure for distributing such water and the amount of second class water does not significantly contribute to the overall share of water used for irrigation.

The farmers’ perspective about the engagement in decision making was positive. The majority of farmers confirmed that they would like to cooperate with the engaged organizations for more effective policy making and would like to contribute to the public discussion.

3.2.4 Future water resource management under changing climate

Efficient management of water resources should be tackled at farm level up to regional and national levels (Faysse et al., 2012). All farmers who were interviewed are aware of the changing climate, however their beliefs varied about the extent of the changes being predicted. Most mentioned during the interviews were the shortages of rainfall during the winter in 2015. Farmers also confessed to applying more fertilizers and pesticides to increase their yields than in the past and that their crops are more often attacked by insects and suffered disease outbreaks. With the changing climate and extreme events, less water demanding and drought resilient crops should be encouraged for planting. Appropriate adaptation policies and active engagement with agricultural communities can help to integrate farmers into a climate adaptability policy development and to minimize their scepticism and luck of trust in effective policy making (Galdies et al., 2016). Malta also lacks any kind of agricultural services, which could help farmers with their cropping system, irrigation and climate change adaptability.

Table 3-1 The results of the farmer's interviews on water resources which were conducted during author's visit to Malta in June 2016

	FARMER 1	FARMER 2	FARMER 3	FARMER 4	FARMER 5	FARMER 6	FARMER 7	FARMER 8	FARMER 9	FARMER 10	FARMER 11	FARMER 12	FARMER 13
LOCATION	Naxxar	Ta'Qali	Mellieha, Mgaar	Zabbar	Gudja	San Gwann	Busket	Burnmarad	Gharab, Gozo	Zabbur	Dingli	Rabat	St. Paul's Bay
AREA (HA)	2.7	17	4	1	1	2	6	4	7	2	3.2	6	7
CROP TYPE	tomatoes potatoes fruit trees	grapes	potatoes tomatoes broccoli	potatoes onions lettuce	potatoes onions pumpkins	tomatoes potatoes cabbage	peaches onions melons	vegetables	tomatoes, potatoes, melons	onions potatoes	lettuce cabbage	cauliflower lettuce melons	lettuce tomatoes cabbage
IRRIGATION TYPE	drip	drip	drip, sprinkler	drip, sprinkler	drip	drip	drip	drip	drip	drip	drip, sprinkler	drip, sprinklers	drip
BOREHOLE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
ARTESIAN WELL			✓				✓			✓			✓
SPRING													✓
RESERVOIR													✓
RAINWATER HARVEST		✓			✓			✓		✓	✓	✓	✓
WATER CONSUMPTION M3/YEAR	x	x	x	20.000	x	x	x	x	x	x	x	x	x
WATER QUALITY	✓	✓	salinity	✓	✓	salinity	✓	salinity	✓	salinity	✓	✓	✓
WILLINGLESS TO PAY FOR WATER	✓	✓	✓	✓	✓	x	✓	✓	✓	✓	x	x	x
WILLINGNESS TO PARTICIPATE IN DECISION MAKING	x	✓	✓	x	✓	✓	✓	✓	x	✓	x	✓	x
INTERESTED IN USING ADVISORY SERVICES	✓	✓	✓	✓	✓	✓	✓	x	x	✓	x	✓	✓
WILLING TO USE TSE	✓	✓	✓	x	✓	✓	x	✓	x	x	x	✓	x

	FARMER 14	FARMER 15	FARMER 16	FARMER 17	FARMER 18	FARMER 19	FARMER 20	FARMER 21	FARMER 22	FARMER 23	FARMER 24	FARMER 25	FARMER 26	FARMER 27
LOCATION	Buskett	Zebbug	Zebbug	Zebbug	Dingli	Mellieha	Mgaar	Naxxar	Mellieha	Dingli	Mgaar	all around Malta	Zebbug	Rabat
AREA (HA)	3.2	1.5	1.2	3	3.5	7.2	2.3	3	7	4	6	15	3	4.5
CROP TYPE	peaches pears nectarines	tomatoes cucumbers courgettes	tomatoes potatoes cauliflower	Onions celery potatoes	cauliflower broccoli plums	spinach cabbage broccoli	lettuce strawberries	peppers cabbage lettuce	lettuce melons mint	melon tomatoes lettuce	celery beetroot cabbage	Veg fruits	onions tomatoes potatoes	Tomatoes Potatoes wheat
IRRIGATION TYPE	drip	drip	drip	drip, sprinklers	drip	sprinklers	drip	drip	drip, sprinklers	drip, sprinkler	drip, sprinklers	drip, sprinklers	drip	drip
BOREHOLE	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓
ARTESIAN WELL				✓			✓		✓		✓	✓		✓
SPRING					✓		✓							
RESERVOIR		✓	✓		✓									
RAINWATER HARVESTING	✓	✓	✓							✓			✓	
WATER CONSUMPTION M3/YEAR	x	x	x	x	17 000	x	3 million	x	30 000	x	x	x	x	x
WATER QUALITY	✓	✓	✓	✓	✓	✓	✓	salinity	✓	✓	salinity	✓	✓	✓
WILLING TO PAY FOR WATER	✓	✓	✓	x	x	x	x	x	x	x	x	x	✓	✓
WILLINGNESS TO PARTICIPATE IN DECISION MAKING	✓	✓	✓	✓	✓	✓	✓	✓	x	✓	x	✓	✓	✓
INTERESTED IN USING ADVISORY SERVICES	✓	x	x	✓	✓	✓	✓	✓	x	✓	x	x	✓	✓
WILLING TO USE TSE	✓	✓	x	✓	✓	✓	x	x	x	x	✓	✓	✓	✓

3.3 Modelling of irrigation water needs of potatoes and gaps in the agricultural water usage estimation among the Islands

3.3.1 Modelling irrigation demand

Potatoes were selected as a representative crop for WaSim modelling as it is the most commonly cultivated crop with the highest share of irrigation (18%) the Maltese Islands (NSO, 2012). Potatoes can be grown all year around and there are usually two growing seasons per year. The spring potatoes are usually planted in late October and mature in spring and the second growing season is from late August and mature in December/January. The growing seasons for crops are highly dependent on rainfall, evapotranspiration and temperature as shown in Figure 3-3. The highest temperature and evapotranspiration rates are during the summer months when irrigation demand peaks and the rainfall is at its minimum.

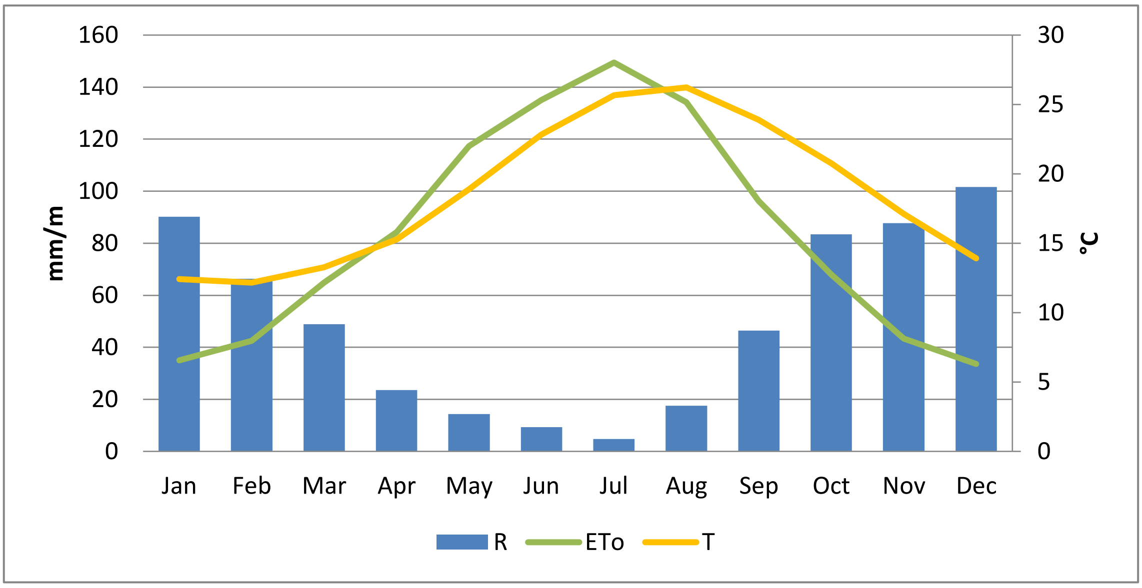

Figure 3-2 Analysis of the mean monthly averages of rainfall, evapotranspiration and temperature data 1956 – 2015 at Luqa Meteorological Office.

The irrigation needs for various growing seasons throughout a year were examined to understand when is the optimal time for growing potatoes with the least irrigation demand as shown in Figure 3-4. High variations were observed between the growing seasons. According to NSO (2012) the average irrigation demand of potatoes were 125 mm/year in 2010. Considering two growing seasons per year on the same field the irrigation water demand always exceeds 500 mm/year. The rotation of crops is strongly recommended, especially with the combination of lesser or no water demanding crops during the summer months.

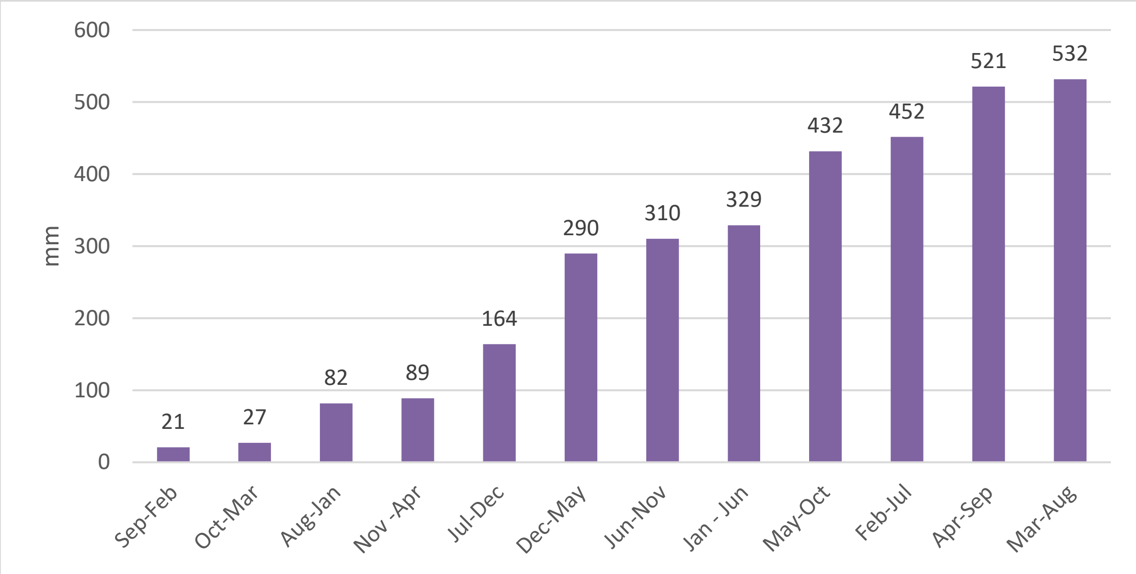

Figure 3-3 Mean averages of irrigation water needs (mm) per growing season (152 days) throughout a calendar year 1956-2015

3.3.2 Gaps in estimation of the water use in Malta

In total, there were 8,900 boreholes in Malta, from which 2,600 were metered by the water utility (Farmer and stakeholder surveys). Farmers pay for drilling a borehole and energy costs for pumping the water. No additional cost for water itself is charged. Many farmers have also invested in irrigation systems which led to inefficiency in the water use (Attard, Azzopardi, 2005). There has been a growing problem with illegal boreholes in the past years. Illegal boreholes are not registered by the water utility. There are no official estimates of the number of illegal boreholes in Malta. According to the stakeholders' survey the number of illegal boreholes which are in use is significant. The official statistics do not include illegal boreholes, domestic users of boreholes, industry borehole extraction, bottling plant borehole extraction and private RO (Roberts et al., 2015), which makes the estimates of the water use unreliable. According to the MWA the trade with water was recently observed, especially trade of the water from illegal boreholes and private RO. Malta lacks any kind of regulations for issuing new boreholes and should consider closing their boreholes for sustainable recharge of the groundwater aquifers. The “polluter pays“ concept should be also introduced.

3.4 Implications, limitations and future research

This research is very important for understanding the current water crises in Malta and its extent. This research will be also presented to the relevant authorities in Malta as evidence of the current situation. Similar research including farmers and stakeholder’s surveys is very sporadic in Malta. More research dedicated to the understanding of farming practices could help to better understand farmer attitudes towards the water issues, including farmer’s role in decision making and raise the awareness of the problem among farmers and the wider public.

The main limitation of this work was the understanding of the questions which farmers were asked during the interviews. Due to the language barrier and time limitation, the farmers were very brief and did not go into details. Only large scale farmers were interviewed as small scale farmers do not sell their products on the markets and the time constraints did not allow the author to visit small scale farmers. During the stakeholder survey, the questions were very broad and usually interviewees talked about one specific issue which they found most important.

There is much scientific evidence regarding the current water crises in Malta, however the research on the groundwater estimates, response of the aquifers to rainfall variation and pumping of the groundwater under a changing climate is missing. Establishing an efficient groundwater licensing system can track the volumes of water which is pumped from the aquifer and can give rise to better monitoring and enforcement to subsequently motivate farmers to go back to traditional ways of collecting water such as rainwater harvesting. Future research should also focus on farmer’s behaviour and attitudes towards water issues as such research does not exist in Malta. It is also important that farmers are encouraged to engage in negotiations between policy makers and invited to discuss new policy implications and to have their opinion considered. From the farmer’s interviews it has been made clear that farmers would be willing to cooperate. Malta needs an efficient plan on how to tackle its water issues very soon as its freshwaters are under serious threat of deterioration.

4 CONCLUSIONS

Malta lacks efficient water policies to protect its freshwater resources from over-abstraction and groundwater pollution. The current estimates of the water resources in Malta are strongly contested with wide variations. There are several existing users of water such as private reverse osmosis plants, bottling plants, industry borehole extraction and illegal boreholes which are not included in the national statistics. Maltese farmers are not aware of how much water they use and they do not fully realise the extent of the water shortages. Farmers irrigate on a time based schedules which is causing over irrigation of the land and higher evapotranspiration rates. Some farmers confessed they do not collect water at all for irrigation purposes as they believe they have sufficient water resources. Agricultural water resource management should be tackled at the farm level and farmers should be included in the water allocation and water management decision-making processes.

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APPENDICES

Appendix A Farmers and stakeholder questionnaire

Assessment of the environmental water resources impacts of agricultural development in Malta, MSc Thesis

Zuzana Vlacilova

General stakeholder questionnaire on agricultural water resources

Date:

Stakeholder: Farmer, Malta Water Association, Malta College of Arts, Science and Technology (MCAST), Water Services Corporation (WSC), Sustainable Energy and Water Conservation Unit (SEWCU), Ministry for Sustainable Development, Environment and Climate (MSDEC)

***This questionnaire is anonymous. Obtained information are confidential and will be used for scientific purpose only.**

Water Resources

1. Do you think that water is unlimited resource in Maltese Islands? What is being done to protect water?

2. Do you think that water in irrigated agricultural crops sector is well managed? If no, please specify what the issue is and what can be done to solve this issue.

3. What is the biggest challenge in water resources of irrigated agricultural crops sector?

4. What is the biggest threat in irrigated agricultural crops water resources? What can be done to minimise the impacts of this threat?

5. Policy maker: How does the cooperation between Ministries work while creating/updating agricultural and water policies?

Technology

6. Do you think that water infrastructure is adequate? If not, what would you change and how would you change it? What else can be done to improve water infrastructure?

7. Do you think that sewage treatment effluent can be used for irrigation proposes?

If yes

Farmer: Would you be willing to use such water? If not why? What do you think about this idea?

Policy maker: What policy and water quality standards should be applied to protect human health? What infrastructure should be built to facilitate STE and its storage?

Stakeholder engagement and collaboration

8. Do you think that farmer's groups and associations would help to share farmer's experience, knowledge and would lead to more sufficient agricultural cooperation? Would you participate in such association? How would you participate?

9. Is there any public discussion/cooperation between farmers and government about farmer's needs for water resources and agricultural issues?

10. What are your views on farmer's collaboration? What are the barriers and which tools enable better collaboration for farmers?

Survey of farmers' perception on agricultural water consumption

***This questionnaire is anonymous. Obtained information are confidential and will be used for scientific purpose only.**

Farmer's introduction to his farm, key issues:

FARM DESCRIPTION	
Date	
Location	
Area of the farm (ha)	
Cropped area (ha)	
Total irrigated area (ha)	
Total water consumption (m3)	
Dominant soil type	

<u>Current Water Resource Management</u>

1. Do you think that water for irrigation purposes is easily accessible and its price is sufficient? Is water cheap/expensive? Would you be willing to pay more?

2. Do you think that water quality and quantity of irrigated water is sufficient? What can be done to improve it?

3. Do you have enough information about water and agricultural policies? Would you participate in discussion with government about creating new policies which directly influence you as a farm? How would you participate?

<u>Future Water Resource Management</u>

4. Would you be willing to change your agricultural practices for more efficient water usage/more efficient irrigation techniques to save water?

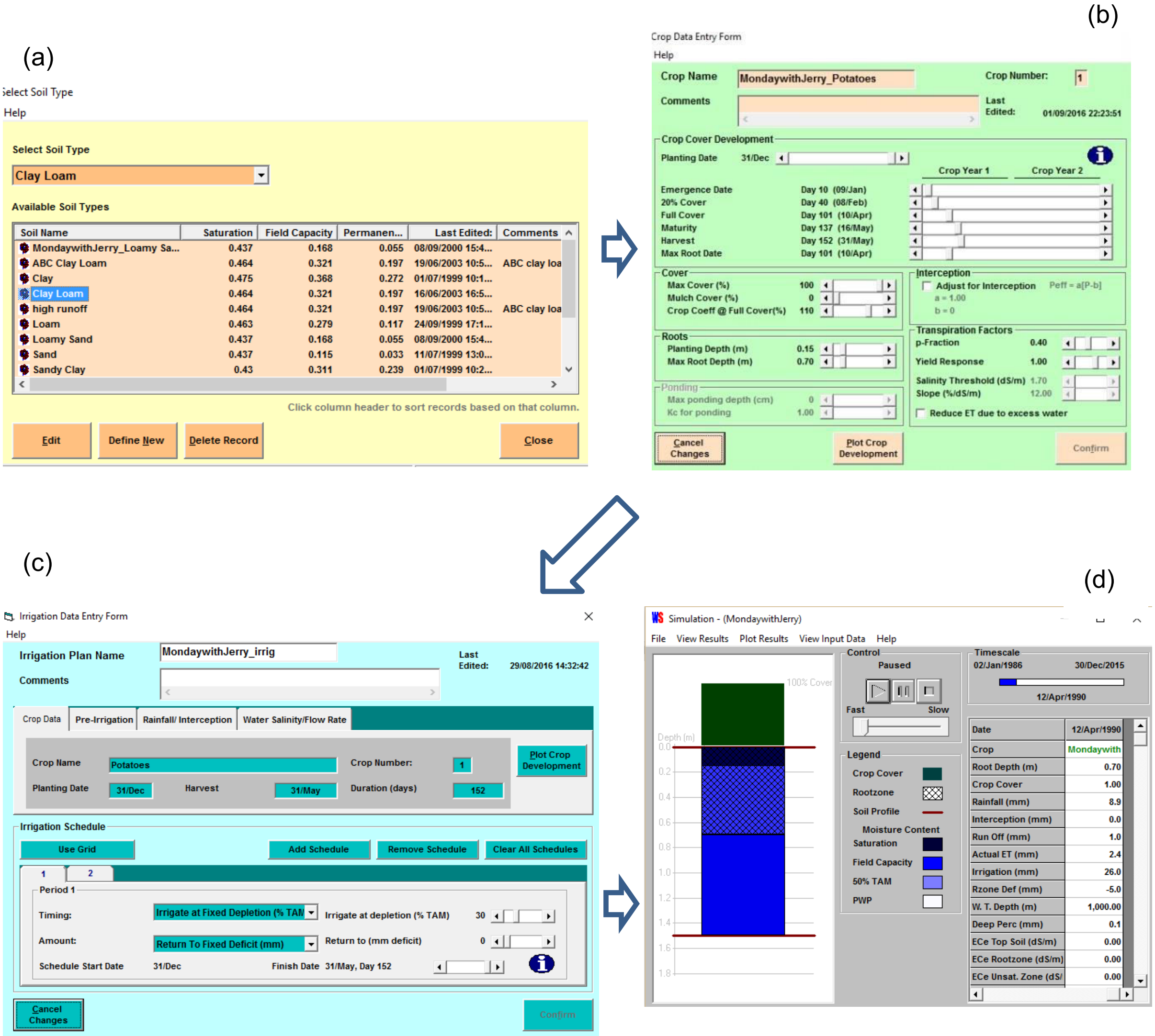
5. Would you be willing to plant less water demand crops if you would be aware how much water you could save?

6. Would you use agricultural advisory services if it would be for free? Who should be the advisor: independent farm organization/Ministry/NGO/other – specify?

7. Do you believe that climate change will influence your farming practices in the future? If yes, how and what can you do to minimise its impacts?

<table>
<tr><th>Crop type</th><th>Irrigated area (ha)</th><th>Total water consumption (m3)</th></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="3">IRRIGATION DESCRIPTION</td></tr>
<tr><td>Irrigation water sources</td><td colspan="2">% of total volume</td></tr>
<tr><td>1. Borehole (direct)</td><td colspan="2"></td></tr>
<tr><td>2. Mains water (direct)</td><td colspan="2"></td></tr>
<tr><td>3. Winter storage of water</td><td colspan="2"></td></tr>
<tr><td>4. Other</td><td colspan="2"></td></tr>
<tr><td>TOTAL</td><td colspan="2"></td></tr>
<tr><td>TOTAL depth of irrigation applied(mm)</td><td colspan="2"></td></tr>
<tr><td>TOTAL volume of irrigation applied (m3)</td><td colspan="2"></td></tr>
<tr><td colspan="3">NOTES</td></tr>
<tr><td colspan="3"></td></tr>
</table>

Appendix B WaSim modelling set up



Apx-Figure 1 The WaSim set up modelling for selection of soil texture (a), crop requirements (b), irrigation schedule (c) and model simulation (d)