Irrigation management in conventional and organic potato production – A case study on the East Anglia region UK, working towards a sustainable future

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Abstract

The production of the potato crop in the UK is one of the most irrigated crops. This leads to serious pressure on water resources during the summer months, when water is the least available. The East Anglia region is the driest region and it is the main area of growing the organic and conventional potato. As irrigation is essential for most farmers in this region, the problem is difficult and irrigation management is becoming increasingly important. The UK national government are at present demonstrating a stronger emphasises on sustainable development; although their action in terms of reaching this goal has been weak so far and the problems of water availability continue.

The objectives of this thesis will investigate and compare the organic and conventional irrigation management of the potato crop in the UK East Anglia region. As the two agricultural practices tend to manage irrigation differently the results will illustrate if there are any significant waster use disparities, which is the overall aim of this paper. Moreover, it will discuss further adaptation of irrigation efficiency together with a discussion of its feasibility. To examine these questions, there is an initial literature review, which is based on qualitative information originating from scientific journals, governmental documents, international websites, and includes information gathered from farmers in East Anglia. The interviews on the organic and conventional farmers were based upon semi-opened interviews, starting with general questions and leading into more specific question of which all farmers received. The interviews suggest that there is a difference between organic and conventional farmers use of irrigation. This difference of use in water can play a vital role to attempt a sustainable use of natural resources, which is currently being used on an unsustainable level. The study further suggests additional policy steering tools which are a key factor in the process of changing farmers' traditions and behaviour within irrigation.

Keywords: United Kingdom: Agriculture; organic, conventional farming; irrigation management, the potato crop

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List of Acronyms

BPC – British Potato Council
CAMS – Catchment Abstraction Management System
CAP - Common Agricultural Policy
Defra – Department of Food and Rural Affairs
EA – Environment Agency
EEA - European Environment Agency
EU - European Union
IFOAM - The International Federation of Organic Agriculture Movements
LEAF – Linking Environment and Farming
NEFG - The Nafferton Ecological Farming Group
UK – United Kingdom
SA - Soil Association
WFD – The EU Water Framework Directives

1.0 Introduction

Climate change has swiftly become a reality for the United Kingdom (UK) with increasing flooding and droughts (Kundzewicz et. al 2007:175). With summers becoming warmer, the demand for water is slowly increasing affecting the agricultural potato production as they are in great need of water for irrigational purposes. Potatoes are the most irrigated crop in England and they are mainly grown in the driest area, the East Anglia region (See Figure 1) (Stalham and Allen 2001:251). In contrast to the 1961 to 1990 baseline, by 2050 early and main-crop potato are expected to require about 20%-30% more irrigation respectively. Therefore, the potato production in this area are in need of further implementations of advanced water sustainability as the negative impacts of water abstraction of natural resources are becoming increasingly evident. (Knox et. al 1996:2). Some implementations have already been carried out through efficient land and water management but more needs to be done through both agricultural practices.

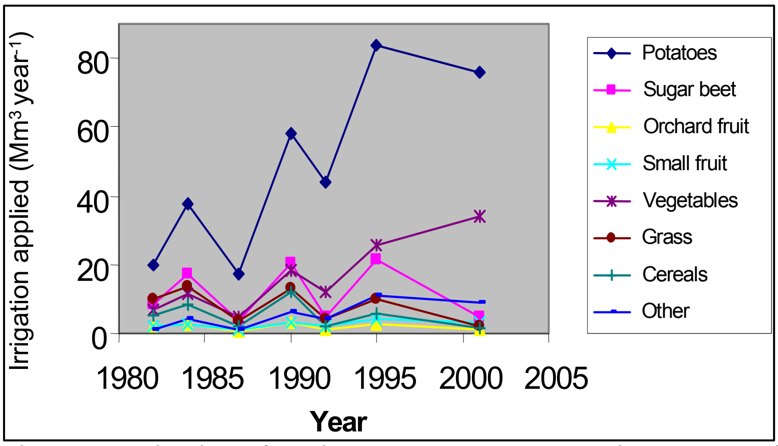


Figure 1 - Irrigation of outdoor crops UK. Source: Thompson et al. (2005)

1.1 Aims and Objectives

The main goal of this paper is to analyse conventional and organic potato production in the East Anglia region to explore if there are any differences in water use which then could be implemented to improve the current water use in the area. The reason for examining the differences in the water use of organic and conventional potato crop growing is to further research the specific aspects of what separates the practices, and use those differences to apply to all other farmers. Knowing those different irrigation management tools will shed light upon what farmers' values, habits, as well as traditions are. With that understanding this paper will then know how to possibly alter this into a more sustainable use of water through various techniques which is the main aim of this paper.

The objectives of this paper are:

- To identify existing irrigation practices used by conventional and organic farmers in East Anglia.
- To compare organic and conventional farming of potato (*Solanum tuberosum*) irrigation practice to then evaluate the irrigation inputs and jointly investigate the relationship of their water management practices.

- To further suggest policy and non-policy recommendations to key UK stakeholders and evaluate its implementation feasibility, towards increased water sustainability in the area.

The paper will address the differences organic and conventional irrigation practices including the policy variations as this may contribute to change. Data from secondary sources will be used for the production of the desktop section, using literature from scientific literature, which briefly describe the potato with and introduction of the East Anglia region. A brief description of the diversity between both agricultural practices which includes comments and information based up in the interviews from farmers. The irrigation management equipment including its tools and instruments will be explained on the East Anglia habits from information by the interviews, including its policy requests. A single case study is made with empirical data gathered from organic and conventional potato farms in the East Anglia region in regards of their irrigation management to discover the main hypothesis of this paper.

1.3 Definition of Sustainability

To be able to follow what is meant by sustainability in terms of this paper and its chosen topic a definition is what follows. The universal and most commonly known definition made on Sustainable Development was made by the World Commission on Environment and Development in 1987:

"Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"

Sustainable agriculture development requires aspects that include the natural environment, the global or national economy and social human needs together. To narrow the understanding of sustainable development and to be of relevance of this paper, the European Environmental Agency (EEA) (2008) has defined sustainable agriculture as:

"Sustainable agriculture entails the management of natural resources in a way, which ensures that the benefits are also available in the future. A broader understanding of sustainability extends to the protection of landscapes, habitats, and biodiversity, and to overall objectives such as the quality of drinking water and air."

There are confusions in relation to sustainable agriculture and organic agriculture and some might argue that there are none. However, the EEA has defined both practices and the definition for organic agriculture is:

"A method of production, which puts the highest emphasis on environmental protection and, with regard to livestock production, animal welfare considerations. It avoids or largely reduces the use of synthetic chemical inputs such as fertilisers, pesticides, additives and medical products."

Sustainable agriculture does not emphasise environmental protection as deeply as organic agriculture, including stating potential harmful chemicals to activate reduction measures or increased animal welfare. As environmental sustainable measures within the EU are yet still optional to some extent, conventional farming guides another agricultural dimension, and the EEA (2008) definition is:

"Farming characterised by high input use that strives for maximum production, often at the expense of environmental considerations."

Conventional farming tends to mainly focus on the economical benefits disregarding environmental safety. The contradictions of the agricultural practices have lead to difficulties in their management complicating environmental sustainability to stronger implemented through policy and legislation. To tie these definitions into the topic of this paper and make it important, a definition made by the author is:

The optimal definition for the usage of water in potato production should contain:

- Optimal use of water that does not jeopardise current or future agricultural production
- The optimal use of water increases the availability of water for future generations
- Optimal use of water increases availability of water for the whole ecosystem to further develop sustainability

2.0 Methodology and Materials

The methodology of this paper has been divided in to two parts. The initial section of this paper is a background literature review and is to provide necessary information for a reader to grasp the scope of the topic. The materials were achieved through natural and social scientific resources to illustrate relevant existing information and information provided through interviews of farmers in the East Anglia. The literature review will begin with a short explanation of what the potato production in the country. Subsequently, following an introduction to the area of the study, East Anglia. An explanation of the differences of organic and conventional will be provided to grasp of what farmers in East Anglia are doing differently. The desired result of new irrigation technology of equipment or aiding instrument are essentially to reduce water pressure on their natural resources. In addition of this paper, the current technological tools mainly used by British farmers will be briefed in the literature review including the interview information. The literature review also briefly includes the applicable national conventional and organic irrigation policies to further explore the possible hinder or benefits leading to a local farmers water use. This will mainly be explained through tables to see the true desire to improve sustainable development of irrigation management. The second part of the paper, a case study is presented on the focus of the UK East Anglia region, comparing its organic and conventional potato irrigation use. The comparison can be of a normative foundation, so it aims to explain the conditions and propose further improvements of its future developments (Yin, 1984:132).

The comparison is also of an analytical nature, meaning it is also to illustrate the results found of its practical differences and how those differences then may be able to provide further solutions.

The case study will further the debate of potato agriculture sustainability in terms of irrigation management, recognising its serious need of water use reduction in East Anglia. This paper will advocate of what agricultural tools or practice for the potato crop might be better in terms of sustainability for the East Anglia region. As the present water conditions for British agricultural needs are becoming a critical topic of discussion as weather patterns are becoming increasingly unpredictable leading to political, economical uncertainties, and social worries, possible solutions are now a pressing matter. From this, it was determined that a multi-disciplinary approach of my irrigation management review was necessary to understand all components of the selected problem of this paper. The East Anglia is predominantly well-known for its flat terrains with nutritional soils, but suffers from sudden weather changes which have affected seasonal water availability providing agriculture with irrigation resource uncertainties. East Anglia is the region where organic and conventional potato crops are mainly cultivated even though its immense water requirements for ultimate yield leading to serious pressure on water resources (Knox and Weatherhead, 2005:139). These concerns were the main reasons of choosing this location for this study. The secondary data was mainly collected through scientific literature from journals and books as well as governmental accessed from the Internet. In order to empirically assess the conditions of potato farming in a region of high agricultural production, 14 telephone interviews were carried out in the Cambridgeshire County in the East Anglia region. The reasons of choosing telephone interviews as the method was the costs of travelling in the UK would have been too great. Furthermore, it also provided anonymity for me and the farmer. Another reason of not arranging personal meetings was that many farmers were not able to see me in person because lack of time and therefore suggested to do the interview through the phone. Telephone interviewing naturally has its disadvantages of not receiving the personal connection of one another and therefore the interpretation of information can be tentative (Bryman, 2002:129). Seven farmers were organic, officially certified by the Soil Association (SA) and seven were conventional farmers who were registered in the British Potato Councils registry. It was there where I received their personal information. Each interview lasted for about 30 minutes, depending on the interviewee and they were all asked the same questions. The interviews were conducted in the SA office between 20th February to 1st April. Before every interview, I explained the purpose of my questions and the general synopsis of my paper; this made them more relaxed on the phone and more willing to answer most of my questions. I also asked if they wished to be anonymous, and most of them felt in terms of the paper they wished to remain anonymous, so all names will be confidential. I was not able to record my conversations with them although I took short notes as precisely as possible for their given answers at the time of the phone call (Bryman, 2002:133). As a result, I was able to write down my interviews immediately after the call to be sure of have gathered all the information of the interview. In my text I will refer to my interviewees by numbers, 1 to 14, instead by name as it will be easier to follow.

2.2 Limitations and Assumptions

There were some limitations to my chosen methodology; one major limitation was the amount of interviews obtained. The wish was to have interviewed more farmers though because the lack of time and several farmers were not able to give an interview; this unfortunately affected the amount of farmers interviewed. Furthermore, some questions made during the interviews could not be answered properly or correctly or as most of the farmers did not have the answers which lead to a few question not being implemented into the results. Additionally, there was a lack of interest of the Environment Agency to be interviewed personally on the matter of their irrigation guidelines and CAMS (Catchment Abstraction Management System) regulations. There are water use and management within potato farming washing the crop which is not included as part of the water use I will be investigated.

3.0 The Potato Crop (Solanum Tuberosum)

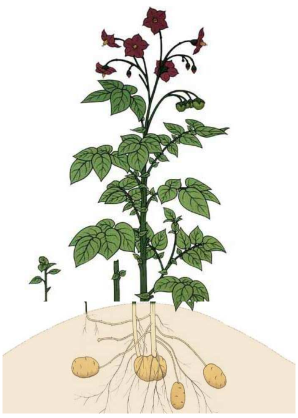
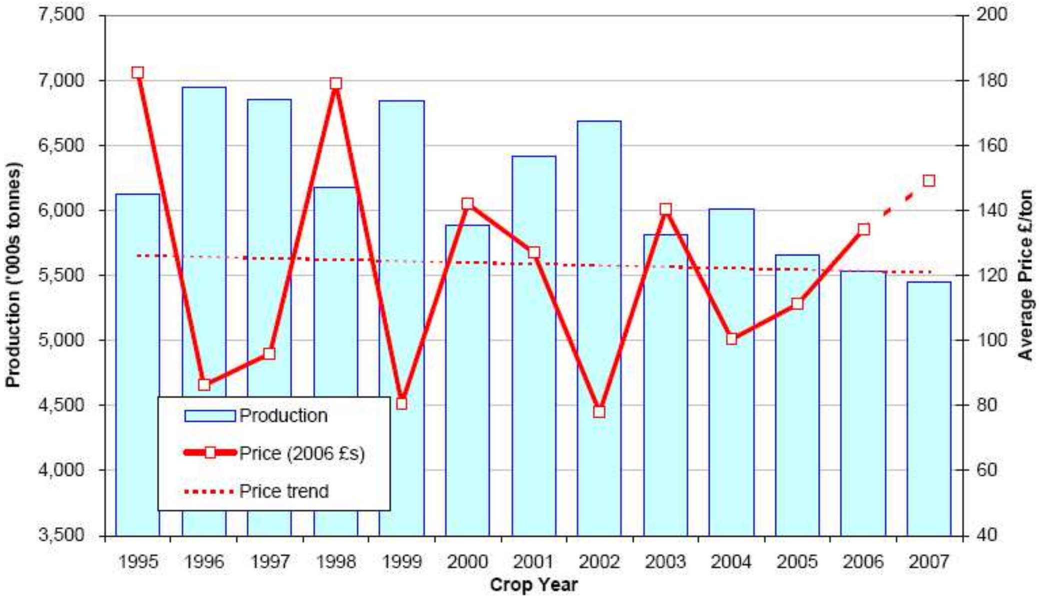


Figure 2 – The Potato (*Solanum tuberosum*)
Source: Potato 2008

The potato belongs to one main species, the *Solanum tuberosum*, (See Figure 2) (Hawkes, 1992:13). The potato crop is a tube-bearing herbaceous plant, which means that the roots of the plant are an addition of the plants stem (See Figure 2) (Hawkes 1992:45). The tuber contains almost 80% of water which makes its need for water quite extensive (Hawkes 1992:45). The soil must maintain as moist as possible to not become too dehydrated as this can affect the growth of the crop, especially in the initial growth stage. Assumptions that have been made that wetter soil are better for potato roots growth (Gregory and Simmonds, 1992:224). This is one reason why timing of irrigation is important. The leaves of the potato plant are also of a special necessitating, as the canopy assists the soil to maintain it's moist. Mackerron and Waister (1985) provided a simple model of potato growth and its yield suggesting that the potato leaf will catch radiation by 95-98% and functions as a sunshield to maintain moist in the soil. Without any fertilisation the leaves will be smaller and as a result only catch approximately 79-85% radiation which is a number more relevant in terms of organic production (Gregory and Simmonds, 1992:220). Although, today most farms cut the potato stems for pests and other disease reasons. By cutting the leaves the soils becomes drier means the plant will require additional water to be placed through irrigation. The alternative between pests or additional water utilised is a straightforward decision for a farm who wishes not to loose its yield.

Yields per hectare have been growing steadily since the 1960's and England is nationally producing about 47 tonnes/ha with the main crop (British Potato Council, 2006:3). The UK population consumes the crop in different manners, either fresh or processed. Even though the general consumption of the crop has decreased, the trend of processed potatoes instead of fresh potatoes has increased (British Potato Council, 2006:5). The average total potato production is around six billion tonnes, so if it exceeds this amount prices are also lowered. In East Anglia there are organic and conventional potatoes grown with marginal crop yield differences, conventional with 42 tonnes/ha and organic with about 31 tonnes/ha. All, but two organic farmers agreed through the interviews that irrigation is not the major component to their total crop yield, as it mainly concerns the soil nutrients not being adequate. Interviewee 8, his organic yield is about nine tonnes less than his conventional potatoes. Approximately the same amount as all the interviewed conventional farmers. The average price trend has decreased slightly which could depend on increased imports of the crop. The price of potato has fluctuated over the last few years, mainly due to when production increases so does the price (see Figure 3). There are three main potatoes grown, the main crop, first earlies, and second earlies (Hawkes 1992:45). The different potato types require different irrigation levels as they stay in soil for different durations (Williams et. al, 2006:34). According to the interviews made in East Anglia, the majority of both organic and conventional farmers were actually growing mainly earlies and mains as it is more profitable and it's a high demand for all kinds.

Figure 3 – Production and price of potato 1995-2007



Source: British Potato Council, 2007

4.2 An East Anglia focus

Figure 5 – Map of England – East Anglia marked.
Source: Anglia Water, 2007

East Anglia is one of the eight regions in England, excluding Wales and Scotland (See Figure 5). Anglia is mainly referred to the agricultural region as it contains most productive agricultural land, including cultivating the potato crop (Gowing, Ejieji, 2001:138). The region contains more than 1000 agri-businesses relying on the supply of water (UK Irrigation Association, A fair share of water for agriculture, 2008). It is also referred to one of the direst regions of England and Wales with less than 600mm total annual cover of rainfall. Some of this rain will be taken up by living thing or through evaporation leading to less water being able to be used for irrigation (Environment Agency pg: 12). Thirty percent of all potatoes produced in the East Anglia using most of the irrigation in the whole region leading to abstraction difficulties. The increase in demand for irrigation water within the agricultural sector of 3% annually also leads to serious water demand issues (Environment Agency pg: 12). The highest demands of ground water in England are usually concentrated around the East Anglia and Midland region and lasts for about 12 weeks in the summer time when availability is the least (Gowing, Ejieji, 2001:138). In Figure 6, East Anglia's groundwater availability in the summer is illustrated, red being unsustainable or unacceptable water abstraction regime and yellow, not water available. As noted it is large areas of which these water difficulties occur and therefore should be used with caution. Although, the potato production in the region has become a major contributor to water stress leading to complications of water management.

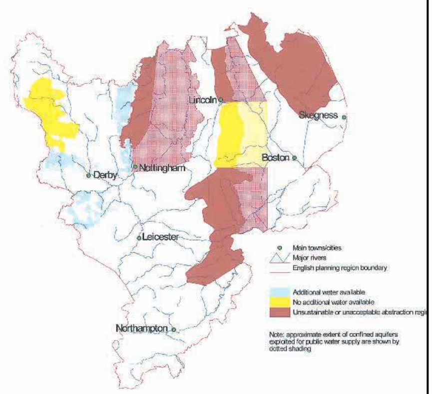


Figure 6- Current availability of groundwater, East Anglia
Source: Environment Agency

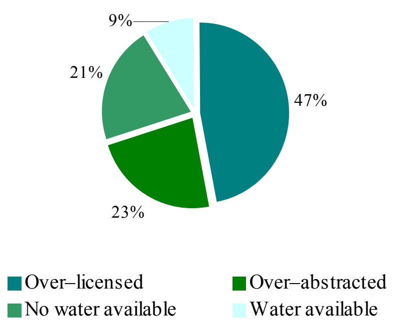


Figure 7 – Proportion of the total licensed volume for irrigation in the East Anglia 2006. Source: Environment Agency, 2001

Figure 7 is presented by the Environment Agency, showing almost 50% of the region is over-abstracting its water supply. 20% of some water sources are not even available because of droughts or over use. Even though East Anglia has 50% over-abstracted, there are no water bans. In terms of less use of environmental resources, the EA seems to not yet have a strong enough incentive to advance their environmental sustainability targets but focuses instead on the fair share of water allocation between stakeholders. This demonstrates a tension between social and environmental sustainability.

4.0 Organic and Conventional Agricultural Diversity

Organic agriculture is defined as including the 'whole system' approach to farming and food production (Soil Association Organic Standards, 2008:1.2). Conventional farming is a broad term and lacks real definition on what it really required of a farmer compared with organic farming. When CAP (Common Agricultural Policy) officially came into force in 1962, it did not only change the appearance of the European landscape through agricultural intensification schemes to maximise profits and minimise costs (Soucère et. al, 2003:6), but it also created a consistent farming practice (Verhulst et. al 2004:471). However, it is important to note that it is not only the CAP that has influenced the methods of conventional farming. Over the last 50 years technology has grown immensely, and with these technological changes traditional cultivation methods are further questioned or perhaps even forgotten. Over time, the European public acknowledges the result of increased availability of farmed goods through popular price cuts of products since CAP began, yet unaware of its negative environmental impacts and the farming methods continues. As seen in Table 1 organic farming is explicitly defined with strict principles. But because conventional farming is difficult to define let alone generalise, Table 2 only explains the very basic idea of British conventional farming which has not been developed only through their personal traditions and cultures, but mainly through CAP.

Table 1 – Organic Farming Principles

Organic Agricultural Principles	**Conventional Agricultural Principles**
1. To produce food of high quality in sufficient quantity. 2. To work within natural systems and cycles throughout all levels from the soil to plants and animals. 3. To maintain the long term fertility and biological activity of soils. 4. To treat livestock ethically, meeting their physiological and behavioural needs. 5. To respect regional, environmental, climatic and geographic differences and (appropriate) practices that has evolved in response to them.	1. To fulfill its multifunctional role in society: producing safe and healthy food, contributing to sustainable development of rural areas, animal and welfare standards and protecting and enhancing the status of the farmed environment and its biodiversity. 2. To establish common rules for the approval of genetically-modified organisms (GMOs) in agriculture.

(Source: SA Organic Standards:1)

Table 2 – General Environmental principles of conventional and organic farming	
Organic Environmental Principles	**Conventional Environmental Principles**
1. To foster biodiversity and protect sensitive habitats and landscape features. 2. To maximise use of renewable resources and recycling. 3. To minimise pollution and waste.	1. Agri- environmental measures: Offering financial assistance to encourage change by; reducing the numbers of animals per ha/land, leaving field boundaries uncultivated, creating ponds/wetlands, or by tree or hedge planting i.e. nature conservation. 2. Insisting that farmers must respect environmental laws, if they wish to qualify for direct income payments

(Source: CAP Booklet)

Table 1 illustrates the differences between the agricultural principles of conventional and organic farming defined by SA and EU CAP. The stronger or weaker emphasis on the carefully selected wording usually can be interpreted as a specification of farmers' traditions that the practice aims to pursue which is therefore the comparison is being made. The initial point stipulated by SA states 'produce high quality in sufficient quantity' whilst conventional needs to refer to 'food safety and healthy food'. Generalised wording of the two phrases could lead to general implementation. The second quote of organic principles 'work within natural systems and cycles throughout all levels from the soil to plants and animals' compared to the 'protecting and enhancing the status of the farmed environment and its biodiversity' shows that the vague conventional terminology can lead to a lack of environmental interest of including a whole ecosystem (not only farmed environments and animals). Unlike the organic principle that mentions the importance of all levels of a cycle including all its animal and environmental life. Animal rights and their welfare is also being mentioned by both, although the organic agricultural specifies their wording further by emphasizing the importance of the ethical, physiological and behavioural needs.

GMO (Gene Manipulated Organisms) are increasing in growth in Europe within conventional farming but is so far not allowed to be produced as human food nevertheless is positive towards it progress. The principle for it to be allowed is made clear in table 2 as the organic values are strongly against GMO though does not speak of it in their principles.

'Respect regional, environmental, climatic and geographic differences and (appropriate) practices that has evolved in response to them' is an interesting organic principle connecting it to potato production. As organic farmers in East Anglia, according to this quote, should consider regional climatic geographic differences and apply appropriate practices, potatoes should not necessarily be included as they are the most water demanding crop in the driest region of the country.

In Table 2, the comparison of the environmental principles suggested by the two practices is made. The principles are more relevant to irrigation management and can be further more connected to its sustainability. What could be initially mentioned is that is the organic environmental principle of fostering biodiversity including its sensitive habitats and landscape features. In terms of relating that to water, they should therefore maintain and protect the groundwater aquifers and lakes which is considered biodiversity, habitats and landscapes. In terms of conventional environmental principles, farmers mainly need to follow agri-environmental measures which basically are economic incentives as an influence to achieve any environmental goal including the maintenance of biodiversity etc. Maximising the use of renewable and recycling for irrigational purposes, building rain- and water storages. Again, conventional farmers have no incentive to concern themselves with this unless they achieve financial benefits. Minimise pollution and waste through surface runoff, waste water by not optimising most efficient hours and time of day resulting in most efficient use of water.

National government as well as the EU needs to take action and provide stricter goals. From there, traditions which many farmers still uphold will eventually break and the agricultural sector will advance towards a more sustainable future, which is typically suggested in numerous legislation documents. Incremental together with reward-based programmes will encourage and place pressure for farmers to progress. The UK has approximately 3.5% of the UK's total agricultural land certified as organic in 2006 and is expected to continue its growth (SA Organic Market report 2007:7) and the rest of it is grown conventionally.

5.0 Potato Irrigation Management

Weatherhead et al. (1997) concluded in a study that the main potato crop increases its tubers by 25% in yield production with irrigation. Crop water demand is influenced by factors like groundwater, temperature, radiation wind and humidity (Stalham et al., 1999:8). These factors naturally indicate of the average conditions of the soil and its water content and therefore efficient irrigation methods can be placed. Though as the conflict between desired tuber size outcome and the terms of the environment irrigation is still a required tool to use if growing potato. As irrigation machines as well as personal scheduling and monitoring are becoming more efficient and resourceful for farmers to use, the intension of using it might not be as efficient.

5.1 Irrigation equipment

The majority of irrigation equipment used throughout the UK is the boom and gun with a hose (Weatherhead, 2005:13). The downside of the instrument is the high evaporation losses and one of the lowest application rates, resulting in higher application quantities (Thompson et. al. 2007:15). Other equipment like trickle irrigation, water sprinkles and spray lines are also used but not as much as the hose. In East Anglia the case is not very different according to the interviews made on organic and conventional farms. They both use and boom or gun on their lands and considers this to currently be the best tool on the market in terms of labour and cost efficiency. None of the interviewed Anglia farmers were using trickle irrigation even though it is the region of most trickle equipment (Knox and Weatherhead, 2005: 141). In terms of potato crop cultivation, the drip irrigation system is considered to be the most accurate tool looking to reach total yield but most importantly, its efficient water use (Patel and Rajput, 2007:210). Though, there are merely about 5% overall that owns this type of equipment in England and the number has remained constant over the last decade but a decline has been noticed (Weatherhead, 2005:13). Though in Knox and Weatherhead (2005) it is reported the instrument are not declining but in fact increasing. An organic farmer owned a trickle irrigation system as he felt the desire to try additional water saving equipment, but realised its labour and expense intensities and therefore unwilling to use it further. However he did take note that whilst using it, there were substantial reductions of water being used compared to his previous system. Only one grower in total of the interviews was a non-irrigator (Interviewee 8). He’s personal beliefs are that irrigation is a bad technique in terms of environmental sustainability and should not be allowed. Instead he uses tile drainage with a main function of increasing the underground water table which provides water directly to the potato root-zone. After the crop has consumed enough water the tiles are reduced and water is let out which is not being used. In Interviewee 8’s system, the water that doesn’t gets used is re-collected and there are usually no run-offs and it saves water to become used for another occasion. However, the largest reason of all for all the farmers to irrigate was the weather, as almost all stated that rain water is just not enough for the potato crop in the summer season.

As water resources like groundwater, aquifers, and public mains are increasingly sensitive in the region renewable resources and water storage is increasingly important (Weatherhead, 2005:12). The most common resource was groundwater for the interviewed conventional farmers in the region. In East Anglia, the interviewed organic farmers place more emphasis to attempt to use renewable irrigation supply. This was done through water/rain storage or collection and building large water reservoirs. The main problem with storages is the valuable land it would uptake as well as the risks and expenses to build one which seemed to be the main reasons of why the interviewed farmers not owning one. Also the high cost of reservoirs is difficult to tackle but can be overcome by sharing the burden by other farmers. Farmers who were connected to both an abstraction licence and a reservoir or some kind, were concerned that their reservoirs could empty before the end of the season which lead them to using more of their licence as a security measure. Environmental values and empowerment seemed to be the driving-force behind organic farmers having more water independence.

5.2 Monitoring and scheduling

Almost half of the UK farmers only use their own eyesight or instinct as judgement to schedule irrigation (Thompson et. al. 2007:15). Technical devices exist in various kinds but includes a high price and do not necessarily provide a result useful for a farmer. Though if used properly and with care efficient scheduling can give efficient results. Soil-water monitoring measures the water in the soil, and is placed around the crop root-zone to be able to calculate the exact amount of water needed for desired growth (Thompson et. al. 2007:15). Instruments used for monitoring are for example neutron probes, different sensors of soil capacitance and tension meters together with computer calculation programs estimating the water balance (Ojeda-Bustamente et. al, 2004:53). Additional problems with the instruments include the somewhat small areas of measurement in the soil it provides (15-30 cm radius depending on the soil type) which may provide faulty answers and modest benefits for a farmer (Stalham et. al, 1999:23). Using scheduling instruments can be complicated so only about 30% of UK's irrigators utilise them (Thompson et. al. 2007:15).

Monitoring the response of the crop to soil water availability is another instrument for scheduling that measures the temperature of the potato leaf and notify the status of the plant and when water is needed or when it is under stress. It is crucial to determine if the water applied is in fact going to be used by the crop, because water use is not the same as a crop water response. There have been observations that many crops display a need of irrigation but uses less than half the water applied which is extremely wasteful (Stalham et. al., 1999:30). Another method is through model calculations including the evapotranspiration from a crop using meteorological data (wind, temperature, and solar radiation) (Thompson et. al. 2007:16). Satellite images has become very useful in this field, however in the UK's case, with increasing irregular seasonal weather patterns ultimately affecting the irrigation levels placed in the fields (Thompson et. al. 2007:16). Though forecasts may seem as unreliable, but it provides short-term information of regional or local rainfall and temperatures etc. to aid farmers with quick decision (Gowing and Ejieji 2001:138). In East Anglia, the interviews presented different results between the farmers. Conventional farmers were slightly keener on the advanced tool; they believed it might provide some economic benefits. Conventional interviewee 1 and 5 had private companies using various instruments on their land, providing calculations for farmers to follow and allowing them more time on other matters. Even though these two farmers said it is expensive with companies providing the information, and they found their water use has decreased. Most organic farmers believed they did not require such advanced equipment for expected yield outcome and therefore chose not to buy them. However, personal measurements include eye monitoring and personally feeling the crop is the most popular use in terms of scheduling in both practices. Most farmers agreed that that advanced scheduling tools were too expensive and time consuming. Only using personal measurement tools could use up to 20% more water applied than necessary for the crop to absorb (Weatherhead and Knox, 2005: 15).

5.3 Farmers' traditions

The time of day for irrigation has been suggested by scientific and organisational understanding being one of the better methods for irrigation efficiency, as it reduced the loss of water to evaporation (Environment Agency, 2007:19). According to the information found by organic and conventional farmers in the East Anglia region, conventional farms tend to irrigate at daytime, though some wish they could irrigate at night time. Half of the interviewed organic farms irrigated at night time, and the daytime irrigators desired to do it at night time. The majority were aware of the downsides of irrigating during daytime times but felt there was nothing in their power they could do to change this. Two of the interviewed farmers (organic (12) and one conventional (2)) had automatic hoses, capable to function well on their particular land at night time, except when it was windy. In addition, they said the decision of choosing night time irrigation is one method of water efficiency not having to be too expensive for a farmer.

The farming profession in Britain is somewhat known for their traditions and at times reluctant to change. According to many of my interviews they unfortunately confirmed that many farmers were indeed not too eager to alter their behaviour for the sake of the enhancing environmental sustainability. The majority of conventional farmers from East Anglia said they were not willing to change just for the health of the environment, though the majority of organic farmers would like to. Although, during the interview, most farmers had the urge to blame governments for not applying more regulations at the same time they were against to have to obey them as they felt the government did not understand them.

6.0 UK Irrigation Policy

Considering British policy documents of irrigation or water resources there is no strong emphasis towards practical sustainability development. However as CAMS is regulated by the EA a major setting and an idea originated from the EU Water Framework Directive (WFD). CAMS main objective is to satisfy all stakeholders to receive their share within one catchment, implying the priority of human needs over the protection of natural resources. The SA updates its Organic Standards yearly but has only included water management section this year, but make sure it stresses the importance of reducing water measures, unlike CAMS. Table 4 illustrates both CAMS and the SA's standards of irrigation and natural resource handling leading to a discussion of its affects on any farmer who uses irrigation. The incentive to become increasingly sustainable would increase and hopefully narrow-minded and non-efficient traditions within agriculture could be softened. It is the opinion of the author that although sustainability is raised as an issue in many of these legislations, there is little practical information designed to pressurise farmers towards these goals.

6.1 CAMS abstraction charges

In terms of abstraction charges, any farmer who wishes to irrigate must pay for a licence. There is a fixed annual charge of £125 and subsistence charges of minimum £25 including the total amount of water being used which is calculated by semi-fixed rate of water costs (See Table 3). The amount for the Anglian region could be considered cheap as the water availability is so scarce. The EA also charges additional costs depending on different factors:

- Volume (annual licensed volume in cubic metres)
- Source of water resource
- Season – summer, winter or all of the year
- Loss of water
- Standard unit charge (SUC) – a charge for the region where the abstraction is authorised.
- Environmental Improvement unit charge (EUIC) – charge to recover the costs of compensation payment.

Table 3 – CAMS Abstraction charges	
Region	**2008/2009 Standard Unit Charge £/1000m3**
Anglian	25.18
Midlands	14.31
Northcumbria	25.36
South West	19.71

Table 4 – Soil Association Organic Standards affecting potato farmers

National	Year	Main objectives	Water resource protection implementations
Soil Association Organic Standard - Water Management 4.16	2008	• Aims to conserve groundwater • Prevent soil degradation • Maintain optimum soil moisture levels, and • Maintain freedom from contaminants.	• Select appropriate crops, varieties and growing systems • Employ efficient irrigation techniques, and use scheduling information to plan your irrigation efficiently. • If you abstract water or irrigate, you should (and from 2012 you must) draw up and implement a water management plan to minimise your impact on the local water resources • You should (and from 2012 you must) re-use water, including reclaimed water if it is possible • To reduce the need for irrigation and its impact on natural water cycles and reserves: select appropriate crops, varieties and growing systems, employ efficient irrigation techniques, and use scheduling information to plan your irrigation efficiently • If you irrigate, you should: use methods, such as trickle and boom systems, that distribute water evenly and efficiently to the crop, water crops in the evening or early morning to minimise evaporation losses, and base your scheduling on direct soil moisture measurements (being the most accurate system)

Table 5 – CAMS general rules affecting potato farmers

National	Year	Main objectives	Water resource protection implementations
CAMS (EA)	2003	• Abstraction licensing of ground/river water with fees, for a fair stakeholder allocation • The EA are allowed to remove ones licence if considered damaging	• Small abstractions (20m3/day) will not need a licence • Trickle irrigation will need a licence in the future (currently it doesn't) • All abstractors have a responsibility to not let their abstraction harm others • Time limits, with renewal possibilities as long as three tests have been made including environmental sustainability, continued justification of water use and efficiency of water

The differences between the two irrigation regulations are wide though it is important to realise that all irrigators need to be included into CAMS and follow their legislation. SA is only followed by organic growers. The main differences in their main objectives are that CAMS focuses on the fairness of stakeholder allocation whilst the SA has their emphasis on water related environmental protection. Here has CAMS already laid an emphasis on the human rights of water and that all are entitled to their share. SA wishes to express the importance of the environments protection including aspects within water. In CAMS second objective they place an emphasis if farmers misbehave or mistreat its licence, the EA will remove their privileges. Though the SA tends to not place any direct threats on withdrawals on their organic farmers if any misbehaviour occurs, but as SA initially certifies farmers, they will inspect the farms and the general management before labelling anybody organic, including their water management of this year. However, SA does perform random tests on farms if they desire to check their maintenance and if any notion of distrust they will remove their label of their farm. The other objectives placed on the SA's water management are further specifying environmental protecting required accomplishing. SA as well as CAMS has further rules to be able to implement the objectives and the SA is being additionally protective of the resources including specifications of their management tools, habits or renewable resources. SA provides advice like using trickle irrigation, water crops in the evening or early morning to minimise evaporation losses, and base your scheduling on direct soil moisture measurements, unlike CAMS mentioning only time limits as a management tool. CAMS mentioned trickle irrigations need of a license in the future which could lead to farmers being off-put getting the equipment as a license will add costs.

7.0 Interview Results

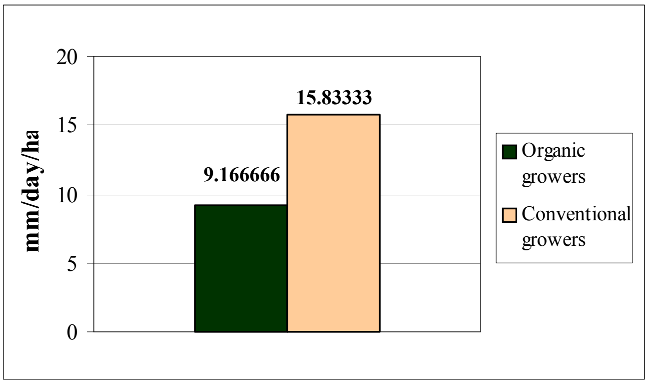


Figure 8 - Average volume of water applied (mm/day)

Average volume of water applied (mm/day)

Figure 8 illustrates how much the different farmers irrigate in terms of volumes per day. Conventional farmers tend to irrigate more with about 16 mm/day on average as the organic had about 9 mm/day. There were only 12 participants of this question, as two farmers one in from each agricultural practice was not aware of their water application rate and therefore excluded. All numbers provided by farmers' were their approximation of their use from 2007.

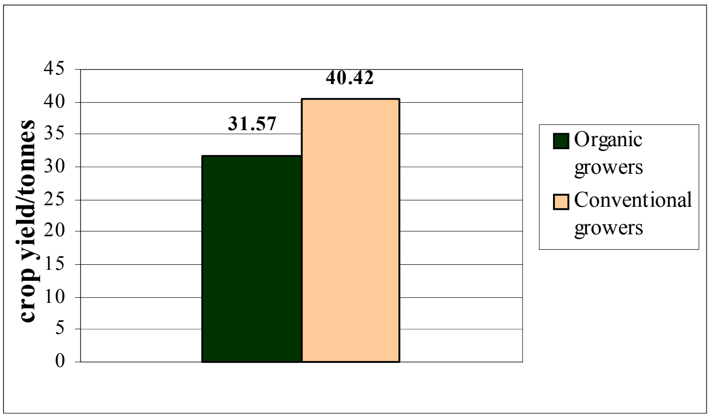


Figure 9 – Difference of conventional and organic average crop yield/tonne 2007

Figure 9 illustrates the average crop yield/ tonne from year 2007 by the growers interviewed. The conventional gathers about 40t/ha whilst the organic crop yield is about 31 tonnes/ha.

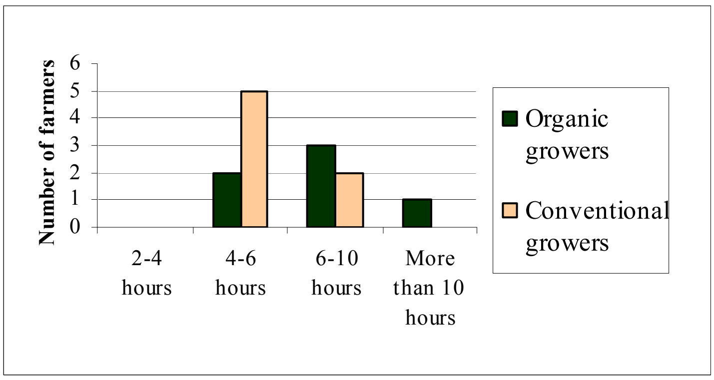


Figure 10 – Average hours of irrigation/day between conventional and organic growers

Figure 10 illustrates the average time spent by farmers irrigating their crops per day during summer time. Conventional farmers seem to generally water between 4-6 hours. Most interviewed organic farmers also tend to water over 6 hours a day. One organic farmer also tended to irrigate over 10 hours a day. Within the organic farmers the non-irrigator is not included in this figure as he does not irrigate.

8.0 Analysis part 1 – Interpreting results

From the results that have been extracted from the interviews made, there are further analyses that can be made. There has been an assumption made to be able to make these calculations. The amount of days irrigated by farmers is usually about 3 months (May – July) and therefore it has been assumed that 60 days are irrigated by the all farmers.

Volumes of water per weight of potato can be calculated:

Volume/tonne of potato = Volume/weight

<u>For conventional farmers:</u>

15.83/1000*100*100 = 158.3 m^3/ ha (volumes/hectare)

158.3* 60 = 9498 m^3/ha

9498/40.42 = **234.66** m^3/tonnes

<u>For organic farmers:</u>

9.16/1000*100*100 = 91.6 m^3/ha

91.6*60 = 5496 m^3/ha

5496/ 31.57 = **174.09** m^3/tonnes

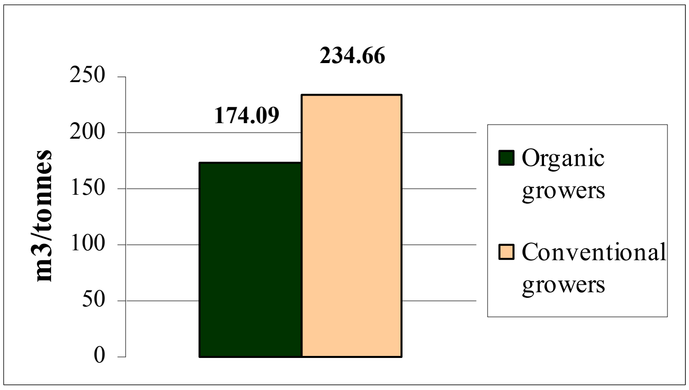


Figure 11 – Comparison of volume of water per tonne of potato

According to the results found in this paper, the farmers interviewed, organic growers tend to use less water/tonnes of potato with approximately 174m3/t (See Figure 11). Basically, no matter how the potato is grown, they are the same crop, with the same needs so the difference will not lie in if the actual potato is organic or not. It has become apparent that it must be the different agricultural practices that affect water use per weight of potato. In table 6 the main irrigation practices are placed comparatively with organic and conventional, to increase the transparency of the arguments of which will be placed in the analysis.

Table 6 – Main differences in irrigation practices of organic and conventional potato farming		
	Organic	**Conventional**
Volumes of water applied	9.16 mm	15.83 mm
Type of irrigation equipment	Mainly boom and gun, with one non-irrigator	Mainly boom and gun
Rate of application	1.4 mm/hrs	2.7mm/hrs
Annual crop yield	31.57tonnes/ha	40.42tonnes/ha
Monitoring and scheduling	Uses less advanced tools, mainly relying on personal measurements	Slightly more advanced tools used, but mainly relies on personal measurements
Time of day application	Half irrigates at night time other half during the daytime	All irrigates during day time
Understanding water values	Majority has understanding of the importance of water	Conventional farmers has little perceptive of the importance of water

It will now be discussed under the subsections, the types of effects that these irrigation factors will have on water use per weight per potato.

Type of irrigation equipment

The irrigation equipment used by the interviewed conventional and organic farmers was similar with the majority using the boom and hose or gun. These tools are the more water wasteful kind of irrigation equipment, though as the costs and little labour expenses compared to other equipment, leads to being the major driver for farmers to use these tools. As both kinds of farmers are using these tools this appears to not have been a factor in the two practices using different water volumes. However, the rates at which they apply the water are different. This will be explained in the next section.

Rate of application

The rate of water application can be calculated:

<u>For conventional farmers:</u>

15.83/5.85 = **2.7 mm/hrs**

<u>For organic farmers:</u>

9.16/6.5 = **1.4 mm/hrs**

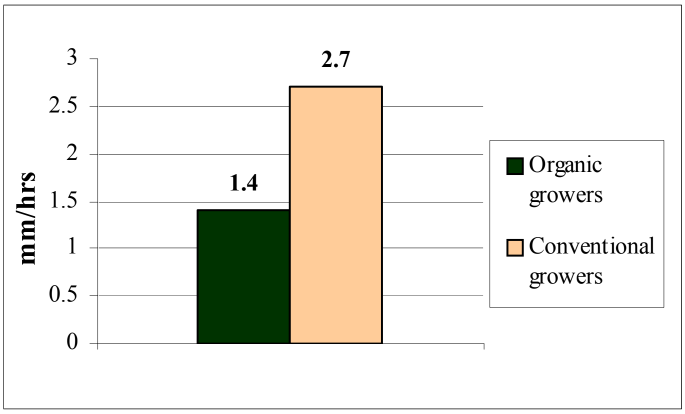


Figure 12 – Comparison of rate of application

It is found through the calculations based on the interview responses that organic farmers tend to apply water at slower rates on their land but for a longer period of time. Slower rates will result in more efficient water usage per potato as the potato root is more likely to absorb the water provided instead of being wasted as run-off or trickled through the soil. Organic farmers make sure that the hoses or booms are distributing/applying water slower. The environmental values of farmers do play a role into this decision of farming as it is obvious that organic farmers are receiving decreased yields which might be related to the amount of water applied. However, this discovery of result is fascinating as it intertwines with the main objective of this paper: to discuss the possibilities of the differences of water use between conventional and organic. It appears the rate of application is a crucial factor of why organic use less water.

Although, an additional issue regarding the rate of application, its relationship with farmers owning storage/reservoirs. An investment of reservoirs or storages could be risky, the worry that many farmers also face is that their stored water can run out. This could then lead to farmers using both sources through a licence as well as a renewable. However, precaution of this occurring would be for farmers to lower their rates of application. As organic uses more renewable than the conventional farmers, this may very well affect their decision-making into the use of slower rates.

Scheduling

Looking at the use of scheduling tools between the practices, the majority of farmers were using personal measurements like feeling the crops on the fields and general looking. They also have rain gauges on their fields to be able to measure how much rain has been placed on the fields. Some organic farmers were using more advanced scheduling tools like neutron-probes. This could have helped them to make more efficient use of their water, so lowering their water consumption per potato. Although more conventional farmers were utilising advanced scheduling tools, they used more water than organic. This could be for two reasons. Conventional farmers simply might not use the instruments properly as they can be quite complicated to utilise and therefore not show a decrease in their water use. It is much more likely that during the day, the sun dries the soil, and therefore the scheduling monitors will start irrigation during the day. Some of this water will be lost to evaporation resulting in more water consumption per potato. As such, scheduling equipment may contribute to the lesser water sustainability.

Time of Day

The time of day of farmers placing their irrigation either night time or daytime, will have an impact on the soil moisture. Half of the interviewed organic farmers were irrigating during the night whilst all conventional farmers were irrigating during the day. This would have a major affect on the level of waters as moist in the soil would be maintained longer than it would have been for conventional farmers irrigating during the day and forcing them to apply more. As scheduling tools falsely illustrates farmers to irrigate (during the day) when it is possibly not necessary, could also have a connection to why they appear to not be so efficient for the interviewed farmers using them. Farmers' traditions interact to some extent with these scenarios. Environmental values within organic practice were higher noted throughout the interviews leading them into irrigating at night time. Conventional farmers had a different attitude as they wanted to get their job done fast and efficiently with no major obstacles and the desire to do additional labour just for the environment was not acknowledged.

Traditions

Framer's traditions are likely to have a general effect on the way that they conduct farming. So it will affect their practices such as rates of application, type of equipment, etc. As conventional farmers have values which are aimed at maximising production, their practices will be reflecting these values. As organic farmers still want to make money but also want to subsist with the environment, they will be more respectful of environmental limits. Therefore more environmental values will be likely to result in more water sustainable potato production.

Conclusions

From this section, we have found that rate of application, the usage of reservoirs (which affects application rates) and the time of day of application all reduce water sustainability. The next section explores how feasible it is for the organic practices used to be applied in the conventional farming scenario. Farmer's values will not be considered in the next section because it is often unfeasible and impossible to change values, as they exist within you and are unlikely to change.

9.0 Economic Feasibility

It appears that the rate of application, the time of day of application, and scheduling equipment are the major factors influencing the interviewed organic farming using less water/tonne of potato. This chapter explores how feasible it would be for conventional farmers to use the organic farmers methods. We will also consider the usage of reservoirs, as this is likely to affect the rate of application.

Rate of Application

The main reason for conventional farmers that would prevent them to apply a slower rate of water on their crop is that they want to maximise profit at all times. Why is it that conventional farmers need to maximise profits whilst organic do not? Whilst I believe that organic farmers' environmental values play a part, the economics of potato production is also likely to play a part.

<u>The economic aspects of organic using less water/weight of potato</u>

The economic aspects of organic and conventional farming implications have their planned irrigation management. The price of potato of 2007 (See Figure 3), extracted from the registry of the British Potato Council and the average organic price figures has been provided by the Soil Association, and has been added into this section to be able to calculate value of yield versus the each practice lands.

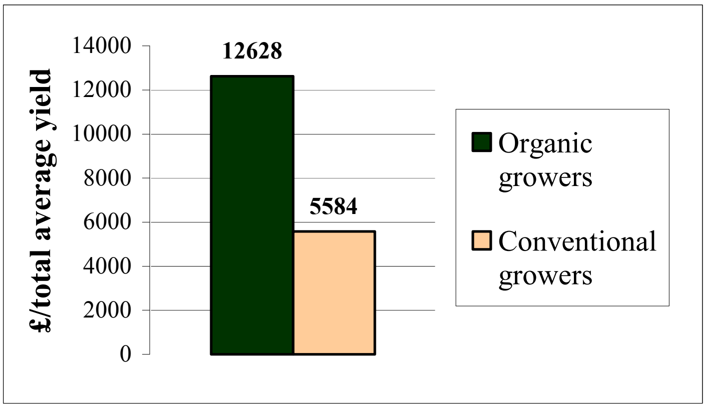
Value of yield/hectare = price/ton * yield/hectare

<u>Conventional:</u>

40.42*138.16 = **£5584**

<u>Organic:</u>

31.57*400 = **£12628**



The different values of yield per tonne between the two practices are quite diverse as organic potatoes are worth so much more than conventional (See Figure 13). This value difference largely depends on the demand and supply chain of potatoes. There has been a steady increase of demand of the organic crop, leading to that the supply has not yet been able to catch up. This relationship is then resulting in that organic is worth much more than conventional. Obviously, this relationship may not be the only factor involved as potential seasonal challenges like potential floods or drought takes place it could also affect the price of potato yield. The risks of pests and disease is also a factor of which organic farmers need to attend to more carefully than organic which can affect the monetary value of the crop.

By analysing the potato price figures back to the previous section of why organic use less water, these value figures found, may suggest that organic farmers can afford to produce fewer yields because the value of the crop is so high. They tend to not loose any serious money on it; in fact they are earning more money than the conventional farmers and being more environmentally sustainable. By receiving more money for their yield, it gives organic farmers the opportunity to spend additional money or time on environmental sustainable traditions. An environmental expenditure they would then afford is slower rates of application. Organic farmers could earn a lot more money if they used same water rates as conventional though chooses not to. The reasons being mainly, environmental values and as well as the value of organic potato are so high that farmers do not need to, unless they really want to. Though, the economical sustainability for organic farmers is a chance of which may not exist permanently. The economical benefits are yet only in place as the imbalance between supply and demand continues to provide profits though this niche will only continue as long as the supply-demand imbalance will carry on.

The economic aspect for conventional farmers as they receive a less price per tonne of potato means that the importance of more yields is crucial to receive the profits they desire (See Figure 13). Though, the importance to change their behaviour even so, is clearly vital if environmental enhancement is to begin. The notion to introduce lower rates of water on conventional farmers' crops would not be a popular decision as this means that their yield might be lowered. Farmers who are already in economic difficulties can possible become poorer and not be able to support themselves.

However, relative level of rate of application can have major affects on conventional farming as this will affect their maximum yield. The crop yield for farmer's who only applied 15mm/day and the 25mm/day, the difference is minimal. Some of the conventional farmers apply on average 15mm/day to 25mm/day. The average crop yield for the farmers irrigating at 25mm/day had approximately 42 tons potatoes/ha, whilst the 15mm/day received about 41 t/ha. Yet, there is no deny that one tone/ha less will mark a difference in the total agricultural output for a farmer but this aspect should be considered. This is only an example brought up of one interviewed farmer who had a difference in his water and yield to illustrate the differences in water quantity use and the yield he receives from that.

Therefore, there should be a limitation of water application rate over approx. 15-20 mm/day. This is a difficult procedure as it would require calculations on farmers size of lands and the amount of water provided which can complicated the work for the EA. The ability depends on wheter the EA are willing to do this additional work.

Application of time of day

In East Anglia, it is noted that conventional grower irrigates more during the day as some organic farmers generally irrigates during night time. The organic farmers were able to do this for several reasons; by handling the irrigation themselves, labour availability and automatic equipment making it possible to not be present at night time. However, the main difference between organic and conventional farming is largely that conventional farmers tend to have very large sized lands. With large amounts of land, the farmers won't have the possibility to irrigate themselves during night time. Larger lands also require more labour, which is difficult to find anyway. This is a major difficulty which conventional farmers will be faced with if they were to apply this efficiency tactic.

Conventional farmers could however manage to have automatic hoses that would function during night time. Though even if they were to get automatic hoses, they would probably need several machines which would require additional coordination and expenses of which they might not have or wish to pay. Difficulties in labour availability in rural areas for night time irrigation shifts was one reason which the interviewed conventional farmers mentioned frequently. This is indeed a difficult situation placed on rural areas as such; automatic irrigation equipment might be more optimal even though the cost for this is still a difficult factor. A simple method to locate labour could be tried by investigating possible hiring agency's, and place adverts requesting farming and irrigation aid. An advert would most likely have some respondent of which a farmer might be interested in.

Reservoirs

The feasibility for conventional farmers to invest in reservoirs, or water/winter storages seems to be of little interest resulting from the extracted interviews. In terms of land size for conventional, they would have much better opportunities to create one than organic as they tend to have land limitations. The empowerment of owning your own renewable source of water is attractive to any farmer though as conventional tends to use more; this aspect should be even more attractive to them. As any renewable source in terms of water, the initial costs of having it built will be a lot and therefore a risk. Farmers could invest with other nearby farmers leading to reduce costs could be an opportunity as well as being a tool of cooperation of communication between farmers. The process of building reservoirs could take years and farmers will indeed loose land but when it would be done, farmers would be able to not have fears or worries of restrictions on groundwater or any other public source. The East Anglia region has less water rainfall than the rest of the country. A reservoir of which gathers rainwater is a brilliant source of water for farmer but should be aware of the risks in terms of amount of collection and size of storage to make sure the retrieval will be enough. Though as large parts of groundwater and other sources of water in East Anglia is under stress and at times incapable to provide water for farmers.

Conclusions

From the options that we have studied, it has become apparent that time of day of water application is the most feasible tool to use for conventional farmers to use to reduce their water consumption. The main reasons for why conventional farmers do not use this is because the lack of labour, equipment and the size of their lands. Another option would be for farmers to create water storages/reservoirs on their land. Reservoirs are a good investment as it provides water security to a farmer. Although, depending on the reservoir/storage size it is expensive option. The rate of application is an option, but requires for the EA to be wiling considering the issue in more depth. This would be unpopular with the conventional farmers as they believe it would affect their economy too severely. Conventional farmers are earning half the amount of money that organic farmers are, therefore they are unlikely to be willing to apply slower rates. Additionally, the belief of farming being a profession to maximise agricultural services was created by EU CAP after the WWII. Ever since then, environmental emphasis and consideration is difficult for farmers to even consider as they know environment will not be immediately affected by their action but after a long time.

There should be a stronger encouragement to use efficient equipment for irrigation which is possible for farmers to use, like automatic hoses. Even if only one part or section of a conventional farm becomes irrigated during night time because of an automatic hose, it can make a difference. This encouragement should come from the EA as the SA is encouraging their organic farmers. Though, only organisational encouragement will not be enough for farmers to make real change, only policies which encourage farmers to change their traditions will. Wasteful traditions are the force behind many farmers unwillingness to change leading to inefficiency, especially within irrigation. Policy alterations to be able to make sure all water stakeholders get their share of water are difficult when many areas are like East Anglia; dry and over-abstracted. Therefore CAMS should begin with to assure water is being used as efficiently before trying to reduce the use. The possibilities of policy improvement will be further discussed in the next section.

10. 0 Policy Recommendations

For agricultural tradition to be altered the understanding that policy is the method to steer farmers into using better equipment, instruments and adapting to practicalities of which are better according to the policy initiators. Policy does not necessary have to include mandatory change but can also include guidelines to try and regulate as well as motivate farmers to change for more sustainable practices. According to the findings of this paper there are a few aspects of which conventional farmers can attempt to install within their practice to become more water sustainable. The first table made below will illustrate those possible options and conclusions of its feasibility will also be made. The second table are overall recommendations for potato growers on how to become more sustainable and a feasibility analysis on that will be made as well.

Table 7 – Recommendations for conventional farmers through policy implementation

Method	Policy suggestion
Affecting the rate of application	• CAMS policy that specifically providing farmers who choose to use slower rates allocates them with more time.
Time of day	• Lower abstraction costs at night time
Reservoirs/water storages	• Provide discounts or subsidies to farmers who wish to build them, possible by buying part of the land that the reservoirs get built on • Gradual increase in pressure on farmers to use renewable sources
Scheduling/monitoring tools	• Support further technological research to find more tools to aid water efficiency

The main goal of these policy suggestions is to attempt to minimise the use of water for conventional farmers. Organic farmers do need to continue to develop and minimise their water impact as well, although according to the results found, they are running better. Affecting the rate of application through policy is possible if the suggestion is feasible. Another aspect is if CAMS would encourage farmers who irrigate that they will be allocated more time to irrigate if their rates are slower. The way CAMS will be able to control this is through calculating each farms that would be interested their amount of land and how much water is required. Initially this method should begin as an encouragement only, after the initial farmers have tried it and have provided feedback, CAMS can make it into step by step initiative with regional goals of converting to slower rates.

CAMS have already stated that farmers must have certain time limits that are supposed to make sure farmers do not stress water resources by watering too long. Though by issuing such a suggestion it also places stress upon the farmer to irrigate faster as they have shorter time to irrigate. This then leads to faster rates as well and CAMS have done opposite to what they desired with the policy originally. Although CAMS has now added a clause within this section emphasising farmers who irrigate slower will be rewarded with more time.

This outcome will have a positive outcome if farmers would decide to attempt a lower application rate but it does not persuade them to try.

The time of day is an interesting method of practice at it appears to be simple yet difficult to execute. The best want to achieve this would be to lower abstraction costs at night time. This would make farmers want to at least attempt to irrigate at night time as well as trying different irrigation methods and possibly stimulate labour if found. This however leads into the other scenario that farmers have difficulties to find night time labour.

Building reservoirs is a suggestion of which can aid many farmers into feeling empowerment, ownership and general safety of using irrigation as a tool. The benefits are quite a few as well as the negative aspects which then the EA should assist with. The main concern is for farmers to dedicate land of what they could cultivate on instead and the expenses of creating one. Farmers should then have the possibilities to apply for money assistance to encourage the process they are about to achieve. As reservoirs can be very adaptable to the environment even though farmed land will have to be dug up, though water based biodiversity would appear. Naturally these biodiversity benefits would not necessarily be of any benefit to a farmer but as they are providing environmental sustainability, subsidies could be pledged from the EU. The SA has already placed a responsibility on organic farmers to try an attempt renewable water sources within their water management. CAMS need to do the same, as their main objective is to make sure all stakeholders are being treated fairly. At the moment, the water resources are not being treated accordingly and CAMS need to adjust for that reason.

Scheduling and monitoring potato crops will provide water use benefits if farmers are logical and use the equipment properly, or they are designed to reduce evaporation, by primarily working within the night time schedule. As part of EA/Defra's responsibility is to show that they are keen to see further technological advancement of which they can later on illustrate to farmers to keep them interested in the use of such tools.

10. 1 Non- policy recommendations

Providing further recommendations to several layers of stakeholders involved in potato irrigation of East Anglia has the aim to enlighten the importance of sustainable awareness leading to its further development for both types of farmers. Table 8 will suggest the ideas if recommendations:

Table 8 – Further recommendations on potato production in East Anglia
• Moving parts of the potato production to the West of England
• Stimulate rural development in increase labour availability
• Ensuring agronomic education and knowledge for all farmers
• Increase awareness and knowledge on systems like tile-irrigation etc.
• Support by the British Universities scientists on agriculture and irrigation sustainability to further educate farmers and EA/CAMS
• Enforcing increasing dialogues between farmers and other farmers

Primarily, in terms of potato production itself there are a few options chosen of which will reduce irrigation volumes. The idea of moving parts of the potato production in wetter parts of the country would be an option. This would primarily reduce irrigation in the East Anglia region and possibly give way for other more appropriate crops to be produced. One possible negative impact could be the loss of an economically valuable crop for a farmer although there are many other crops which could be produced for the same value if not more. The West would experience landscape alterations and by growing potatoes in wetter areas increases the risk of blight. The Nafferton Ecological Farming Group (NEFG) has recommended from their ongoing research that a wide crop variety and spaced out crops on fairly small fields is one efficient way of controlling the disease which should then be used by all growers not just in wetter regions. Placing seaweed or manure-based composts also seems to be alternative treatments to blight. There are also other crop varieties of which show resistance towards blight which could be used according to the NEFG though states no certainty yet. Of course there are no certainties with any of this but as most potatoes grown in the UK becomes processed; there is no real need for ultimate quality on the tuber. It would seriously reduce the amounts of water used. As the agronomical aspects of the potato have not been specifically targeted in this paper, its usefulness in terms of water reductions are still worth mentioning.

Having said this, one aspect of these recommendations is that farmers usually have to be very well-informed and more attentive in terms of the potatoes agronomy. Farmers should try to maintain the potato canopy; it could assist in the soil moisture. Avoiding soil compaction so the roots can absorb water easier is also an application with while for farmers to investigate. Farmers should not use their irrigation privileges to control their scabs as this is very wasteful. If farmers have problems with this, there are other methods in hand. In terms of recommendations for the actual farmer besides the ones just given, what is mostly important is that they begin to implement some instruments and tools which are more water efficient. Monitoring and scheduling which has been one of the main areas of investigation of this paper was not excessively used by any of the interviewed farmers. Attempting test-areas of not irrigating to see if the potatoes are affected by it in a negative manner would be interesting as well as responsible. Farmers should also seriously consider a water reservoir to collect water which could be shared by other nearby farmers if the installation is too expensive for them.

The regional offices of the EA or Defra should continue to stimulate the rural development as this will attract more labour into the area. It is already suggested that organic farming do stimulate employment factors in rural settings more that conventional (Lobley et. al 2005:21). There has been a fair bit of scientific research behind this and by the personal interviews performed on organic farmers for this paper; most of them did mention that they need more labour than others or previously when they used to be conventional.

Instead of allocating money to personal farmers, irrigation education could be provided though Defra and the EA as this might be more efficient. Demanding British universities to act further through opening their scientific research on potato production and irrigation efficiencies could provide interesting changes for a farmer. As Interviewee 8 mentioned, he only found out about his tile drainage system by reading science-based information. Information usually very difficult for farmers to uphold as only a selective amount of people may use it.

However, mainly the government need to provide serious goals of irrigation reduction for potato production which will automatically create an incentive for farmers to change their patterns as well as traditions. Step-by step goals should have been in place years ago. In terms for organisations like the Soil Association, their organic standards is being continuously updated which is good, even though their water management chapter was only entered in 2008. All sustainability aspects are covered in most of their Standards, but even so, they need to make sure their farmers are learning to be as efficient with water as possible. Educational tools should be provided for farmers in terms if irrigation and water efficiency. Their environmental principles in general are in relation to conventional very much more sustainable, but even them could be refreshed (See table 9).

Table 9 - Organic environmental principles with enhanced reflection of sustainability	
Environmental principles	**Environment principles**
1. To foster biodiversity and protect sensitive habitats and landscape features. 2. To maximise use of renewable resources and recycling. 3. To minimise pollution and waste.	**1.** To foster biodiversity and protect sensitive habitats and landscape features **(The principles should include all natural features)** 2. It should be **minimise** the use of resources and materials 3. To **eliminate pollution and maximise** waste recycling and well as minimise its size.

A dialogue between its farmers could increase not just awareness but also a more joint force of change in behaviour. If one farmer succeeds with one previously seen 'complicated method' then it might lure more farmers to at least consider further personal adjustments. The farmers union and similar organisations does not seem to be enough. Local levelled farmers merging together to discuss alternative and perhaps jointly purchasing instruments would be ideal. Both the EA and DEFRA should encourage local environment branched municipalities to investigate if there is an interest of such cooperation between farmers

10.3 The feasibility of these actions to occur

The recommendations suggested are more radical compared to the previous ones. The desire of these recommendations is to make sure there will actually be a change with the aid from all possible angles. Though, this might be more unlikely to occur, it important to inspect all possible actions that are possible to take. In terms of relocating potatoes in to wetter areas does indeed have its problems as well, however as mentioned it is possible to mix varieties of potato, which then will become processed food. It could be an optimal solution to begin with. The rest of the fresh potatoes that gets consumed within the country can stay within East Anglia where there are no over-abstracted areas or no availability of groundwater. These situated areas should also have some renewable sources which could be built in step by step. This is doable as well though the initiative needs to become stronger from all directions. The organic initiative farmers' is already present by the SA, even though it could go a step further, should be further adapted to conventional farmers policy. The involvement of scientist is already present through many organisations like Defra, EA and SA though what is crucial is that they themselves communicate with farmers and not the organisations. This is how farmers may get use of the scientific world and scientist will be able to learn more of a farmers' world.

11.0 Conclusions and perspectives

The East Anglia production of potato, either conventional or organic requires a lot of water and will continue to do so and with the development of climate change outcomes on decreasing the availability of water will ultimately just increase the pressure of water. This was one of the reasons of why the investigation of this topic was interesting yet important. Though, according to the interviews made on the farmers in the region, it suggests that organic farmers tend to use less water per weight of potato. Organic farmers were being more efficient in using water resources through applying water at night time and their rate of applications were slower and they were using more renewable resources which affected their total amount of water. Having said this, the final production in terms of average total crop yield is still substantially less than conventional, although this is does not necessarily connected to the irrigation patterns. In terms of organic farmers' personal values and traditions which also alter the behaviour of farmers and could lead to using less water though, the interviewed farmers were not in a consensus on this point. The understanding of the irrigation differences of the conventional and organic was the main objective of this paper. The understanding provided the possibility to suggest policy implementations which could further enhance water sustainability and provide security for future generations to come. In terms of what could have been more of this paper is the investigations of farmers' values and traditions and how to further develop this to benefit sustainability. So therefore, further studies should be placed upon this area of study.

12. References

Anglian Water (UK) (2008)
http://www.anglianwater.co.uk/assets/AW%20region%20map.jpg, accessed at: 23-05-08

British Potato Council (2008)
http://www.potato.org.uk/department/market_information/annual_trends/index.html?menu_pos=seed date accessed: 12-02-2008.

Broadmeadow, M. (2002) *A review of climate change implications for trees and woodland in the East of Englan*d, http://www.woodlandforlife.net/wfl-woodbank/documents/Report.pdf, accessed at: 29-04-08.

Bryman, A. (2002) *Samhällsvetenskapliga metoder* Sweden: Liber ekonomi

Common Agricultural Policy Explained Booklet (2008)
http://ec.europa.eu/agriculture/publi/capleaflet/cap_en.htm, accessed at: 23-05-08

Department for Environment Food and Rural Affairs (Defra) (2008) Future Water – England Water Strategy Accessed at: http://www.defra.gov.uk/environment/water/strategy/pdf/future-water.pdf , date accessed: 2-05-2008.

Donald, P., Pisano G., Rayment M., Pain D. (2002) *The Common Agricultural Policy, EU enlargement and the Conservation of Europe's Farmland Birds* Agriculture, Ecosystems and Environment 89, 167–182.

Environment Agency (EA) [on-line] (2008)
http://www.environment-agency.gov.uk/subjects/waterres/564321/309477/?version=1&lang=_e, date accessed: 23-04-2008. http://www.environment-agency.gov.uk/business/444669/587179/1734110/505764/, http://publications.environment-agency.gov.uk/pdf/GEHO0308BNTT-e-e.pdf?lang=_edate accessed: 23-05-2008

Environment Agency [on-line] (April 2001) *Managing Water Abstraction – The Catchment Abstraction Management Strategy Process* Environment Agency http://www.environment-agency.gov.uk/commondata/acrobat/mwa_english.pdf, date accessed: 24-04-2008.

Environment Agency (EA) [on-line] (2008)
Thinking About Getting a Water Reservoir, http://www.environment-agency.gov.uk/subjects/waterres/457898/458132/?version=1&lang=_e ,date accessed: 12-02-2008.

Environment Agency [on-line] (March 2001) *Water Resource for the Future – A Summary for the Strategy of England and Wales. Environment Agency* Accessed at: http://www.environment-agency.gov.uk/commondata/acrobat/wr_national_summary.pdf, date accessed: 10-03-2008.

Environment Agency (EA) [on-line] (2003) *Water Resources for the Future booklet* Accessed at: http://www.environment-agency.gov.uk/commondata/acrobat/wr_national_summary.pdf, date accessed: 3-03-2008.

European Environment Agency (EEA) [on-line]
http://glossary.eea.europa.eu/EEAGlossary/S/sustainable_agriculture and
http://glossary.eea.europa.eu/EEAGlossary/I/intensive_farming
http://glossary.eea.europa.eu/EEAGlossary/O/organic_farming, date accessed at: 2008-01-04.

Gowing, J.W., Ejieji, C.J. (2001) *Real-time Scheduling of Supplemental Irrigation for Potatoes Using a Decision Model and Short-term Weather Forecasts* Agricultural Water Management 47, 137-153.

Gregory, P.J., Simmonds, L.P. (1992) *Water Relations and Growth of Potatoes - The Scientific Basis for Improvement (*Ed) Paul M. Harris Chapman & Hall.

Hawkes, J.G. (1992) *Biosystematics of the Potato; taken from The potato Crop – The Scientific Basis for Improvement* (Ed) Paul M. Harris Chapman & Hall.

Knox, J.W., Weatherhead, E.K,. Bradley, R.I. (1996) *Mapping the Spatial Distribution of volumetric Irrigation Water Requirements for Maincrop Potatoes in England and Wales* Agricultural Water Management 3 1, 1-15.

Knox, J.W., Weatherhead, E.K. (2005) *The Growth of Trickle Irrigation in England and Wales. Data, Regulation and Water Resource Impacts* Irrigation and Drainage 54, 135–143.

Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen and I.A. Shiklomanov, (2007) *Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., 173-210 United Kingdom: Cambridge University Press.

Lampkin, N. (1994) *Organic Farming* United Kingdom: Farming Press Books and Videos.

Mackeroon, Waister (1985) *Water Relations and Growth of Potatoes - The Scientific Basis for Improvement (Ed)* Paul M. Harris Chapman & Hall.

Nafferton Ecological Farming Group [on-line] (2008) http://www.ncl.ac.uk/tcoa/producers/research/blightmop, date accessed: 29-04-2008.

Ojeda-Bustamante, W., Sifuentes-Ibarra, E., Donald, S., Carrillo (2004) *Generalization of Irrigation Scheduling Parameters Using the Growing Degree Days Concept: Application to a Potato Crop* Irrigation and Drainage 53, 251-261.

Patel, N., Rajput, T.B.S. (2007) *Effect of Drip Tape Placement Depth and Irrigation Level on Yield of Potato* Agricultural Water Management 88, 209-223.

Souchère, V., King C., Dubreuil, N., Lecomte-Morel V., Bissonnais Y., Chalat M. (2003) *Grassland and crop trends: role of the European Union Common Agricultural Policy and consequences for runoff and soil erosion* Environmental Science & Policy 6, 7–16.

Stalham, M.A., Allen, E.J. (2001) *Effect of Variety, Irrigation Regime and Planting Date on Depth,Rate, Duration and Density of Root Growth in the Potato (Solanum tuberosum) crop*. Journal of Agricultural Science Cambridge 137, 251–270.

Stalham, M.A., Allen, E.J., Gaze, S.R. (1999) *Irrigation Scheduling and Efficient use of Water in Potato Crops* Research review 1999/2. British Potato Council: Cambridge University Farm

Stanfield, C.B. (1997) *The use of water for agricultural irrigation*, J.CIWEM, 11 Oct.

Subak, S. (2000) *Climate Change Adaptation in the U.K. Water Industry: Manager's Perception of the Past Variability and Future Scenarios*, Water Resource Management 14, 137-156.

Soil Association, (2007) *Organic Market Report 2007* United Kingdom: Soil Association

The Soil Association Organic Standards [on-line] (2008) http://www.soilassociation.org/web/sacert/sacertweb.nsf/e8c12cf77637ec6c80256a6900374463/4d7054234b8da20a8025740b0012f83f!OpenDocument, date accessed: 23-03-2008.

Thompson, A.J., King, J.A., Smith, K.A., Tiffin. (2007) *Opportunities for Reducing Water use in Agriculture* http://www.defra.gov.uk/science/Project_Data/DocumentLibrary/WU0101/WU0101_5888_FRA.doc, date accessed: 20-01-08.

Trewavas, A. (2004) *A Critical Assessment of Organic Farming and Food Assertions with Particular Respect to the UK and the Potential Environmental Benefits of No-till Agriculture* Crop Protection 23, 757-781.

United Nations International Year of Potato [on-line] (2008) http://www.potato2008.org/en/potato/index.html, accessed at 28-04-2008

UK Irrigation Association [on-line] (2008) A fair share of Agriculture – A Strategy for Irrigation in Eastern England http://www.ukia.org/, accessed at 23-05-2008

Verhulst J., Báldi A., Kleijn D. (2004) *Relationship Between Land-use Intensity and Species Richness and Abundance of Birds in Hungary* Agriculture, Ecosystems and Environment 104, 465–473.

Weatherhead, E.K., Knox, J.W. (2000) *Predicting and Mapping the Future Demand for Irrigation Water in England and Wales* Agricultural Water Management 43, 203-218.

Weatherhead, E.K. (2005) *Survey of Irrigation of Outdoor Crops in 2005* Cranfield University http://www.cranfield.ac.uk/sas/water/research/researchareas/irrigationsurvey.jsp, accessed at: 20-04-2008.

Williams, A.G., Audsley, E. and Sandars, D.L. (2006) *Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities.* Main Report. Defra Research Project IS0205. Bedford: Cranfield University and Defra www.silsoe.cranfield.ac.uk, and www.defra.gov.uk.

Weatherhead, E.K., Knox, J.W., Morris, J., Hess, T.M., Bradley R.I., and Sanders, C.L. (1997) *Irrigation Demand and On-farm Water Conservation in England and Wales. Report to Ministry of Agriculture*, Cranfield University, Bedford.

Yin, R.K. (1984) *Case Study Research*. United States of America: Sage Publication.