

Climate change threatens to reduce the reliability of water supplies for horticultural production. This guide describes how it might impact on irrigation water use and the range of adaptation options available to growers.

Climate change impacts on water for horticulture



Water for horticulture - current use and future trends

Horticultural production is a valuable part of the UK rural economy. For many businesses water is an essential component, whether it is for irrigating field-scale vegetables, hardy nursery stock, flowers, or soft fruit. Without access to reliable and secure water supplies many of these businesses would simply not survive. But increasing regulation, droughts, and the longer-term risks of climate change threaten the sustainability of this industry and the rural livelihoods it supports.

Underpinning the rural economy

The UK horticulture sector represents a broad spectrum of agribusinesses, involving growers in the production of a wide range of commodities. Sectors include field-scale vegetables, protected crops, bulbs and outdoor flowers, hardy nursery stock, mushrooms, orchard fruit, and soft fruit. Collectively, these make a significant contribution to the UK economy, both in terms of rural employment and income.

Horticulture and agriculture provides nearly a quarter of all employment in the environmental, food chain, and rural sectors. In 2006, it was estimated that the horticultural and agricultural sectors each employed over 100,000 people. In economic terms both are also very important; although they account for only a very small proportion of the total cropped area nationally (4%), they represent over 20% in terms of crop value.

A significant proportion of horticultural holdings, both large and small scale, traditional and organic, are dependent on irrigation to provide the high quality continuous supplies of premium quality produce demanded by the major multiples, processors, and retailers. Irrigated horticulture represents only 1% of total water use nationally. However, during times of drought, irrigated production is last in line when it comes to water allocation. Other users – domestic, industrial, and the environment – are all given preference. This policy, together with changes in water regulation has meant that many growers are reluctant to invest in long-term irrigation infrastructure. With climate change the current situation will get worse; hotter, drier summers will reduce water availability and will lead to an increase in water demand. This situation is not unique to the UK. Internationally, abstraction of water for irrigation is considered by many to be one of the sectors that will be most influenced by climate change.

Current use and underlying trends in water use

Even in a dry year such as 2003, only 1-2% of total water abstraction in England and Wales was for the irrigation of outdoor crops. Although this is almost negligible in volumetric terms, it is a consumptive use, concentrated in the drier catchments in the driest months, and can be the largest abstractor in some catchments in dry summers.

Over the last 20 years, there have been significant changes in the composition of the crops irrigated. The proportion of irrigation on grass, sugar beet, and cereals has declined steadily. In contrast there has been a marked increase in irrigation of high value crops, particularly potatoes and vegetables for human consumption. In 2005, irrigated horticultural crops accounted for 74% of the total irrigated area, and 86% of the total volume of irrigation water applied (Figure 1). This trend is at least partly driven by the major supermarkets' demand for quality, consistency, and continuity of supply, which can only be guaranteed by irrigation.

Managing the risks

In many parts of England, water resources are under severe pressure. The majority of catchments in which horticultural production is concentrated have been defined by the Environment Agency as being either over-licensed and/or over-abstracted. For agribusinesses operating in these catchments, retaining access to reliable supplies of water in the future will be a major priority. But dealing with changing water availability and rising water costs are only part of the problem. Other 'externalities' are adding to growers concerns (Figure 2).

In the UK and parts of Europe, most horticultural crops could actually be grown without the need for irrigation. But supplemental irrigation helps to improve cultivation and establishment of crops, the timeliness and continuity of harvest, yield, and most importantly quality. With climate change, there will be various impacts on horticultural production, including for example, a reduction in rain-fed yields, less water may actually be available for abstraction, there may be longer growing seasons and new crops may be grown. There are both threats and opportunities for growers with climate change: the key is in understanding the likely impacts, and then managing the risks.

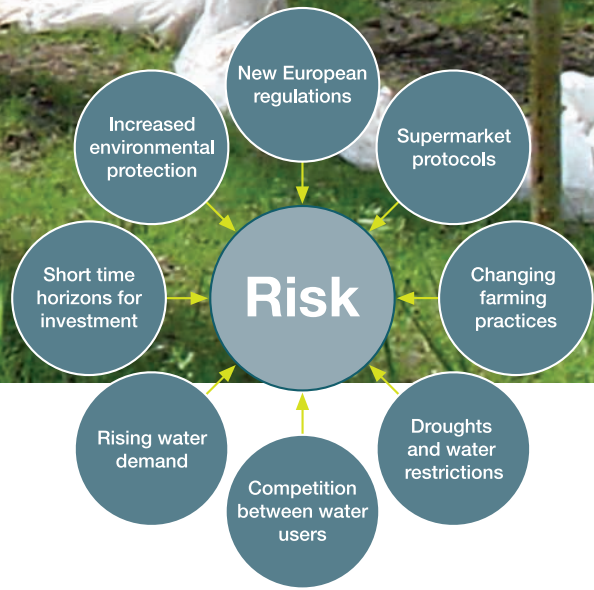
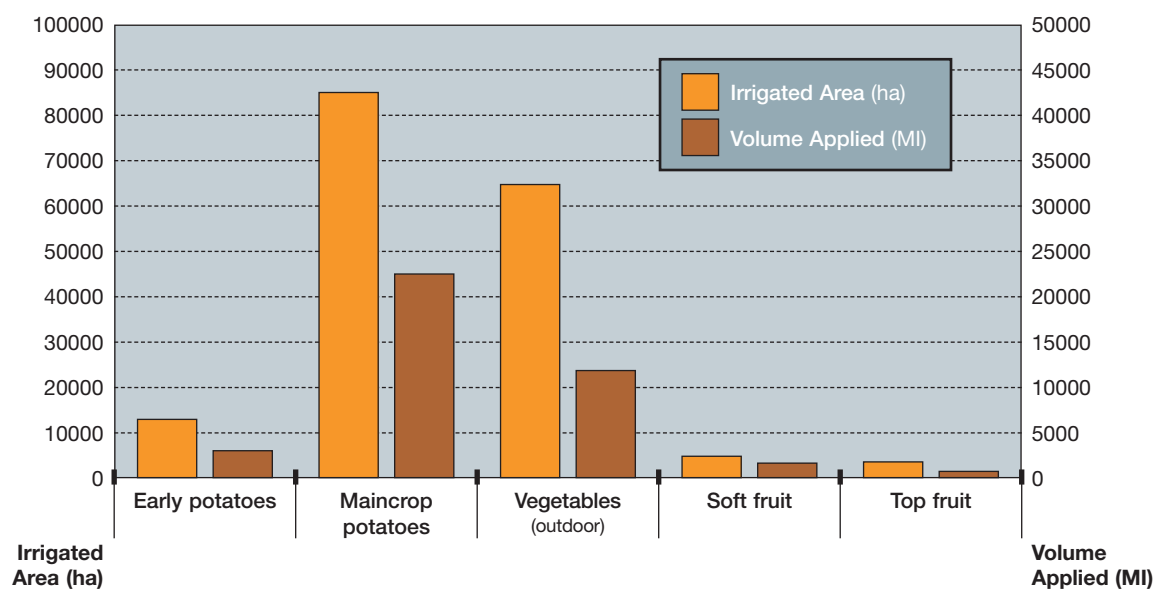


Figure 2. Growers face a growing number of policy, regulatory and climate related risks.

◀ Hall Hunter Partnership grows a range of soft fruit. "In today's farming environment, horticultural production is all about 'adding value'. But everything hinges on a secure access to water, which can no longer be taken for granted" says Mark Hall.



Figure 1. Providing water for field-scale vegetable production, including potatoes, is now driving investment in irrigation and the growth in irrigation water abstraction.



Our climate is changing...

The Earth's climate, although relatively stable for the past 10,000 years or so, has always been changing, mainly due to natural causes such as volcanic activity. But since the 1900s more rapid changes have taken place and these are thought to be mainly man-made. Indeed much of the climate change we can expect over the next 30 years is already determined by what has happened in the recent past and the inertia in our climate system. So what are the implications of this for water for horticulture in the UK?

The drivers of climate change

The Earth's climate is in a continuous state of change - it is inherent in the dynamic nature of our planet. It changes because of the interactions between the oceans and the atmosphere, changes in the Earth's orbit, fluctuations in incoming radiation, and volcanic activity. These forces will continue to have a major influence on our future climate.

More recent changes though are thought to be man-made and the result of increasing 'greenhouse' gas emissions (mainly carbon dioxide and methane) and the extensive clearing of tropical rainforests. Some greenhouse gases are produced naturally and they are necessary to keep the Earth warm - without them the Earth would be about 30°C cooler. But the rapid increase in fossil fuel burning over the last century has released vast quantities of additional greenhouse gases into the atmosphere causing an imbalance in our natural climate system. It is because of this imbalance, that we are now experiencing much greater extremes and uncertainty in our climate.

Temperature – a good indicator of change

One of the clearest signals that something strange is happening to our climate is the changes taking place in global annual mean air temperature (Figure 3). The 1990s was the warmest decade of the last century. In 2007 the temperature was the 8th highest on record. It is difficult to be precise but recent research suggests that average annual temperature in the UK will rise by 1-5°C by the end of this century.

Future scenarios

There is a great deal of uncertainty surrounding climate change and how it will affect us. A major unknown is just how society will respond to the changes - will we do nothing or will we try to mitigate the effects by reducing greenhouse gas emissions?

For this reason UK Climate Impacts Programme (UKCIP) describes how climate may change in the 2020s, 2050s, and 2080s and uses four different levels of greenhouse gas emissions (scenarios) to make these predictions - low, medium-low, medium-high, and high. Averages are quoted for 30-year time slices centred on 2025 (for 2010 to 2040) and 2055 (for 2040 to 2070), rather than predictions for

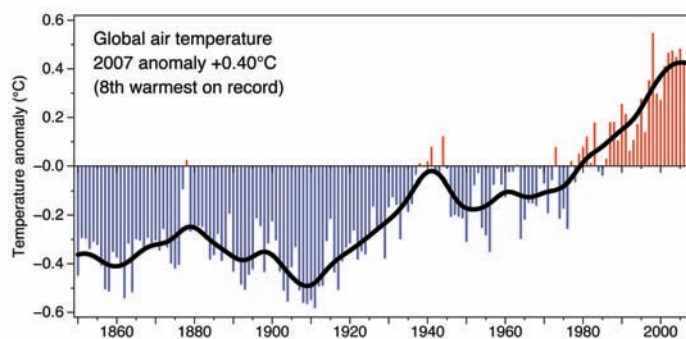
specific years. All the changes are measured relative to the average climate we experienced from 1961 to 1990; this is known as the baseline.

The scenarios provide alternative views of the future, and collectively provide a broad range of changes that society may face. In general we are likely to experience warmer, wetter winters, hotter, drier summers, more frequent summer droughts, more extreme weather events such as high summer temperatures, and more winter storms, and fewer frosts and cold winter spells.

Mapping changes in agro-climate

Information from the latest climate change scenarios, produced by the UKCIP, can help us to assess the impacts of climate change from an agricultural view point. Agroclimate maps have been produced for the different scenarios that show how potential soil moisture deficits (PSMD) may change in the future. PSMD is the potential accumulated soil moisture deficit that builds up through the summer months and reflects the daily balance between summer rainfall and evapotranspiration (ET) - the main drivers of irrigation demand.

Figure 3. Observed increase in global annual mean air temperature, 1860 to 2007.



Source: Brohan, P., Kennedy, J.J., Harris, I., Tett, S.F.B., and Jones, P.D. (2006). Uncertainty estimates in regional and global observed temperature changes: a new dataset from 1850. *J. Geophysical Research* 111.



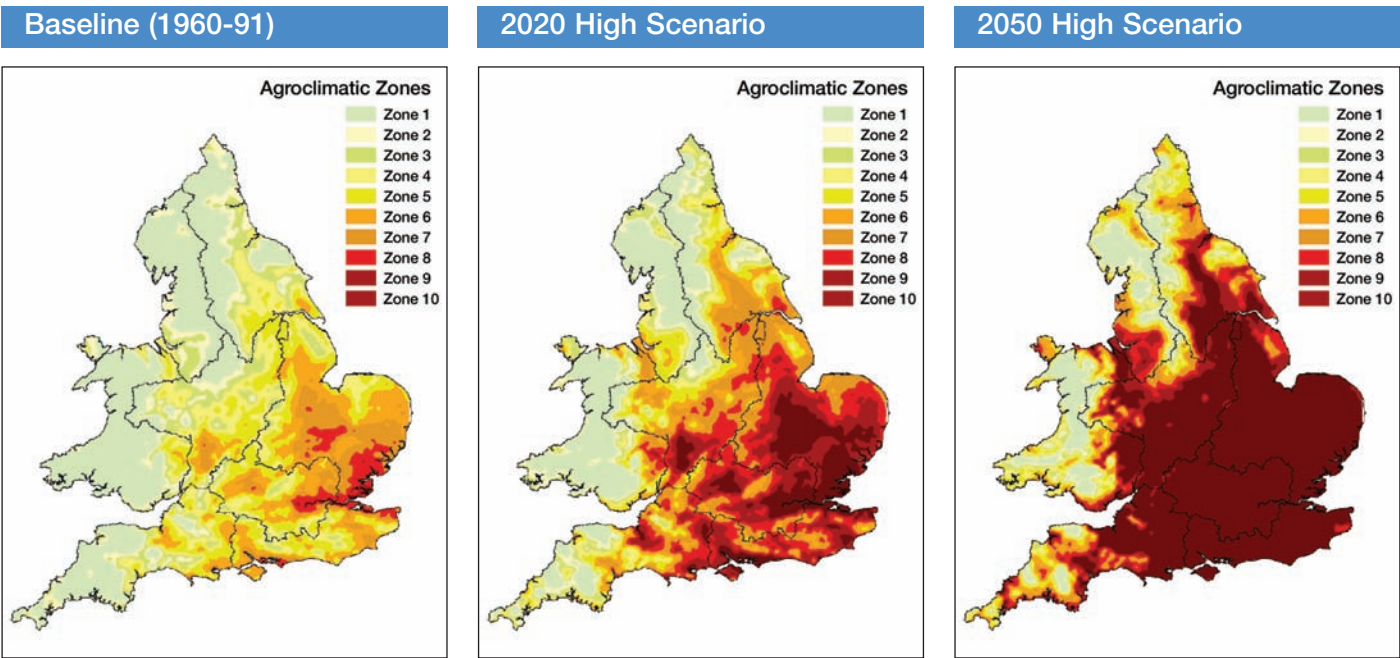
“Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level”.
(Inter-governmental Panel on Climate Change, 2007)

Typical agroclimate zone maps for the baseline, 2020s and 2050s (Figure 4) show how the drier zones move over time. They generally increase in area and spread from the south and east towards the north and west. The most critical zones where irrigation needs are greatest include parts of Suffolk, Kent, areas in West Midlands, Nottinghamshire, and the south coast. But by the 2020s, the irrigation needs of central England will be similar to those experienced now in eastern England, and by the 2050s eastern, southern, and central England will have irrigation needs greater than those currently experienced anywhere in England.

These changes are likely to have serious impacts on outdoor horticultural crop production, particularly those sectors dependent on water for irrigation. In the future we are likely to experience more frequent summer droughts and hence an increase in irrigation demand as a result of higher summer temperatures, lower summer rainfall, and higher evaporation.

One positive sign is the prediction of wetter winters. This may increase the opportunities for storing water when stream flows are high, usually in the winter, and using it in the drier summer months when flows are usually much lower.

Figure 4. Predicted changes in summer agroclimate from the baseline (the long-term average) to the 2020s and 2050s (high emissions scenario).





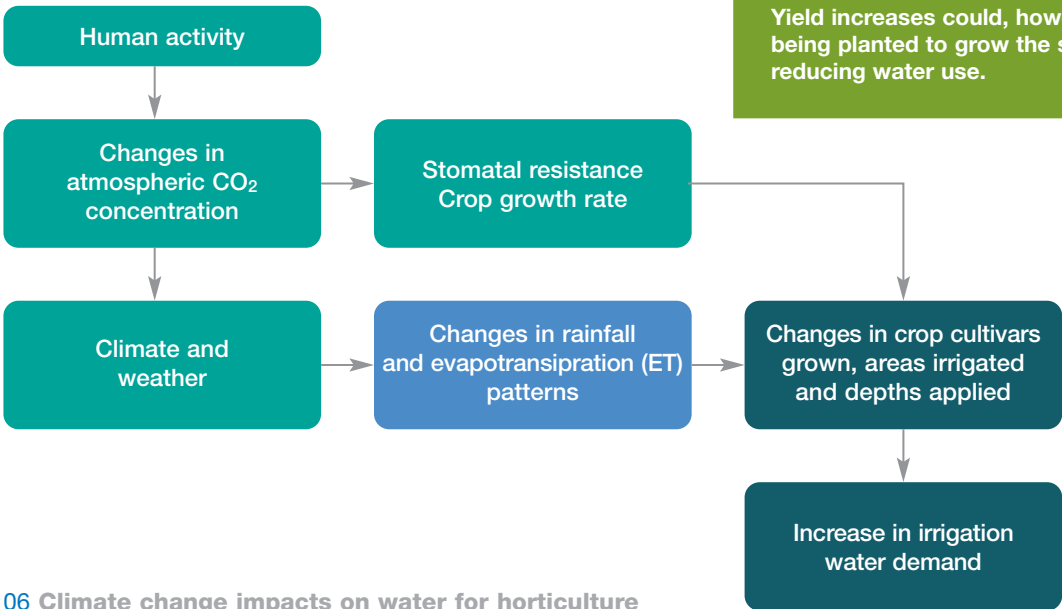
Impacts on water for horticulture

The droughts in 2003 and 2006 highlighted the limitations on water supplies for horticulture and the fragility of the water supply - demand balance. But with climate change, droughts will become a more frequent phenomenon. How will irrigated horticulture be affected?

Impact pathways

In outdoor horticulture, climate change will directly impact on irrigation water use by affecting plant physiology, soil water balances, cropping patterns, the areas irrigated, the methods used and the volumes of water demanded (and abstracted, if available) for irrigation (Figure 5). But there will also be a host of other impacts. For example, higher temperatures and less frosts may lead to changes in cropping, and farmers may irrigate other crops, or new crops (because of changing consumer demands). Agronomic practices themselves may also change, for example, earlier planting and/or earlier harvesting. There may be more on-farm water conservation to cope with changes in the reliability of water supplies. Growers are also likely to increase irrigation efficiency to get “more crop per drop”. However, higher efficiencies and more automation may actually lead to increases in irrigation water demand.

Figure 5. Direct impacts of climate change on irrigated horticulture.



What about CO₂ effects on plants?

In 2001, the CO₂ concentration in the atmosphere was about 370 ppm. The UKCIP predictions suggest that this figure could double, depending on the scenario. The changes will impact on crop physiology and could be a potentially significant driver of irrigation demand.

Higher CO₂ concentrations will increase the potential yield of many crops – due to improvements in the carbon partitioning within the plants. The increased plant growth in root crops, for example, results in an increase in the storage organs, e.g. the main sugar beet taproot and potato tubers, increasing the yield. Where this is the case, crops could be harvested earlier for the same yield - thus reducing water requirements, or at normal harvest time to take advantage of the higher yield.

Yield increases could, however, result in less land being planted to grow the same volume of produce, reducing water use.



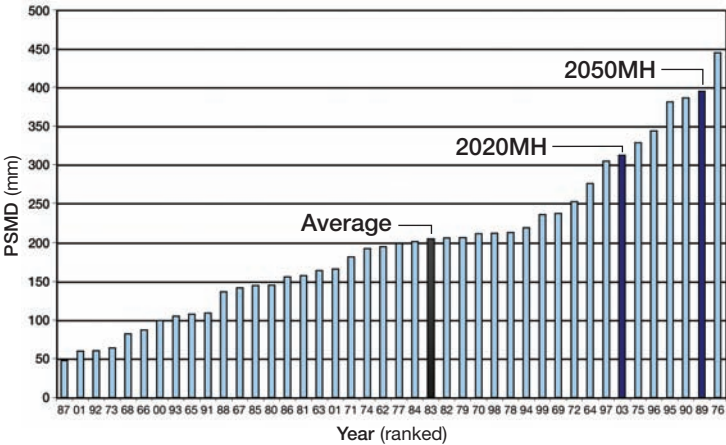
Our average years will become more extreme

On an individual farm, irrigation needs vary depending on crop type and the daily balance between precipitation and evapotranspiration (ET) and the resultant fluctuations in soil moisture status. Because climate change will influence temperature and rainfall patterns, there will be direct impacts on soil moisture. These impacts can be modelled using an agroclimatic indicator known as the “potential soil moisture deficit” or PSMD.

Figure 6 shows the maximum PSMD reached each year for a farm site in Eastern England based on the daily balance between rainfall and ET over a 30 year period. The years in which the PSMD are highest correspond to drought years in which irrigation demands were highest (e.g. 1975-76, 1989-90, 1995-96 and 2003). In irrigation terms, the average year corresponded to 1983.

However, with climate change, an average summer year for the 2020 medium high emissions scenario (2020MH) is expected to be more like the summer we experienced in 2003. Similarly, for 2050MH the equivalent year is 1989, one of the driest on record. This suggests that average years in the future will become much more extreme, and more typical of our current “very dry” years.

Figure 6. Predicted changes in average PSMD.



Irrigation demand: Vale of Evesham case study

A recent study assessed the impacts of climate change on the depths of irrigation applied and on volumetric water demand in the Vale of Evesham, an area of intense outdoor horticultural production.

The study showed that with climate change ‘dry’ year water demand for the existing irrigated crops in the Vale of Evesham would increase by around 13-20% by the 2020s, 25-50% for the 2050s and 38-84% by the 2080s. The crop sectors most impacted will be potatoes, field-scale vegetables, and small fruit production.

These estimates do not include the impacts of any increases in the areas grown due to changes in socio-economic policy. Nor do they take account of elevated atmospheric CO₂ concentration on fertilisation and hence water use and crop productivity.

There is a degree of uncertainty inherent in all climate change scenarios, particularly in relation to water resource issues, where changes in extreme events may be as important as gradual changes.



Preparing for the future - farmer adaptation options

Climate change will impact on the agronomy, economics, and environmental aspects of horticultural production. Under conditions of changing water availability, growers need to consider both short-term and long-term coping strategies. The options available will depend on perceptions of climate change and the threats and opportunities it presents to individual businesses.

Adapting in the short and long term

Modern horticultural businesses are aware of the high value of water for irrigation, and the vulnerability of their high value cropping systems to water stress caused by abstraction restrictions. The financial impacts of restrictions on abstraction can be very high. Prior knowledge of the likelihood of water restrictions enables growers to apply coping strategies based on their individual circumstances. These can be either short-term seasonal plans, or more longer-term strategic developments.

Short-term plans might include re-scheduling the timing of water abstraction to preserve available water, re-scheduling the allocation of water to prioritise specific high value crops, or modifying the irrigation application (depth) and/or timing (interval between irrigations) to improve efficiency. The choice and viability of each option will depend on many site specific conditions, including soil characteristics, cropping practices, contract and market requirements, farm size, and the type of irrigation system installed on-farm.

Farmer surveys

Recent surveys have shown how horticultural growers might adapt to changes in water availability as a consequence of climate change, the range of adaptation options available to them and the perceived time-scales required for adaptation. A recent study in the Vale of Evesham, confirmed that most farmers consider climate change presents a major threat to their water resources and their business. However, many were uncertain over the time-scales involved.

Many farmers believed that climate change was already beginning to have a discernable effect on agronomic practices, with longer growing seasons and some new crops being grown.

How growers respond and adapt to climate change will depend to a large extent on their perception of the risks and/or opportunities that climate change presents to their business. However there are two main strategies to consider. The first is to reduce water needs; the second is to obtain more water (see box). There is however a third way - to stop irrigating and sell your abstraction licence.

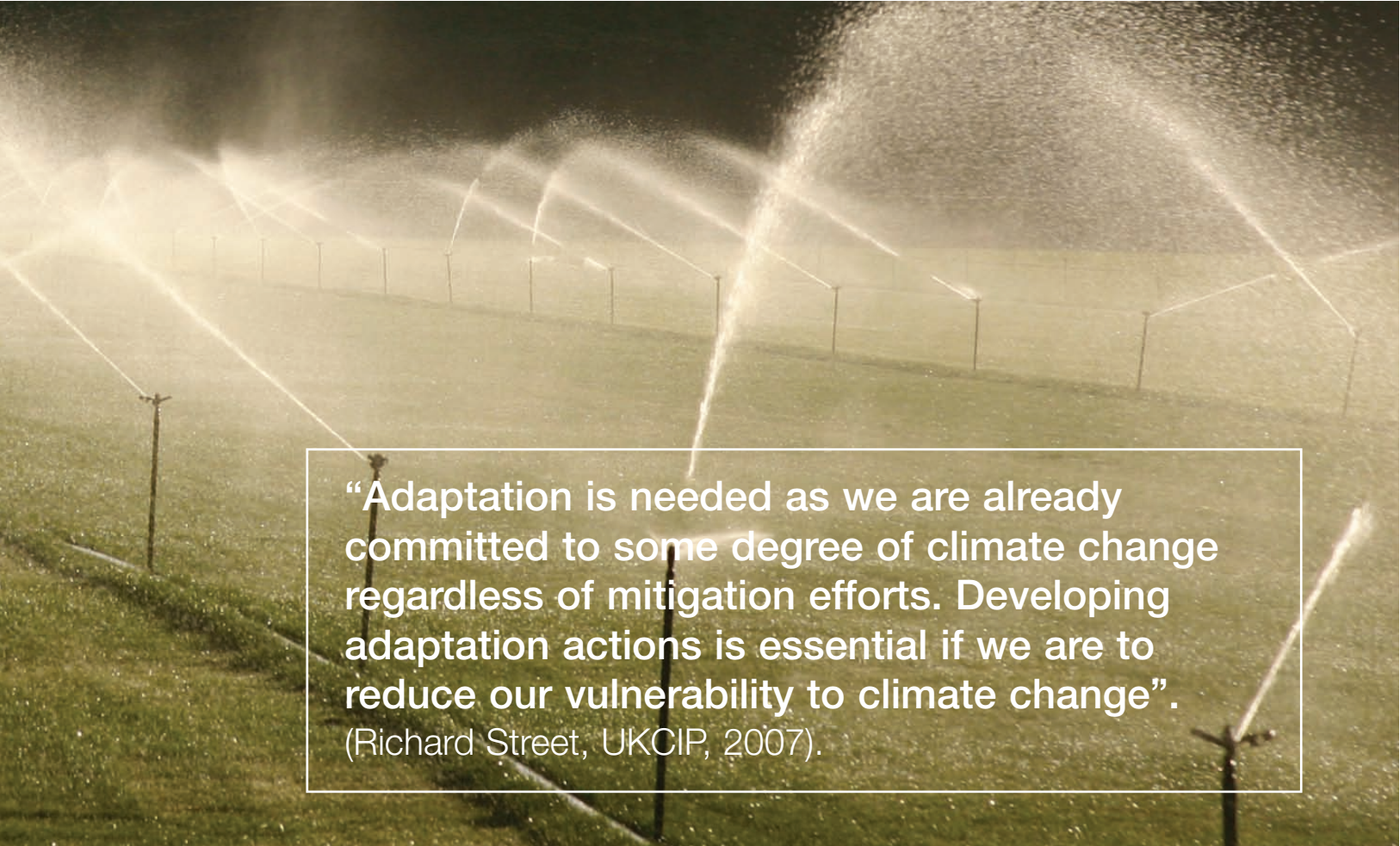
Options to reduce water needs

- Better irrigation equipment to increase irrigation application uniformity and efficiency
- Better scheduling to increase irrigation application efficiency
- Use weather forecasting to avoid rainfall losses
- Encourage deeper rooting of crops
- Introduce low water use or drought tolerant varieties
- Increase shading and wind shelter
- Introduce lower water use or drought tolerant crop varieties
- Decrease the irrigated area
- Improve soil structure to improve water retention

Options to obtain more water

- Purchase or rent land with water
- Convert to public mains water
- Obtain winter abstraction licence and build storage (individual or shared reservoir)
- Rainwater harvesting
- Re-use waste water from farm buildings
- Desalination of brackish or sea water

Growers should assess which are technically and economically appropriate, and then prioritise accordingly.



“Adaptation is needed as we are already committed to some degree of climate change regardless of mitigation efforts. Developing adaptation actions is essential if we are to reduce our vulnerability to climate change”.
(Richard Street, UKCIP, 2007).

Farmers were also asked whether they had already started adapting to water shortages, through for example, responses to changes in water regulation or drought. To obtain more water, the preferred choices were to convert to mains water, harvest rainwater from land and farm buildings, and/or re-use waste water. Many believed there was scope to improve irrigation efficiency through better equipment and scheduling. Whilst building a winter storage reservoir was a viable option for many, most were reluctant to invest in long-term strategic developments given the short-term economic uncertainty surrounding agricultural production.



Case study - farmer adaptation in North Norfolk

Crop yield and land use modelling suggested that farmers will still grow high value irrigated crops such as potatoes and field-scale vegetables. If water resources are limited, they will reduce irrigation of other crops and invest in farm reservoirs and switch from low flow (summer) to high flow (winter) abstraction. However, the extra costs will reduce net margins and make farm businesses more vulnerable. Farmer interviews confirmed that cropping changes and reservoirs are the preferred adaptations.



“Water is only going to become more expensive and less reliable. In my opinion, we should be filling all the holes we dig with water and not using them as landfill”

Robert Smith, Russell Smith Farms, Cambs.



Farmer adaptation - what others are doing

Many potential adaptations for climate change are already “no regret” options; they make sense now by solving existing water resource issues, and will then contribute to your future adaptability.

Building a reservoir

Many growers, particularly in Eastern England, are investing in on-farm water storage reservoirs, either individually or as groups. These are filled at times of high flow, principally in winter, and provide a secure resource for the following summer. Reservoirs are an expensive and capital-intensive investment that requires careful justification, but they can significantly increase the business asset value of the farm and provide additional resources and a welcome certainty for negotiating supply contracts. In some parts of the country, grants are available through the new Rural Development Programme for England (RDPE).

Benefits of building a reservoir

- Greater flexibility, security and control of your own water resource
- Additional abstraction in catchments “closed” to new summer licences
- A marketing advantage for your business
- Increased land asset value
- Slower filling and higher peak rates of application
- Reduced abstraction charges (winter charges are a tenth of summer charges)
- Reduced environmental impacts of abstraction, avoiding potential conflicts
- Additional income through amenity and conservation
- Additional income through water trading with neighbours

Rainwater harvesting and re-use of waste water are also worth considering – and these often work best when feeding into a storage reservoir.

"Once the water is in your reservoir it is yours to use as and when you wish"

– a comment from a farmer who has recently invested in a storage reservoir.

Start working together

Individual abstractors have very little negotiating strength and can become isolated, but by working together they can deal with water resource issues more effectively. Six “WAGs” (Water Abstractor Groups) have already formed successfully in the UK - four in East Anglia, one in Lincoln and another in Northumberland, and others are starting to form. Most have formed in response to water resource threats, and are based on catchment or aquifer boundaries, cutting across the normal crop sector boundaries.

Do you know the other water abstractors in your local catchment? They may have very similar problems, even if growing very different crops.

Benefits of being in a WAG

- Better communication with the Environment Agency over water resource and abstraction licensing issues
- Sharing of catchment and environmental data
- More efficient use of consultants (why pay someone again to reproduce the data they have already charged your neighbour for?)
- Opportunities for joint staff training (often using grants available to groups)
- Easier water trading
- Possibilities for joint licences and/or joint reservoirs



More sophisticated irrigation systems and scheduling tools do not necessarily lead to better irrigation performance. Key factors are the management skills and experience of the irrigator and his ability to use the equipment and tools effectively.

Many irrigators do not need all their water every year due to crop rotations. The group in Lincolnshire have combined their licences into one, and then distribute the water between themselves according to an agreed formula and seasonal need.

WAGs are a world-wide phenomenon

Thousands of local WAGs exist worldwide, for example in Mexico, Peru, the Middle East, India, Nepal, Indonesia, and the Philippines. Everywhere, farmers face water scarcity and they work together by making and following their own rules to share that scarcity in an equitable and sustainable manner. The main benefits are secure water rights, clearly defined, and easily protected by farmers themselves that minimise conflict over water. WAGs in the UK are beginning to show many of these features and this suggests they are evolving into institutions that could take on a greater and more influential role in local water management. The formation of new WAGs is likely to be accelerated by increasing concerns regarding climate change impacts on water security.



Making better use of water

It is a requirement for renewing abstraction licences that abstractors use water efficiently. But because of the cost of pumping water and providing labour and equipment, it also makes sound economic sense to irrigate efficiently. Saving just one application can be financially very beneficial. Conversely the costs of inefficient irrigation - poor quality fruit, scabbed potatoes - can be immense.

Effective and efficient irrigation requires good scheduling, good equipment, and, above all, good management.

Good scheduling requires understanding of your crop water needs and accurate knowledge of your soil water status on a day-to day basis. Many irrigators still rely on gut feeling, but most now use technical scheduling methods. These range from simple tensiometers to sophisticated electronic probes that monitor water contents at different depths and can show water movement in the soil profile. Which of the many methods is most appropriate for you will depend on your crop and soil, how critical your water resources are and whether you can actually use the data.

Good equipment is essential to apply water uniformly and adequately. Uniformities of 80% are usually considered “good” for field irrigation, but that still means applications are 20% wrong on average - and some places will be much worse. Modern systems such as booms, close-spaced solid-set sprinklers, and drip irrigation can potentially improve water application efficiency but much depends on how well they are managed. Achieving higher levels of uniformity and measuring what happens in the field will enable you to schedule water applications more accurately. This in turn can lead to water saving, reduced costs and better quality crops.

- ◀ Preparing for changes in future water availability. WAGs are encouraging their members to improve water efficiency through irrigation management training.

Useful contacts



Jerry Knox

Centre for Water Science
Cranfield University
Cranfield
Bedfordshire MK43 0AL
t: 01234 750111 ext 2756
e: j.knox@cranfield.ac.uk
w: www.cranfield.ac.uk/sas/staff/knoxj.htm



Keith Weatherhead

Centre for Water Science
Cranfield University
Cranfield
Bedfordshire MK43 0AL
t: 01234 750111 ext 2782
e: k.weatherhead@cranfield.ac.uk
w: www.cranfield.ac.uk/sas/staff/weatherheadk.htm



Melvyn Kay

UK Irrigation Association
c/o Moorland House
10 Hayway, Rushden
Northants NN10 6AG UK
t: 01427 717627
e: m.kay@ukia.org
w: www.ukia.org

Useful websites

- The UK Climate Impacts Programme (UKCIP)
www.ukcip.org.uk
- The Intergovernmental Panel on Climate Change (IPCC)
www.ipcc.ch
- The Tyndall Centre for Climate Change Research
www.tyndall.ac.uk
- Hadley Centre for Climate Prediction and Research
www.met-office.gov.uk

This publication can also be downloaded from the Environment Agency website, www.environment-agency.gov.uk

This publication forms part of a project funded by the Environment Agency. The project was implemented by Cranfield University in association with RTCS Ltd. The project manager for the Environment Agency was Ruth Meek (ruth.meek@environment-agency.gov.uk).

The authors of this publication - Jerry Knox, Keith Weatherhead (Cranfield University) and Melvyn Kay (RTCS Ltd) wish to make it clear that the content of this publication and the views expressed are those of the authors and do not necessarily represent the views or policies of the Environment Agency.

The authors acknowledge the Environment Agency for supplying irrigation abstraction data, the UKCIP for climate change (UKCIP02) datasets, and Lindsay Hargreaves (Elveden Estate), Mark Hall (Hall Hunter Partnership) and Geosynthetic Technology Ltd for providing selected photographs.

This document is printed using water-based inks on Revive, a recycled paper combining at least 75 per cent de-inked post consumer waste and 25 per cent mill broke.