Recent droughts highlighted the fragile nature of water resources for agriculture in eastern England. Climate change threatens to make matters worse. So what can we learn from the 2006 drought and what options are available to agri-businesses to adapt to changing water availability?

Coping with droughts and water scarcity
Climate and irrigation - getting the balance right

In England, in most years, rainfall alone is not enough to satisfy the water requirements for growing high quality fruit and vegetables. In 2006, drought conditions seriously threatened production. Irrigation can make up the shortfall but the amount needed varies from year to year. Good irrigation management can overcome the vagaries of our climate to produce premium quality yields – it is all about getting the soil water balance right.

Driving irrigation demand

Rainfall (R) and crop water use – known as evapotranspiration (ET) – are the two climate drivers of irrigation demand (Figure 1). Understanding these and their influence on soil water is the key to timely and adequate irrigation as well as justifying reasonable need for abstraction licence renewal particularly for the drought years.

During the summer growing season, crops are sensitive to the cumulative balance of rainfall and ET. When rainfall exceeds ET then excess water drains from the soil. But when ET exceeds rainfall irrigation is needed to make up the shortfall.

Most farmers routinely measure rainfall on-farm on a daily basis. Often several rain gauges are recorded at different locations across the farm because of the highly variable nature of rainfall. However, few farmers measure ET. This is because until recently it has been difficult to measure ET directly. It is a complex mix of climate variables such as temperature, solar radiation, wind speed and relative humidity. Nowadays more farmers are beginning to measure ET. Modern computers and software have simplified the calculations and automatic weather stations have taken the drudgery out of collecting all the data. Developments in atmometers, such as the ETgage™, have also simplified the direct measurement of ET in much the same way as rainfall is measured using a rain gauge.

ET does not vary much across a farm or indeed between neighbouring farms in the way that rainfall does. So one atmometer can provide reasonably good data for several square kilometres.

Measuring our changing climate

Measuring Potential Soil Moisture Deficit (PSMD) is a good way to measure the variability of our climate, particularly during the summer months when it is useful for assessing irrigation demand from year to year (Figure 2). PSMD is calculated from rainfall and evapotranspiration (ET). The soil works just like a bank account. Rainfall is an input into the account and ET from the crops is the output. When rainfall exceeds ET, as it often does in the winter, excess water drains away. But in the spring and summer ET often exceeds rainfall and when this happens a moisture deficit builds up in the soil. This accumulating deficit is the PSMD. It is usually calculated on a daily basis and is measured in millimetres (mm).
PSMD does not take account of individual farm soils or the ET for specific crops. Nor does it take irrigation into account. Rather it is a simple measure of the changing daily balance of rainfall and ET. Figure 3 is an example of PSMD in 2002 for a farm in Norfolk. At the beginning of the year, there was no deficit because winter rainfall exceeded ET. But as spring progressed a deficit started to build up. During the summer there was very little rainfall and the PSMD increased steadily to 190mm in early August before heavy rainfall gradually began to reduce it again. By the end of 2002 the PSMD was back to zero.

It is the maximum PSMD that we use as a simple measure of climate and we can use it to compare years with very different weather patterns from an irrigation water management viewpoint.

Justifying reasonable irrigation need

Drought years like 2003 and 2006 are times when irrigation is most needed. They also correspond to years when water resources are under severe stress. So accurate information about what happens in drought years is crucial for future irrigation planning and particularly for renewing abstraction licences.

PSMD, measured over several years, can be used to demonstrate that abstractions are reasonable particularly in the driest years when irrigation demand is greatest.

The case study from a Norfolk farm illustrates how this can be done (Figure 4). PSMD values from 2000 to 2006 and corresponding amounts of water used for irrigation show the general trend of water use on this farm. Each year the amount abstracted is different and this reflects the particular climate during the year. As PSMD increases so does the amount of water used for irrigation.

In 2003 and 2006 when the summer was exceptionally dry, large volumes of water were used for irrigation. In 2000 and 2001 much smaller quantities were used because these were much wetter summers. There is nothing surprising about this result – but it clearly demonstrates that water is properly managed on this farm and it explains how local climate variations affect abstractions from year to year. The nearer the points are to the straight line the better the irrigation management, although there will be some variability because of other practical constraints such as cropping and the availability of irrigation water and equipment. If one or more points are some distance from the line this should trigger a closer look at how water was used in that year to see if there were good reasons for the difference and whether there are opportunities for improvement.

Figure 4 not only demonstrates wise use of water from year to year on this farm, it also clearly shows how much is needed in dry years. This is invaluable information both for planning for future droughts and as evidence of ‘reasonable’ need when renewing an abstraction licence.

Climate or weather?

Not many of us go through the day without commenting on the weather. But weather is different from climate. Weather is about day-to-day changes in temperature, wind and rain, whereas climate is about the prevailing conditions over a much longer time span, usually decades or centuries. We live with the sudden changes in weather from day-to-day but our climate has always been gradually changing, mainly due to natural causes. What we are now seeing is more rapid changes in climate which scientists believe is predominantly man-made.
The hallmarks of drought

Droughts usually start long before they are really noticed and the 2006 drought was no exception. Indeed it was a legacy from a long period of below average rainfall starting in the winter of 2004 and culminating in the late summer of 2006. It was centred on south east England and severely affected water resources.

Not everyone experienced the same level of drought; the impact was variable, being less severe in some places than others. Meteorological records show that the north-west, west, and south of England was generally drier than the north and north-east. Although in most areas rainfall was below average throughout the 2005 winter and 2006 spring and summer, most areas also experienced short periods of high rainfall in late spring and late summer. ET across the region was typical for the majority of the year but well above the long term average during June and July. This was particularly the case across Bedfordshire, Cambridgeshire, Lincolnshire, Suffolk, and Essex.

Impacts on groundwater

In eastern England, rainfall provides recharge for the two main aquifers that run in a SW – NE direction across the region. The Jurassic Limestone in the north is monitored by the Environment Agency at Hanthorpe and the Chalk aquifer, in the centre of the region, is monitored at Smeetham and Chesterford (Figure 5).

Groundwater levels in April are used to indicate whether there is a drought or not. If the water levels are below the average water levels for April this indicates a potential drought. But if the levels are below the average for August then a full drought is declared.

In April 2006 a potential drought was indicated in the Jurassic Limestone. But groundwater levels were rising at that time and were close to normal throughout the summer. So groundwater abstractions were not restricted. Only in August did water levels begin to fall below normal, but they recovered again in the winter months.

The situation was more severe in the Chalk aquifer. Water levels were at or close to the August average and so a drought was declared in April. Water levels remained below normal throughout the summer. But they began to recover in the autumn and were approaching ‘normal’ by October 2006.

Impacts on river flows

The Environment Agency monitors river flows at a number of sites including the Witham (at Claypole), Bedford Ouse (at Olford), and Chelmer (at Springfield) and compares flows with monthly long term average flows to assess drought.

Flows were normal at all three monitoring stations at the end of the 2005 summer. But by January 2006 river flows were only 30-35% of the average for the time of year in the Chelmer and the Bedford Ouse.

Figure 5 – Groundwater aquifers and monitoring boreholes
Drought planning

Each year the Environment Agency assesses the water resource situation and shares its findings with the government, water companies and farming community. In 2006, an early indication was given that summer prospects in southern and eastern England were poor. In April, the Agency appealed to farmers in stressed catchments to save water, providing guidance on how this might be done, but as the hot weather in June and July took its toll formal restrictions were imposed. Over 800 licences were subject to formal restrictions (Section 57 or licence conditions) and many more voluntarily saved water.

Coping with droughts and water scarcity

which was notably low. Flow in the Witham was below normal. By March, flows returned to normal in the Witham but remained below normal and notably low in the Chelmer and Ouse until the high rainfall in April brought flows back to normal in May. Flows in the Witham and Ouse remained normal for the rest of the summer. However flows in the Chelmer were below normal between June and August.

Impact on soil moisture

Soil moisture generally remains at field capacity during winter and spring and falls below field capacity during summer and autumn. However soil moisture does vary from place to place depending on local rainfall, ET, and soil type.

In 2006 soil moisture was generally below the long term average across the region. During late spring, heavy rainfall increased soil moisture to more normal levels but the high ET throughout June and July led to soil moisture deficits well above the long term average. Even though ET was high in August, unusually heavy rainfall across the entire region reduced the deficit to a level well below the long term average for the rest of the year.

Putting 2006 into context

So where does the 2006 drought rank among major UK droughts? England has experienced several major droughts in the last 40 years and the impact of these can be seen in the PSMD values for a site in eastern England (Figure 7).


Figure 6 – Main rivers and monitoring stations

Figure 7 – Maximum PSMD values for a site in eastern England between 1962 and 2006
Adapting to a changing climate

The 2006 drought did not seriously disrupt irrigation abstractions in the eastern region but it served to highlight the fragile nature of water resources for agriculture. Climate change can only add to the concerns over future water supplies. So it is prudent for farmers to be fully aware of the impact of droughts and how to adapt to them in the future.

Coping with droughts and water scarcity

Climate change

Our climate has always been changing, mainly due to natural causes. But since the 1900s the rapid changes in climate and those predicted to occur over the next century are thought to be mainly man-made. What is not widely appreciated is that much of the climate change we can expect over the next 30 years has already been determined by existing emissions and the inertia in our climate system. The UK Climate Impacts Programme (UKCIP) suggests that we can expect higher summer temperatures, lower summer rainfall, and more evaporation creating greater pressure on water resources. The UKCIP predicts a 10% reduction in summer rainfall by 2020 rising to 40% by 2080. ET is expected to increase by 40% by 2080. In winter, rainfall increases of 5-25% are predicted with consequent increases in flooding.

Climate change will have a direct impact on PSMD and hence on irrigation demand. The baseline map shows the long term average PSMD between 1961 and 1990 (Figure 8). The zones where irrigation needs are greatest include parts of Suffolk, Kent, areas in West Midlands, Nottinghamshire, and the south coast. Predictions for average PSMD for the 2020s, 2050s, and 2080s show how the drier zones generally increase in area and spread from the south and east towards the north and west. By the 2020s, the irrigation needs of central England will be similar to that 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.

Irrigation demand

The underlying demand for irrigation water is already growing at 2-3% each year. Climate change will add to this by affecting plant physiology, the soil water balance, cropping patterns, areas irrigated, and the irrigation methods used.

The impacts of increased levels of CO₂ on irrigation demand are as yet unclear and there are many feedbacks which are difficult to quantify (Figure 9). Demand forecasting suggests that climate change may increase dry year irrigation demand by around 30% by the 2020s and by about 55% by the 2050s. The greatest increases are likely to be in the south-east and the Midlands.

Adapting to climate change

Dealing with the vagaries of summer weather has always been a challenge for farmers, particularly in the UK. But the greater uncertainty in our seasonal weather patterns will mean agribusinesses need to adapt and consider both short-term coping strategies as well as longer-term developments to reduce their vulnerability to changing water availability.

How growers actually 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. There are two main options 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 consider trading your abstraction licence.

Climate change

Figure 8
Predicted changes in PSMD values from the baseline (long-term average) to the 2020s and 2050s (high emissions scenarios).
Climate change is not a new phenomenon

“It is strange what weather we have had all this winter; no cold at all; but the ways are dusty, and the flies fly up and down, and the rosebushes are full of leaves, such a time of the year as was never known in this world before here.”

Samuel Pepys’ Diary 20th January 1661

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Coping with droughts and water scarcity

Human activity

- Changing levels in atmospheric CO₂ concentration
- Climate and weather

Stomatal resistance

Crop growth rate

Changing patterns of rainfall and evapotranspiration

Changes in crop cultivar

- Growth rates
- Areas irrigated
- Depths applied

Increase in irrigation water demand

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
- 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
- Obtain high flow abstraction licence and build a storage reservoir (individual or shared)
- Rainwater harvesting
- Re-use waste water from farm buildings
  - As a last resort:
    - Convert to public mains water
    - Desalinate brackish or sea water

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

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.

Our average years will become more extreme. PSMD is a good indicator of agroclimate (Figure 7). The highest values of PSMD occur in the drought years and are the periods of highest irrigation demand – 1975-76, 1989-90, 1995-96 and 2003.

An ‘average’ irrigation year with our present climate is 1983. But with climate change, the average irrigation year, assuming the 2020 medium high emissions scenario (2020MH), will be more like 2003. For 2050MH the average year will be similar to 1989 – one of the driest years on record. So in future our average years will become much more extreme and similar to what we now refer to as “very dry” years. This will have major implications for designing irrigation systems and water distribution networks.
Copies of this booklet can also be downloaded from the UK Irrigation Association website www.ukia.org

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Acknowledgements
The authors acknowledge the Environment Agency for provision of water abstraction data, modelling and GIS mapping by Quentin Dawson and Juan Rodriguez-Diaz, and Julia Knox and Tim Hess for supplying selected photos. The map shown in Figure 6 was derived from the BGS 1:625,000 Digital Geological Mapping, under permit IFR/101-11C. British Geological Survey © NERC. All rights reserved.

Note: This booklet is for information purposes only. Always seek independent professional advice when planning irrigation developments.