SYNTHESIS REPORT

Facing the future together

REPORT FROM THE FARMING AND WATER ACTION GROUP

THE UK WATER PARTNERSHIP

Global Food Security

Sustainable, healthy food for all

Contents

This Synthesis report was produced by Theresa Meacham and Tim Benton from the Global Food Security Programme. The report synthesises the work of three working groups focussing on: 1) Agriculture's impacts on water quality, 2) Agriculture's impacts on water availability; and 3) Water use in our food imports. These working groups were set up by the Global Food Security Programme (GFS), under the auspices of the UK's Water Research Innovation Partnership (UKWRIP), which has now evolved into the UK Water Partnership, launched in February 2015. Contributions for this report were received from the authors of the three working groups, outlined below:

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This and the companion reports represent the views of the working groups not the organisations from which they work.

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Summary

In a world where there is increasing demand for food and water, and environmental change is impacting on weather and the availability of land and water, there are significant and intensifying challenges for both the agri-food and water sectors. Our aim was to explore the links between water and food production and the challenges for delivering both food and water to society, in a sustainable way. We identify issues, evidence gaps and potential solutions to reduce the tensions towards delivering more food, more water and good environmental conditions. This synthesis report is supported by three detailed reports, which explore the links between: 1) agriculture and its use of water; 2) agriculture and its impact on water quality; and 3) the impact of sourcing our food from overseas, on water in the producing countries.

From these three detailed reports, which identify the challenges for water and agriculture, and provide recommendations for policy makers, industry, practitioners and academia, a number of cross-cutting recommendations arise and are outlined below:

1. Resilience of the food system

Key Findings:

- Extreme weather events (e.g. flooding and drought) will increasingly influence agriculture's water impacts and become more important than averages in the future. Improvements to both forecasting and planning capability are therefore needed.
- Water quality and demand issues are long term issues, which develop over the long term and are also solved or addressed over the long term. For example, public water supply reservoirs can take up to 10 years to get planning permission, which can be a major long term barrier. Not recognising the timescales involved, could result in poor decisions for the future.
- The availability of products sourced by retailers overseas will shift in the future due to changes in climate. This poses risks for the UK supply chain and, by supplying the UK; a water-stressed area takes on risks for its own security. Identifying and managing these risks is a challenge for complex supply chains (where a supermarket may source many thousands of lines).

Recommendation 1: There is a need to further develop long term planning for changes in water usage and water availability in the future, here and in our overseas supply chain. This needs to involve better predictive ability from academics and Government, better management from land managers and better management strategies for the future along the supply chain. Public policy can provide key incentives to build resilience.

Recommendation 2: A key component of climate change is changes in the incidence and patterning of extreme weather. **Managing for extreme weather**, and the uncertainties inherent in predicting changes in weather patterns, is arguably a greater issue than planning for the change in average conditions (such as on average drier summers). Greater linkages are needed with the emergent climate services community.

2. Integrated thinking

Key findings:

- Food, water and other ecosystem services supplied by land interact, requiring this nexus[2] to be explicitly recognised and managed for the benefit of all stakeholders.
- Whilst aspects of the land-water system are well understood, this understanding often remains relatively siloed. Information needs better integration especially to understand the inherent trade-offs that may underlie societal choices around agriculture versus water versus the environment.
- European land-and-water policy is influenced by a number of different frameworks and directives (e.g. Water Framework Directive (WFD), the Common Agricultural Policy (CAP) and the Habitats Directive), which are not always well-aligned. This can make navigating the policy landscape difficult for land managers (and their advisors). Aligning policy instruments, or translating them into clear and consistent land management advice to aid management decisions, would be beneficial.
- To build resilient supply chains, supermarkets increasingly need to be forward-looking, taking into account that environmental change will impact upon production, and in different ways in different places.

Recommendation 3: Many of the risks associated with food-and-water management can be predicted via using integrated models at local to global scales, and from short to long temporal scales. Such models can be used to support public and private decision making. **There is therefore a need to improve modelling capacity, allowing choices to be explicitly explored.** This requires increased investment (public and private), supporting the development of integrated models for understanding and decision support, data management infrastructure, and human capacity for their development.

3. People and places

Key findings:

- Expertise in agriculture, water and wider environmental issues exists in silo (both sectorally and disciplinarily, as well as across UK regions and between the UK and overseas). This applies equally across industry, government and academia, so greater effort is needed to foster interdisciplinary communities where knowledge of the whole-system can be pooled to aid management decisions.
- Agricultural-water interactions are also heterogeneous in terms of spatial and temporal scales, so solutions to issues often have a place- and time-dependency that requires "smaller scale" solutions than often imagined. Equally, long lag times between management and its effects require concerted long term monitoring and mitigation efforts.
- Should it be left to the farmer to decide on key water management issues? The level of water management expertise is variable across land managers and the amount, and complexity, of the available policy and advice information means that they need help making decisions. There is therefore a need to empower farmers to manage their land based upon sound knowledge. A benchmark for farm management's water quality outcomes could greatly enhance water co-benefits from agricultural practice.

Recommendation 4: Many of the challenges involved in managing for the triple outcomes of water and food security and environmental conditions are inherently trans-disciplinary and require expertise in agriculture, soils, water, aquatic systems and biodiversity as well as the allied industries and policy communities. **To facilitate knowledge exchange and co-design of research to address knowledge and understanding gaps, a discussion forum or knowledge network should be established.** This can also advise and influence the future direction of public and private water policy in relation to agriculture. The network would act as a hub of the best available knowledge and could expand on the 'community of practice' approach using the types of approach seen in the Demonstration Test Catchments, Catchment Sensitive Farming and Water Friendly Farming projects, providing a platform for sharing best practice between industries and also feed into Government and extension services.

Recommendation 5: At the farm scale, farmers should be further empowered to make informed decisions about water usage on their land to bring about catchment scale improvements in water quality and availability. **Farmer empowerment can come through sharing knowledge and building peer-to-peer networks between farms, within an area, and between farmers and other stakeholders in water and the environment.** The knowledge network should help facilitate such local network building and be able to *deliver impartial, authoritative and evidence based information to facilitate simultaneous management for food, water and the environment*.

4. Consumer engagement

Key findings:

- There is considerable societal value in managing water, producing food and maintaining a healthy environment. All are linked in complex ways, although this is often not transparent from a citizen's perspective, which may rely on all aspects in different ways. The food we eat requires water, and it impacts upon water in ways that affect others and the environment – whether the food is farmed here or overseas.
- Promoting knowledge of the issues, fostering consumer understanding of the connections between them and supporting changes in practice, may increase the way we appreciate food and water.

Recommendation 6: We therefore recommend that **all actors – academia, industry, policy, advisory – work to make water-food-environment science accessible to all.**

The global challenge

World demand for food is expected to rise by 60 – 100 % by 2050[1], driven by growing population and changing diets. Any intensification of food production on the existing area of agricultural land is likely to increase pressure on water resources. This can come about via increasing demands for water for producing more, as well as production's impact upon the quality of water in the environment. At the same time as the demand for increased food production, there will be changes in weather patterns and an increase in extreme weather events, such as droughts, heat, and intense rainfall leading to floods. In the UK, the droughts of 2010-11 and floods of 2013-14 indicate that we have to plan for both increasing and decreasing water availability, especially because South East England is one of the most water constrained areas in Europe.

The impact of climate change on agriculture will vary across the world. But a globally-linked trading system means that a reduction in yields in some places due to climate change (e.g. Africa and Asia), will send economic signals to intensify production in other places, where there is potential for an increase in yields (e.g. NW Europe). It is therefore expected that strong pressure will be placed on UK land management to increase food production in the future. Furthermore, climate change is creating changes in the weather differentially across the world, and this will increasingly undermine the resilience of the supply chains that provide significant produce (especially fresh produce) for our tables. Understanding these risks is therefore an important element for understanding the relationship between food and water.

Unless carefully navigated, there are potentially strong trade-offs from intensifying agriculture impacting on the quantity of water used and the quality of water in the environment, and the challenges of climate change and an increasing demand for food may strengthen these trade-offs. Managing the land jointly to mitigate the trade-offs and create joint benefits for food and water-systems in a sustainable way, requires new ways of working. Different sectoral (i.e. industry, government, policy and academia) and disciplinary (e.g. environmental, modelling, agricultural, engineering) communities will be required to work together.

Our aim was to explore the links between food, water and the environment. We identify the challenges in the area, the routes to navigate these challenges and also any knowledge gaps which currently exist. This report summarises three detailed reports, written by expert cross-sector working groups, which explore:

- the link between farming and the use of water, focussing on water use and availability on farm, how access to water is and can be managed, and how this interacts with the demand for water from the water industry and the environmental needs.
- the link between agriculture and the impact on water quality, affected via e.g. silt deposition in rivers, or agro-chemical run-off.
- how to understand, measure and manage the water used in the production of food we import from overseas; in particular, how do we identify and manage risks, to build more sustainable and resilient supply chains?

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Looking to the future

The 10 year vision

The food-and-water system needs to adapt to meet the demands that will be placed upon it in the future, in a sustainable way. A ten year vision is:

- That planning for the short and long-term are aligned. Over the long term, there will be increased demand for both food and water. At the same time changes in the weather associated with climate change will impact on the production and supply of both water and food. Joint and dynamic management for food, water and other ecosystem services is required.
- For decision making (at all levels: from consumers, to farmers, as well as public and private policy) to be based on greater awareness of the value of water and food, and their inter-dependence.
- That the knowledge gaps, especially around management of water quality and managing supply-chain risk, are significantly reduced and that practice changes as a result.

Overview of the three areas

The following key questions have been formulated from the working group reports.

Key question 1: *Is it possible to balance high aspirations for environmental water quality, with significant growth in agricultural production to meet food security objectives and provide viable livelihoods for farmers?*

In recent decades, a higher proportion of pollution has come from agricultural sources than the first two thirds of the twentieth century. This is a result of a reduction in the amount of effluent coming from industrial sources and human settlements into watercourses, alongside an intensification of agriculture. Agricultural intensification impacts on water quality through the release of nutrients (as a result of soil management and fertiliser application) and other chemicals (e.g. pesticides) into the water environment, through biological contamination (e.g. from microbiological organisms in manure) and via soil being eroded and washed off farmland. However, the quality of the UK's surface and groundwater is affected by a multitude of factors including geology, soil type, topography of the landscape, recent weather conditions, seasons as well as land management. This local context dependency means that simple, quick, "one size fits all" solutions may not apply, as water quality and quantity varies greatly.

In the UK, around 60% of nitrates and 25% of phosphorous in water bodies are estimated to have farming origins[3,4] and it is thought that 75% of sediments polluting water bodies have derived from farming.[5]

The impact of these pollutants is that currently only 24% of water bodies in England and 36% of water bodies in Wales meet 'good ecological status', as defined by the Water Framework Directive (WFD). In Scotland, 65% of water bodies are deemed good or better, but for the 35% which are failing agriculture is deemed to be a major pressure[6]. Finally, in Northern Ireland 22% of water bodies have achieved good status.[7]

Ways to reduce the impact of farming operations across multiple scales

Agricultural pollution can originate from either point (e.g. from a slurry store) or diffuse (e.g. run off from farmland) sources. Often it is difficult to attribute diffuse pollution to a specific sector or activity and the impacts of pollution can occur some distance from the source. The reason for this difficulty to attribute the source of pollution is that the processes by which nutrients and pollutants leave the land are complex, involving an interaction between locality (e.g. slope, rainfall, soil type), management (ploughing, input regimes, field margin management etc.) and a time lag.

Climate change may impact upon water quality by impacting on the volume of water flow, pathways for water movement, and the associated transfer of pollutants from agricultural land to water bodies. Future policies need to include requirements to manage land appropriately to reduce these impacts. Climate change may also impact upon global agricultural productivity, with a likely drive towards intensification of production in the future. Finding ways for growth in the farming sector, whilst reducing its impact on water quality (and other environmental services) is a challenge.

Tools for incentivising better farm management

Water policy in the UK operates at different scales, such as at the European and national levels, the thinking and planning scale of river basins and catchments and the 'doing' scale of sub catchments, water bodies, farms and sites. To improve communication between the different scales of water policy being undertaken across the UK, being able to develop a single message for each organisation could help develop shared actions.

At the European level, the WFD and Common Agricultural Policy (CAP) payments provide substantial opportunities for facilitating sustainable farm practice. However there is evidence that some regulation or stewardship measures are less effective than they could have been through a lack of robust implementation[8] and targeting. The EU Nitrates Directive also stipulates the permitted amount and timeframe of nitrate applications (e.g. manure and fertiliser). For pesticides, the UK's National Action Plan advocates non-regulatory

BOX 1: Maize production and water quality

Maize production in the UK has expanded rapidly from 1,000 ha in 1970 to over 160,000 ha in 2012. It is primarily grown as a fodder crop on dairy farms but increasingly as a feedstock for anaerobic digestion.

Maize is a comparatively risky crop from an environmental perspective. It is spring sown and harvested late in the year when soils are more likely to be saturated. These factors make maize-fields particularly susceptible to soil compaction and erosion, which can lead to water pollution, sediment loss and flooding, and an increase in greenhouse gas emissions.

BOX 2: Catchment management

An area of agricultural land does more than produce food and impact upon water, it provides many services to society (from biodiversity management, to recreation and amenity uses, and provides cultural values). Many of these services are delivered at a large spatial scale: that of the catchment or landscape. However, most land management is undertaken at the field or farm scale. Farmers base management decisions on a wide range of environmental, economic and social factors. It is important, when developing land management interventions to protect water resources or reduce flooding, that wider agricultural and environmental outcomes are considered. In many cases trade-offs exist whereby an intervention to address one problem exacerbates another. For instance, whilst reducing manure spreading in the winter is likely to reduce water pollution, warmer summer conditions are likely to increase ammonia volatilisation and air quality problems. Government considers many such issues when designing water management policies.

Whilst some farm management interventions to reduce pollution risk and ensure efficient use of water, soil and nutrients constitute 'good practice' and should be universally adopted, the impacts that farming has on water resources are highly spatially variable.

In many cases, bespoke solutions that go beyond good practice are needed to address specific problems. This requires planning, mobilisation of resources and coordination at a catchment scale.

To inform policy making at the national level, as well as making catchment management decisions at the local scale, a holistic understanding of water management is needed. Key to this is an understanding of the many factors influencing decision-making by farmers and the governance of catchment management, coordinating knowledge and resources from the wide range of groups that have an interest in water. The Catchment Based Approach[20] launched by Defra and the Environment Agency in 2013 provides a policy framework to support collaboration amongst such interest groups.

Knowledge streams from many natural and social science disciplines need to be brought together to inform catchment management policy and practice. The Demonstration Test Catchments (DTCs)[21] have brought together networks of researchers from relevant disciplines through catchment-scale studies as a way of generating such interdisciplinary learning.

approaches as much as possible via an initiative called the Voluntary Initiative[9].

Across England and the Devolved Administrations, a number of regulatory approaches are being, or have been implemented, to reduce pollution from rural sources. Bottom up approaches have had some success, however these projects are often somewhat ad hoc and rely on dedicated individuals with vision and an entrepreneurial approach. Catchment partnership approaches, are now central to UK and devolved Government approaches to water quality (see 'Catchment Management' case study box). This is showing notable success in Scotland where the majority of farmers are changing practice as a result of the approach taken[10].

What requires more work and new thinking?

Despite the existence of a number of excellent examples of good farm and management practice, such measures are still only applied over limited areas. This means that there is scope for further water quality improvements. A number of drivers may lead this, for example economic factors which cause a rapid change in practice (e.g. fertiliser use has declined as prices have increased). Alternatively, improving the accuracy of weather forecasting will also assist in allowing farmers to apply nutrients at the right time, reducing losses through overland flow and leading to both economic and environmental benefits.

There is a need to help widen the uptake of new applications on the farm and encourage acceptability of certain practices (e.g. finding alternative re-use points for lower grade water – such as using it for non-food crops, like biofuels). Demonstrator projects have been successful for this and may benefit from being more joined up in the future (see 'Catchment Management' case study box). The ESRC has recently launched a three year food-water-environment Nexus project, to foster debate, innovative research and practical collaborations across the Nexus.[11]

Currently there is no framework for translation of science into policy and action on the ground with regard to agriculture, the environment and water in the UK. New measures are therefore needed to address this. A free advisory hub, setup for knowledge exchange to deliver a clear set of messages that are informed by science, policy and demonstrator projects/farms could be a way to increase uptake of best practice.

The UK landscape is spatially variable and as such, regions differ in their capacity to contribute to production and also the resulting environmental costs. 'Smart' landscape planning to make the best of the local context[12] could help to deliver both agricultural productivity and other ecosystem services, like water or biodiversity. Long term monitoring of water quality may help to support process understanding and the impact of environmental change. These new datasets, alongside developments in modelling capacity, will provide new opportunities for understanding and mapping options and risks and the interaction between management for food and its impacts on water.

Key findings from this report included:
Overall, there is significant scope, via management of land for both food and water outcomes, for intensive farming to co-exist with high water quality and therefore sustainable water management. However, from considering the key question, a number of issues are identified:

1. Decisions involving agriculture and water need to be made based on a long-term perspective with appreciation of the time it takes for policies to have a sustained impact.
2. We need unified predictive models encompassing all key aspects

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of agriculture and water management that inform future policy and commercial interests.

3. There needs to be greater recognition from policy makers and industry that different solutions will be needed in different agri-water systems.
4. Long-term support for research infrastructure is required to measure and analyse data necessary to inform decision making.
5. Farmers need better information with which to make informed management decisions regarding water management.
6. There are existing solutions to some problems and this knowledge needs to be effectively disseminated with appropriate incentives for implementation to have maximum impact.
7. We need greater collaboration between researchers, industry, advisory services and policy makers, with the necessary framework to deliver effective joint working and the opportunities to share best practice.

Key question 2: *Are there tensions between the availability of water and the production of food in the UK, and how can they better be navigated?*

The pressure on the UK water supply is increasing, mainly due to an expanding population, particularly in the south-east of England. Climate change is also creating one of the main long term pressures on water availability in the UK and is expected to intensify the hydrological cycle, leading globally to more floods and droughts on average, though not in all regions. The pattern of change over the 21st century is not expected to be uniform, with the contrast in precipitation between wet and dry places and wet and dry seasons expected to increase.

The UK is generally perceived to be wet; however, water availability varies not only from place to place, but also from time to time. In some places and at some times, water availability is constrained. In addition to there being a gradient of rainfall from west to east England, there is also an increase in the population density in the South East of England, meaning that there is greater demand.

Agricultural Irrigation

Although the total volume of water used for agricultural irrigation is small relative to other uses, irrigation potentially has a large impact on water resources. Potatoes and other vegetables account for the majority of water used for irrigation in England and Wales (25% and 54% of irrigation water use, respectively)[13]. Water use is consumptive (i.e. water is not returned to the environment in the short term) and is concentrated in the months and years when resources are most constrained and also in the driest areas of the country (mainly in East Anglia, South East and parts of the East Midlands). As a result, in some dry summers, irrigation of food crops can be the largest abstractor in some catchments.

To ensure that the expectations for food production, water use and the environment can be met over the rest of the century, effective management of water supplies is required. Better forecasting of extreme weather events and their evolution is needed. This includes extreme rainfall and flood risk but also greater knowledge is required around the interaction between heat, drought and the length of time for groundwater to recover in terms of recharge. Towards this goal, a five year UK droughts and water scarcity cross council initiative was established in 2013[14]. Efficiencies in water use should also be sought. for example, in the horticultural sector, sensors can be used to determine the irrigation needs of covered crops.

There is currently an insufficient understanding of how agricultural practices could be adapted to cope with changes in the weather. There is also insufficient understanding of how the intensification of farming methods and new ways of production impact on the environment, by affecting water availability, both through the impact of usage and water management.

Water for livestock

Livestock farmers use water for drinking water, washing animals, cleaning yards and cleaning parlours. It is possible to reduce the volume of water consumed through new housing and adopting new production techniques. There is also scope to reduce water losses through maintenance (e.g. fixing leaks in water troughs) and good

BOX 3: On-farm reservoirs

On-farm reservoirs can ensure that the resilience of water levels can be maintained. J.B Shropshire & Sons Farms, is a family owned business in excess of 4, 000 ha of land in East Anglia. Since the 1990s, the company have constructed five reservoirs, giving access to around 2 million cubic metres of water. This has been necessary to support their specialist salad and vegetable crops such as bulb onions, Little Gem and Iceberg Lettuce, celery and potatoes, wheat and sugar beet.

These reservoirs have been strategically situated next to the water courses of The Old West, The River Cam, The Little Ouse, and within easy access to Farms at Stretham, Barway, Littleport, Prickwillow & Shippea Hill. Water is also taken under licence from the main rivers in the area. Without the security of stored water, cropping the fields with salad crops would be too risky for the business to undertake. In the future, to ensure that the future resilience to low water levels can be maintained, on-farm reservoirs may be made larger than currently required.

Technology and innovative farming methods are an important part of on-farm reservoirs. Irrigation scheduling is used to match irrigation with crop requirements, with trained agronomists and moisture sensors. The farm also uses drainage channels, mobile pumps and irrigation booms to deliver water to the field.

management (e.g. trigger sprayers when washing down) or the reuse of cooling water.

Rainwater collection may be a more viable alternative water source for livestock farms than extraction or using mains water, as many are located in the wetter parts of the country, have large areas of surfaces and roofs and lower quality water can be used for washing-down and cleaning. However, whilst this may reduce on-farm water costs it does not create 'new' water as the water captured may otherwise have contributed to streams or aquifers. Livestock farms still require an adequate mains water supply to meet water requirements during periods of low rainfall and drought.

Reservoirs and water transfers

Reservoirs are increasingly viewed as the best way to secure reliable water supplies for agricultural irrigation and are the preferred adaptation for coping with the increased risk of water scarcity. They provide a secure water storage mechanism, because once water is in the reservoir, the farmer can plan the following year's cropping and their supply contracts with supermarkets and processors with much greater certainty. They can also improve water supply for domestic and environmental uses by reducing abstraction during summer months. Larger reservoirs may help to attenuate peak flows when flows are high and maintain low flows during dry spells.

Investing in storage is always a more expensive option than direct summer abstraction, even though summer water charges are ten times higher than in winter. Most farmers find it difficult to justify costs in relation to returns they expect from the investment. Most reservoirs being built are supported by government grants in order that they are viable financially, or they are financed as part of an aggregate extraction package.

Water transfers are where there is an artificial movement of water from one water body to another. They can be an effective way of providing water for agriculture and public water supply, with the particular benefit of moving water form an area of surplus to an area where water is scarcer. Building a new transfer is expensive, usually requiring extensive engineering works over a large area. So, determining whether new transfers are worthwhile depends on the costs and benefits of the alternative sources of water. There is a need for better understanding of opportunities to reallocate water between different uses.

Managing water availability

Water catchments provide a range of important ecosystem services to society as a whole, not just to grow food. For example, fresh water for drinking, raw water for use in industry, flood prevention, leisure activity destinations and habitat for biodiversity are all important services. Any change in the behaviour of one part of this complex system, can therefore lead to negative, indirect impacts in other parts. Further understanding of the wider impacts of climate change on water availability, including a better understanding of changing catchment hydrology is therefore needed.

Fostering a 'nexus' approach, where the linkages between food, water, energy and land are explored would help decision makers to understand and optimise 'tradeoffs' at multiple scales[15]. The Nexus Network is a three year initiative funded by ESRC to bring together researchers, policy makers, business leaders and civil society to develop collaborative projects and improve decision making on food, energy water and the environment.

The management of the competing demands on water resources needs to incorporate advances in thinking into public and private policy. Flexibility and responsiveness will allow new information and methods to be used as they are developed. Any management aimed at addressing water quantity in agriculture, needs to take into account other requirements of the wider water system. Catchment management approaches, where methods are used to move water from place or times when it is not scarce, to places or times when it is scarce can be used to achieve balances across the wider water system.

Key findings from this report

1) The main challenges were identified as, 1) allocating water for farming, water supply and the environment in a way that meets the wider needs of society, 2) using water efficiently, especially in times of scarcity, and 3) looking to the future, to make sure that expectations for food production, other water use and the environment continue to be met over the rest of the century.
2) There is the potential for market failure to occur with respect to water use. This can arise from a variety of routes. Farmers often lack information on current and future water availability and their possible options to manage these better. In such a complex area, people may not fully understand or manage the risks they face and policies set in one area can have unexpected impacts in other places. Finally, managing water and food production needs a long-term view, but many of the decision-makers inevitably have to take short term decisions about cropping patterns and varieties. All of this suggests that more work is needed to understand the risks and potential solutions to this important problem and that these must translate into practical action that protects both food and water security.
3) A number of key evidence gaps exist, which could aid water management on the farm, across the catchment and throughout the supply chain. These are:
   - An increased understanding of the link between farming practices and run-off – both at high and low flows, in order to develop appropriate mitigation actions for water management; this requires new research.
   - Identification of opportunities for saving water on the farm and innovations created to make them viable.
   - Better management of the demand for water generated by the food supply chain, both in the UK and globally for food imported into the UK, in order to improve water use efficiency and reduce environmental and social issues.
   - Better forecasting of short and medium term water availability that is of benefit to agricultural users.
   - A better understanding of the wider impacts of climate change on future water availability, including a better understanding of changing catchment hydrology.
   - Improved mechanisms to exploit the significant opportunities to reallocate water between different uses to the wider benefit of society.

Key question 3: *Can we assess and manage the risks, for both the UK supply and exporting countries, from water used for our food imports?*

Water is required to produce food, whether that is for plant growth, for animals to drink or for food-processing. Approximately 70 % of the world's freshwater withdrawals are used for agricultural production. Globally, the relationship between water, food and trade varies significantly; for example a country with plentiful supplies of water may have a competitive production advantage over a country where water is scarce. However a country's economic strength also plays a role, with economically strong nations being able to afford to import water-rich crops and so conserve their own water resources for other purposes.

It is likely that in the future, water availability in the places where our imported food is grown may be subject to shifts in supply. These shifts may be due to the impacts of climate change, or changes in demand arising from other users (i.e. an increasing population and competition for land and water for different societal needs). With

only around 53-62% of food demand in the UK produced locally[16], two key questions emerge:

1. What are the supply chain risks to our food imports? And how big a problem is it?
2. What is the impact on our food choices on overseas water security? And how big a problem is it?

Quantifying the amount of water used to produce food

The concepts of 'virtual' or 'embedded' water can be a useful proxy for assessing the risks to a supply chain. During the production process, consumed resources (e.g. energy, water and fertiliser) become 'embedded' within the product and therefore become depleted at source. The embedded resources have been used and therefore do not retain their original form or function, becoming 'virtual'. So, virtual water is used to describe the sum of the different steps of the production chain.

Virtual water can be traded from one place to another in the form of food or other commodities, and this is known as 'virtual water trade'. When food is imported, water stress is being exported to the location of food production and in extreme cases this has the potential to undermine local water security. Virtual water can be misleading if no distinction between water-use in rain fed agriculture ('green water') or water use in irrigated agriculture ('blue water') is made. Measuring virtual water is also important, so that unsustainable water extraction and consumption can be identified and compared.

Risks from obtaining food from overseas in a changing world

It is anticipated that there will be an increased global demand for fresh water in the future. This demand is driven by the increase in the global population to 9.6 billion by 2050, placing greater demand on resources, particularly in sub-Saharan Africa and parts of Asia[17]. At the same time, socio-economic development will enrich the BRIC countries (Brazil, Russia, India, China and South Africa) and allow them to purchase more water intensive diets.

Climate and environmental change are expected to alter water availability in the future, with it becoming more variable. To adapt to these changes, farmers and growers may choose to grow options which are less vulnerable to weather. In addition, governments are examining the uses that water is put to and assessing opportunity costs via a more holistic appreciation of overall sustainability. In the future, the price of food is likely to increase, as the supply chain becomes unable to absorb extra costs.

The impact of these climate, environmental, demographic and economic changes on UK food imports is difficult to forecast. However, ensuring that the UK food supply chain remains resilient is a key concern. Resilience could be increased by choosing suppliers from locations where there are fewer sustainability issues. Retailers can also work with suppliers to ensure that food producers are enhancing their suitability in the face of increasing climate and market variations.

One of the challenges for understanding the impacts of water use in overseas supply chains is the constantly changing landscape for trade and access to water. There is an increasing need for new methods that are able to identify risks and rewards in water management (e.g. environmental, physical and social 'hotspots' of risk) taking into account future weather and climate variability.

Water footprinting involves quantifying the potential environmental impacts related to water[18] and it offers society a useful method to identify where and how risks related to water availability might arise in the chain of production and import. Water Risk Mapping is an alternative methodology for making strategic decisions about supply chains. Risk mapping involves a spatially explicit characterisation of risk, typically expressed as a map, providing nuanced information that a simple footprint fails to. For example, Figure 1 shows the high use of blue water in major food producing countries such as the USA, Spain, India, China, Australia and Southern Africa.

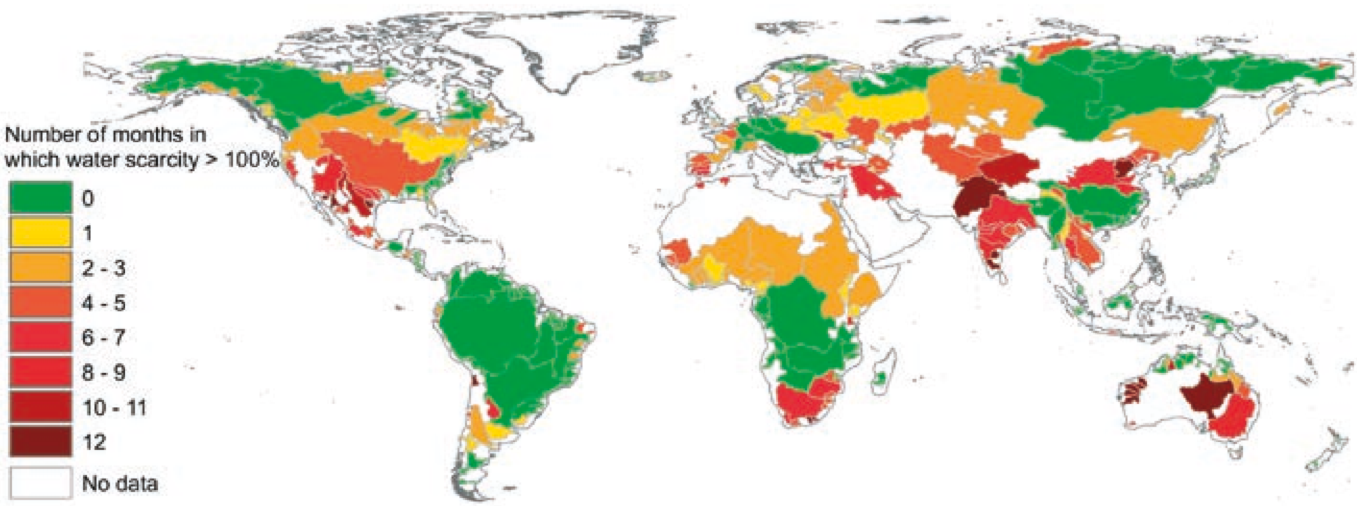
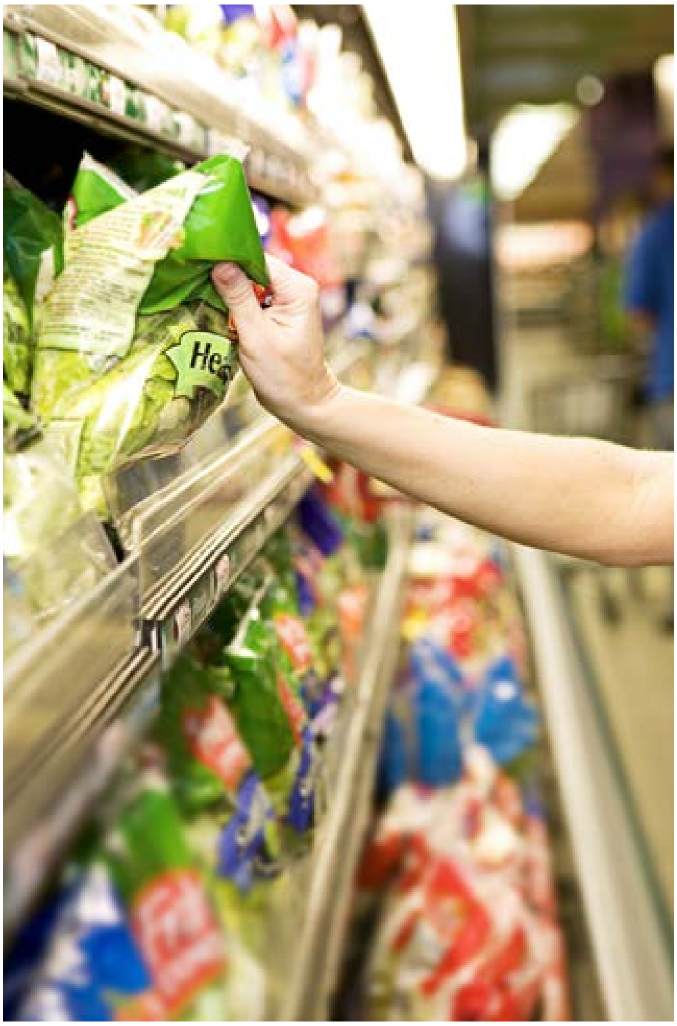


Figure 1: An example of a water risk map. The number of months during the year in which the blue water usage exceeds blue water availability for the world's major river basins, based on the period 1996-2005. [19]

2012 Hoekstra et al/PLOS one



The role of retailers in the food chain

To respond to water issues, retailers are increasingly seeking to identify global water vulnerable areas. This enables them to respond within existing supply chains and also informs their strategic future sourcing decisions. Abandoning an area due to water vulnerability should be seen as an act of last resort for the private sector due to the socio-economic impacts this would have and due to the wide range of potential mitigation options available.

Where are the knowledge gaps?

A number of knowledge gaps have been identified for managing risks in the overseas supply chain. These knowledge gaps include the impacts of climate and environmental change on water resources. The social effects on abstraction, the risks or rewards involved in water management, tools to determine these risks or rewards, and finally how to manage the above uncertainties effectively. Retailers and manufacturers need to consider where their priorities lie, since addressing water issues and brand management may have different outcomes.

Partnerships are needed at the local scale (e.g. industry, NGOs, Government) to improve local management practices and improve data collection for a common good. Public and private policies should also be developed that integrate food production and its impacts on water, allowing the assessment from local to global scales. Finally, there is a need to promote the teaching and research of agricultural systems from a land, water and livelihoods point of view.

Key findings

A number of key findings emerge from considering key question 3:

1. The concept of "virtual water" is insufficient. Tools to identify the risks associated with food imports and their strategic importance for the supply chain are in high demand and need to be both spatially and temporally highly resolved.
2. A more integrated understanding of the risks to food production and of water use will arise through working in partnerships (across academia and the food chain).
3. Governance and advisory systems and structures should facilitate better management of food and its impacts on water both in the UK and abroad.
4. Catchment management systems should be encouraged (by UK actors) overseas, with the ability to monitor and collect data around water use and impacts on water quality. Farmers, extension services and advisors should work in partnership across catchments, to avoid local gains in best practice being eroded by other suppliers exploiting resources unsustainably.
5. Public and private policies should be developed that integrate across global food production and its impacts on water (and the broader environment), allowing assessment from local to global scales.
6. Teaching and research of agricultural systems from a joint land, water and livelihoods point of view should be further developed, promoted and embedded in stakeholder communities. In turn, these should aim to better understand and quantify the complex productivities and efficiencies of rain fed and irrigated farming at the local field, basin, regional and global scales.
7. In the future, UK funders should facilitate greater engagement with "international agricultural water and land use" to underpin decision making for sustainable and resilient production both from a UK food chain and exporting countries' water security perspectives.

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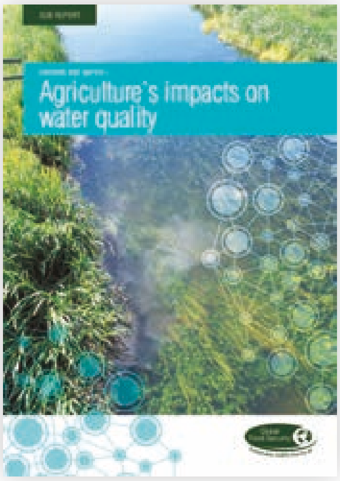
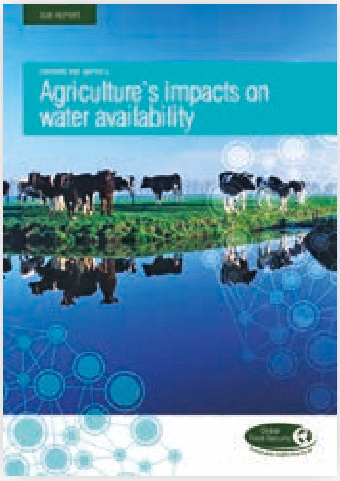
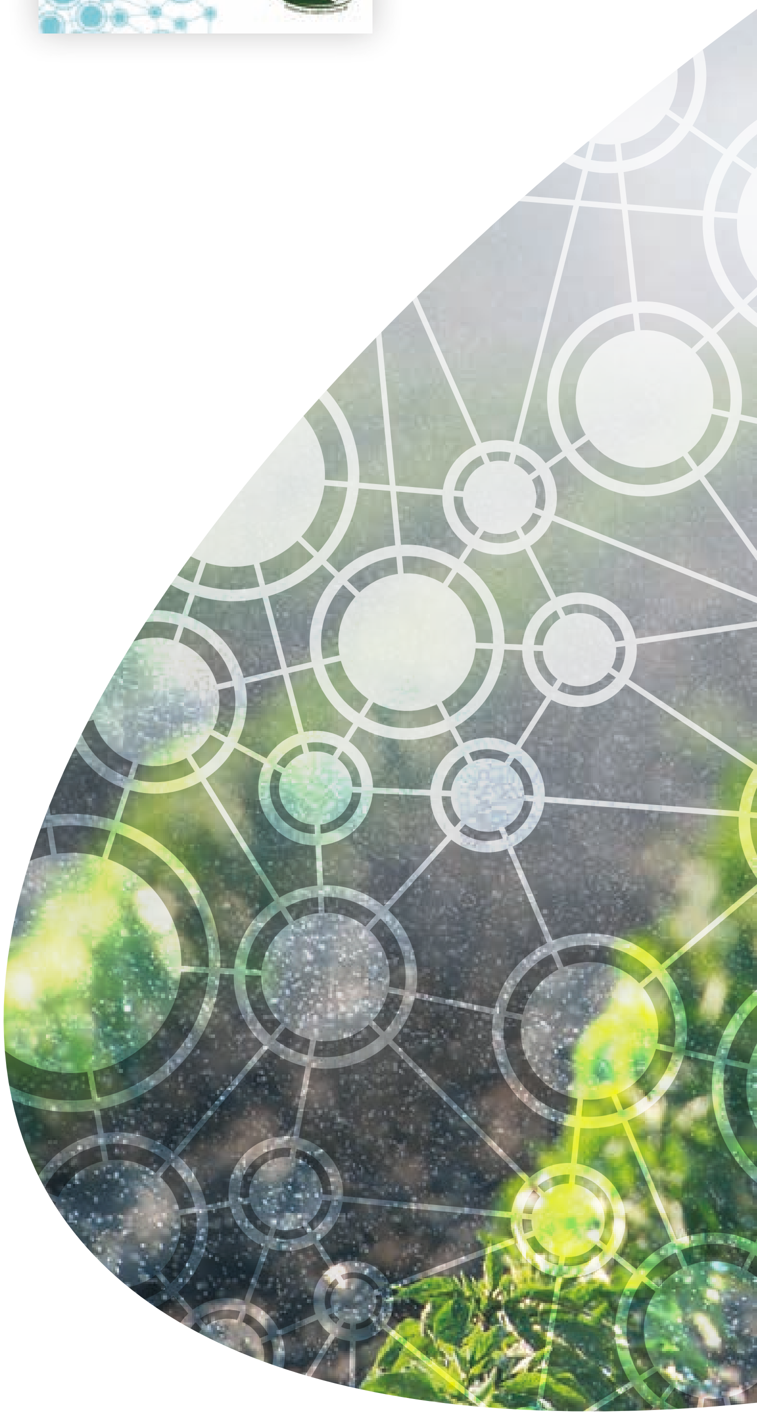
Available Sub Reports







Global Food Security (GFS) is a multi-agency programme bringing together the main UK funders of research and training relating to food. GFS publications provide balanced analysis of food security issues on the basis of current evidence, for use by policy-makers and practitioners.

The UK Water Partnership, launched in February 2015, brings people and organisations together to address the key challenges facing the water sector, and catalyse action to benefit the UK economy and improve UK and global water security.

For further information please visit:
www.theukwaterpartnership.org
www.foodsecurity.ac.uk

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