Review

Water and its role in food and health security – the importance of water to food production

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Water is vital to food production: every calorie of plant food requires at least one litre of water, while one calorie of meat or dairy product can require up to 10 litres of water. Water is supplied either through rainfall or through irrigation. Irrigated agriculture uses 18 per cent of agricultural land, and produces 40 per cent of agricultural products. But urbanisation, agricultural land degradation, the mandating of biofuels, drought and climate change are reducing the amount of water available to agriculture. The green revolution of last century doubled cereal production with only a very small increase in land. This century we need a blue revolution, a dramatic increase in the amount of food produced from irrigation or blue water. The blue revolution must be based on knowledge, with that knowledge accessible, and useful, to farmers in both the developed and developing world.

Key Words: water, food, drought, irrigation, climate change

INTRODUCTION

The expression peak oil is well known: it is used to describe the point at which the maximum extraction of the world's resources of petroleum is reached. After the peak comes the terminal decline of supplies, along with rising prices.

Now peak water is looming. Water is very different from oil: it is in abundant supply on the global level, and replenished through rainfall. But it is reasonable to describe local extraction and use of water in some regions as having peaked, and this has extraordinary implications for how those dependent on those water sources live and particularly for how they eat.

Paul Bulke, the head of Nestle, the world's largest food company said the biggest problem the world faces is not greenhouse gas emissions, though he acknowledges it is important. He said it is not running out of oil. Paul Bulke says the biggest problem the world faces is water. And he says Australia, because of its extended dry, is way ahead of Europe in understanding this.[1,2]

In addition to peak water we have the problem of peak land, the declining availability of good farming land. Some is lost to degradation, but more is lost to urbanisation as people, particularly in Asia, move from living a peasant lifestyle in the country to the city. As those cities expand, good farmland goes under tar and cement.

BACKGROUND: THE GREEN REVOLUTION

The green revolution doubled cereal production between 1970 and 1995 while increasing the area devoted to cereals by only a small amount. For example, global cereal grain yields have increased 213 per cent since 1960, but the area under cereal increased just five per cent.[3]

Next on the agenda must be the blue revolution, growing more food with less water.

Every calorie of plant food needs one litre of water to grow it, while every calorie of meat or dairy products requires up to ten litres of water.[4,5] Generally speaking, fruit and vegetables need less water than grains, which use less than animal products. And grass fed animals use less water than grain-fed beasts.

This distinction between the water needs of vegetables, grains and proteins is important, because growing wealth in Asia always means a shift in diet. Korea, for example, in the thirty years from 1975 to 2005, moved from an agricultural economy to an industrial economy. There was a concurrent shift from a rice-based diet to consuming significantly more protein. Meat consumption increased fivefold, from around 6.4 kg/year to 31.0 kg, while dairy consumption increased more than tenfold, from 4.6 kg/year to 62.7 kg. The average daily calorie intake per person also rose from 2,390 to 3,014.[6]

The importance of water to food production cannot be overstated. The water used to produce food is called virtual water. The amount of water needed to produce everyday food items is staggering: it takes 600 litres of water to make one litre of milk, and over 18,000 litres to make one kilo of butter. It takes 50,000 litres to produce one kilo of grass-fed steak, and much more if that steak comes from grain-fed cattle. It takes 780 litres of water to produce one litre of orange juice, although it takes less to produce one litre of wine, at 360 litres of water.[7]

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Nestle chairman, Peter Brabeck-Letmathe, estimates the average daily diet in California requires some 6,000 litres of water in agriculture, compared with 3,000 litres in countries such as Tunisia and Egypt.[8] To picture that, a 6,000 litre water tank has a diameter of about two metres and is two metres high.

The FAO estimates that, although the average person needs to drink between two and four litres of water a day, they consume 2,000 to 5,000 litres through the water used in producing their food.[9]

Australians are very conscious of personal water use: all of Australia's state capital cities have been on water restrictions due to the long dry affecting the country. In Brisbane residents had been asked to use less than 140 litres per person per day, though that has recently risen to 200 litres, and in Melbourne they are asked to use less than 155 litres. By and large residents have made huge efforts to keep personal usage under those figures.[10,11] Historically, Australian household water use was 315 litres/person per day.[12] Personal use is a fraction of the water used to produce food. Most people waste more virtual water by throwing out spoiled or uneaten food, than they use in their households.

IRRIGATION

The water used in growing food comes in two forms: green water from rain that falls and is stored in the soil; and blue water or irrigation water.[13]

Increasingly the world is being fed from blue water, from irrigation. Human civilisation is deeply linked to irrigation. The control of water in irrigation schemes, from Babylonian times to the present, has always been seen as advancing the wealth of society.

Over the past 50 years, the amount of water used in agriculture has tripled, according to the United Nations World Water Development Report 3. It estimates irrigated agriculture covers 275 million hectares or about 20 per cent of cultivated land and accounts for 40 per cent of global food production.[14] It states: "this success in agricultural production lead to a 30 year decline food prices in most countries, a trend that lasted until very recently".[15]

The FAO reports agriculture represents 70 per cent of global water use. It argues food production kept pace with the increasing global population through improvements in cereal yields, and expansion of irrigated land, particularly in Asia. It points out the world “is going to have to massively improve water productivity in agriculture if it is to feed itself”. But its experience is that most water use is not well monitored, and global figures have proven “too unreliable to allow for meaningful analysis”.[16]

As we are demanding more of our water resources they are coming under increased pressure, from cities and industry, and more importantly from climate change. This is the case in Australia, where there has been a dramatic reduction in the water available for use in the area known as the nation's food bowl, the Murray-Darling Basin.[17]

Australia used to boast that it fed 70 million people. With a population of 21.8 million that means most of the food grown was exported, largely to Asia.[18]

There are similar water shortages being experienced in the northern hemisphere. South-eastern and south-western Australia have Mediterranean climates, with dry summers and wet winters. Northern hemisphere areas with a similar climate, the south-west USA and the Mediterranean area itself are enduring a similar drying. It appears the rain-bearing weather systems in both hemispheres have moved towards the poles.[19]

Many other regions face reduced rainfall under climate change. I would hope that Australia, as a developed nation with the entire affected area under the one national government, might be able to point the way to managing under such significant changes.

THE PRESENT PROBLEM

The chief executive of the newly-created Murray-Darling Basin Authority, which has responsibility for water in the basin is Rob Freeman. He is putting together a plan for the entire basin, and points out it has never been done in the world at this scale. The Murray-Darling basin has about the same area as France.

The basin faces two problems. The first is that water was overallocated - that is too much water was allocated to irrigation and towns at the expense of the environment. But the far more severe problem is the downturn in rainfall and in river flows.[20]

Before the drought struck, the Murray-Darling Basin produced 40 per cent of Australia’s farm produce, including most of its irrigated agriculture, worth AUD 15 billion (USD 12 billion).

The Murray River used to have an annual inflow of 8,900 gigalitres or billion litres a year (a gigalitre is one square kilometre of water, one metre deep). Licences for over 5000 GL were issued in wetter times, in the 1970s and 1980s.

But rainfall has decreased by 15 per cent over the Murray in the last 30 years, with a marked reduction since 1997. Any change in rainfall is amplified in stream flow so that, for example, a 10 per cent decrease in rainfall will result in a 20 per cent decrease in stream flows.

In the last three years the annual inflow into the Murray River has averaged just 1,783 GL, or 20 per cent of the old average. As a result irrigation allocations have been severely reduced, and the results on food production have been catastrophic.[21]

Australia was a major exporter of rice, but rice production fell from 1.2 million tonnes to just 19,300 tonnes last year. This year was a little better at 65,000 tonnes.[22] The next harvest will be little better. Farmers typically grew a wheat crop after rice, using the residual water. The region's cereal crops have been severely reduced due to no irrigation and low rainfall.

Most of Australia's dairy production, and virtually all of its milk production destined for export, occurs in the basin. Australia is the world’s third biggest dairy exporter (after New Zealand and the European Union) providing about 15 per cent of world dairy exports. But milk production has fallen from 11.2 billion litres in 2002 to about 9.2 billion litres this year, with lower production expected next year.[23]

In the area irrigated by the Murray River in northern Victoria, a recent report found that farmers did not irrigate 26 per cent of their grapevines and grain crops in 2008-09. That was up from 20 per cent left unirrigated the

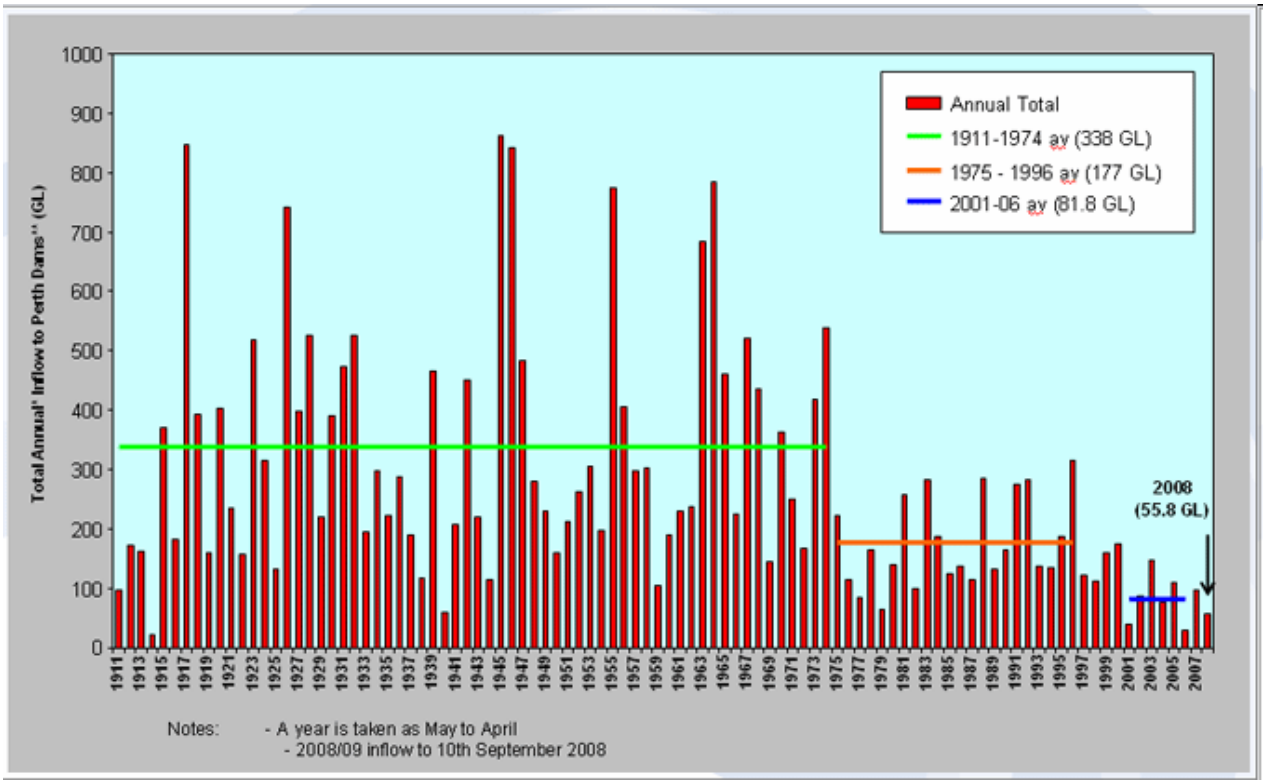

Figure 1. Yearly inflow into Perth's Dams. Source: Western Australia Water Corporation

year before. The report observed that an unspecified proportion of the irrigated crops was stressed and receiving inadequate water. The unirrigated vines and trees died. The affected crops include grapevines, grapes for dried fruit, citrus fruit, almonds, olives, and vegetables.[24]

Not only is there less rain falling across the basin, the rising temperature is also reducing river flow. The basin is highly vulnerable to climate change because an extraordinarily low four per cent of the rain that falls on the basin ends up in the river. Just four per cent. This compares with 48 per cent for most of Asia. If the temperature rises one degree - and this has already happened under climate change - 15 per cent less water flows into the river.[25]

It is not just the inland areas that have been affected. Australia's major cities have all been affected by the long dry, with most now on water restrictions. The urban water industry has embarked on a massive AUD 30 billion (USD 24 billion) investment program in new water sources, in desalination, water recycling and infrastructure.[26]

The first response by the Australian government to the crisis in the basin was to ask the national scientific body, the CSIRO, to assess the water resources in the Murray Darling Basin. In the most costly exercise it has ever undertaken, the CSIRO conducted the Sustainable Yields Project which assessed how much river and ground water there had been historically and to estimated the likely impact of climate change.

The project established that 48 per cent of the waters of the basin have been diverted for use, a figure that is projected to rise to 54 per cent under climate change. But in some rivers, 70 or even 80 per cent of the water is diverted in really dry years. These are all unsustainably high figures.[27]

Australia's Federal government is now investing AUD 10 billion (USD 8 billion) in purchasing water licences from irrigators and allocating that water to the environment, and in making water savings through upgrading irrigation systems.

The question is: is all this due to climate change? Australia has the most variable rainfall of any agricultural nation, and seeing the impact of climate change on rainfall is more difficult than the impact on temperature.

Western Australia has experienced a decline in rainfall, in several distinct steps, since 1974. Perth's dams used to receive 338 GL a year. The 2001 to 2006 average was 81 GL. Last year they got just 56 GL (Figure 1).[28]

Perth now receives 17 per cent of its water from desalination, and a second plant is under construction. The city's water managers are planning a future that does not rely on dams at all, but rather on groundwater, recycling and desalination. There is widespread acceptance that these changes in Western Australia bears the fingerprint of climate change.[29]

As the current dry continues over south eastern Australia, there is mounting evidence that this, too, is climate change at work.[30] This is an important distinction: believing the long dry period is a drought means waiting for rain and a return to business as usual. Understanding it is climate change means making huge structural changes.[31]

The Australian government is only just beginning to grapple with these changes. It is investing in water and climate information, in improved water efficiency and in assisting farmers to leave the land. It is studying the pos-

sibility of establishing agriculture in northern Australia, where rainfall has actually increased.

THE FUTURE

Over the past 30 years, investment in global research into increased farm production, in both the developed and developing world, has decreased.[5] This, according to the chair of the board of trustees of the International Rice Research Institute, Beth Woods, is one of the reasons behind last year's dramatic shortfall in world rice and grain supplies, and the associated price surge. She had been warning governments that the world had been using more grain than it was producing for the prior seven years. The demand was being driven by increased consumption due to rising incomes and mandated biofuels. But she said her warnings fell on deaf ears because food and agriculture were "out of fashion" and governments had lost interest in investing in food production.[32]

The Chatham House report, 'Feeding the Nine Billion, Global Food Security for the 21st century', argues a 21st century green revolution would need to be more complex than the twentieth century one, shifting from an "input-intensive" model, that is using more water, fertiliser, pesticide and energy, to one that is knowledge intensive. It argues for ecologically-integrated approaches, such as integrated pest management, minimum tillage, drip irrigation and integrated soil fertility management. These are all systems that are used, with considerable success, in Australia. The report states these factors "often score higher in terms of resilience and equitability, as they put power in the hands of farmers rather than seed companies."[33]

The blue revolution will require change on many fronts, a significant investment in research and in extension, that is in assisting farmers to put the changes in place.

Australia's pre-eminent water expert, the late Peter Cullen, repeatedly said Australians would have to learn to double crop production with half the water.[34] Professor Cullen said about Australia's water management: "I have always felt that knowledge was better than ignorance, we should try knowledge in this country because ignorance hasn't got us very far." Knowledge will be the key, worldwide, to the blue revolution and the much-needed increase in food production.

AUTHOR DISCLOSURES

None declared.

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水在糧食與衛生安全的角色 – 水對糧食生產的重要性

水對糧食的生產是很重要的：生產每一卡路里的植物性食品需要至少 1 公升的水，而生產一卡路里的肉類或乳製品則需要多達 10 公升的水。水的來源可經由降雨或灌溉。農耕土地的 18%屬於灌溉農業，而產生了 40%的農業產品。但由於都市化、農耕土地劣化、生物燃料的強勢需求、乾旱及氣候的變遷，減少了農耕水源的可獲量。在上世紀的綠色革命中，只藉由增加少量的農耕土地，就使穀類的產量加倍。在這個世紀，我們需要一個藍色革命，藉由灌溉或乾淨的水源，來大量的增加糧食生產。藍色革命必須建立在知識上，而這些知識對於已開發及開發中國家的農夫而言，應是易得知且是有用的。

關鍵字：水、糧食、乾旱、灌溉、氣候變遷