QUALITY AND QUANTITY OF WATER FOR AGRICULTURE

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Keywords: Eutrophication, irrigation, salination, freshwater, fisheries, watershed management, wetlands, remnant vegetation, dryland salinity, nutrients, algal bloom, nitrate, hydrology

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Summary

The situation regarding the world's water supplies is serious. The world's water supplies are scarce and getting scarcer as a consequence of population growth and increasing degradation due to mismanagement. The UN has estimated that two thirds of humanity will face water shortages by the year 2025. Most (97.5%) of the world's water is salty and cannot be used for human consumption or agriculture. The remaining 2.5% is freshwater, and there is 35 million km^3 of it.

Freshwater is a critical resource for many purposes, it has no substitutes for most of its uses, and it is costly to store and transport in the volumes required for agriculture. It has been estimated that it takes a ton of water to produce 1.9 kg of biomass. On this basis, humans are now thought to be using about 26% of the total terrestrial evapotranspiration. It is estimated that 54% of the runoff that is geographically and temporally accessible is being appropriated for human use.

About 70% of the water extracted from rivers and lakes is used for irrigation, and about

half of this is lost through seepage and evaporation. Excessive extraction for irrigation has led to damage to the ecosystem services provided by aquatic systems for society. Worldwide, one ha in five ha of irrigated land is showing signs of salt buildup in the soil. Salinity is spreading at the rate of about 2 million ha/yr in irrigated areas. These problems are affecting many of the world's irrigation areas.

Considerable effort is now under way to improve the efficiency in the use of water and to restore areas that have been damaged through salinity and other contaminants. A challenge for many societies is the need to balance extraction of water for economic purposes with the need to maintain basic ecosystem services on which we all depend.

1. Introduction

Water is one of the factors that limit how many people can be supported on our planet, and where they can live. Already water shortages and pollution cause widespread public health problems, and limit economic and agricultural development, as well as damaging the ecological services provided by the environment. These pressures will worsen under the twin pressures of increasing demand due to population growth (see *World Demography and Food Supply*) and increasing degradation of the water resource. Allied to these drivers of changes are the effects brought about by the institutional arrangements we construct to mange water and by climate change and the variability of rainfall (see *Agriculture and Global Change*).

The situation regarding the world's water supplies is serious. The World Resources Institute has estimated that freshwater for human use found in lakes, rivers, and wetlands make up only 0.008% of the Earth's water. Agriculture uses 65% to 70% of all water extracted from rivers, lakes, and aquifers for human uses. This compares with 20% to 25% used in industry and 10% used for domestic use. The extremely limited amounts of fresh water are unevenly distributed throughout the world, and yet in many industrial, agricultural, and domestic circumstances, they are used inefficiently and beset with serious problems of pollution, salinity, waterlogging of soils, flood control, and disease contamination. The UN has estimated that two thirds of humanity will face water shortages by the year 2025.

Already there are considerable tensions about water and who should use it for what purposes in various parts of the world. People need water for drinking, food preparation, and washing. People use water in a most inefficient way to transport wastes. People are also using water for irrigation to supply food and fiber to an ever-growing population. Water use grew at more than twice the rate of population increase during the twentieth century. On top of these pressures, there are demands to improve the quality of water available for domestic use, and to provide water to maintain biodiversity and ecosystem services for the globe.

As the pressures on our limited global water resources increase, the actual amount of water is decreasing. In many areas, salination and other water quality problems are degrading the water that is available. Excessive extraction of water leads to the shrinking or destruction of downstream lakes and wetlands, and to the drying up of the downstream reaches of rivers. The Aral Sea is one well-documented example where the area of the sea has decreased by 50% and the salinity has increased markedly. A major fishery has been lost and the land being irrigated has been severely degraded through waterlogging and salination. This is one case that has attracted global attention, but there are many other examples. The German Advisory Council on Global Change in its 1999 report described this situation, but coins the general term of the Aral Sea Syndrome to describe these consequences of large scale water development.

2. The World's Freshwater Resource

Most (97.5%) of the world's water is salty and cannot be used for human consumption or agriculture. The remaining 2.5% is freshwater, and there is about 35 million km^3 of it. However, 70% of this is frozen in ice caps, leaving only 0.3% in rivers and lakes which we can utilize. This water is of course not evenly distributed in space or time. Some areas have low rainfall and hence low runoff. For example, average rainfall in Iceland is 600 000 m^3/yr, whereas in Kuwait it is 75 m^3/yr. About three-quarters of total world annual rainfall falls on areas containing less than one third of the world's population.

Of the 119 000 km^3 of precipitation that falls on land, 72,000 km^3 is evaporated or transpired back into the atmosphere, with only 42 700 km^3 entering rivers and lakes.

	%	**Vol 10^3 km^3**
Ice and permanent snow	68.7	24064
Groundwater	30.1	10530
Soil moisture	0.05	16.5
Lakes	0.26	91
Wetlands	0.03	11.47
Rivers	0.006	2.12
Biological water	0.003	1.12
Atmospheric water	0.04	12.9

Table 1. The world's freshwater resources
(from Shiklomanov, 1993)

It is often these areas with low rainfall that have highly variable and unpredictable runoff, too. In tropical areas, much of the rain is seasonal and runs off too quickly for effective use. India receives 90% of its rainfall in the monsoon season from June to September.

	Annual River Runoff km^3	**Annual River Runoff mm**
Europe	3 210	306
Asia	14 410	332
Africa	4 570	151
North America	8 200	339
South America	11 760	661

Australia	348	45
Oceania	2 040	1610
Antarctica	2 230	160
Global	46 770	314

Table 2. Runoff

A further complicating factor is that, although other natural resources such as land are normally controlled by local or national communities which are dependent on them, this is not always the case with water. More than 40% of the world's population live in internationally shared drainage basins and, because of its critical importance in agriculture, industry, power generation, fishing, navigation, and domestic use, water commonly has high political and strategic significance of international importance. For example, disputes over water feature prominently in tensions between India and Pakistan and between Israel and its neighbors.

Even within a single country, there can be significant tensions between upstream and downstream States about the sharing of water. The Murray-Darling system in Australia drains four States, and there have been ongoing tensions about the use of water in the Western US such as the Colorado River. A variety of institutional arrangements of varying effectiveness have been developed to address these cross-jurisdictional issues with regard to water sharing.

3. Utilization of the Freshwater Resource

There are some 400 000 dams higher than 15 m that have been built to try and manage water for human use. It has been estimated that human beings need between 30 l and 200 l of water to provide for drinking, cooking, washing, and sanitation needs. Much of the water we store is used for agriculture. If we accept 50 l/person/day as a minimum standard use, 55 countries with total population of more than one billion people could not meet this standard as a national average.

3.3. Agricultural Uses

Freshwater is a critical resource for many purposes, it has no substitutes for most of its uses, and it is costly to store and transport in the volumes required for agriculture. It has been estimated that it takes a ton of water to produce 1.9 kg of biomass. On this basis, humans are now thought to be using some 26% of the total terrestrial evapotranspiration. It is estimated that 54% of the runoff that is geographically and temporally accessible is being appropriated for human use.

Crop	l/kg
Potatoes	500
Wheat	900
Corn	1400
Rice	1912

Soybean	2000
Chicken	3500
Beef	100000

Table 3. Crop water requirements

Obviously different crops and regions have different demands, but the following estimates of liters of water needed to produce 1 kg of food give some indication. About one third of the world's food is produced using irrigation.

In the US, agriculture accounts for about 87% of the freshwater consumed after its withdrawal.

Agriculture gets its water directly from what enters the soil from rainfall, or what is transported to the plant root zone. This transported water may come from groundwater or from surface water. Surface water may be supplied by direct pumping from rivers, or by storing water in dams and transporting it to where it is needed.

About 1.45 billion ha of land is used for agriculture, of which about 250 million ha is irrigated. Most of this irrigated land is in Asia (64%) with North America 9%, Europe 7%, and Africa 5%. Pakistan, with 80%, has the largest extent of irrigated land. In Europe, The Netherlands with 60% of its agriculture under irrigation has the highest dependence on irrigation. The area irrigated rose fivefold in 100 years, and water extraction increased even faster, by a factor of about six. There was a slowdown in the expansion of irrigated area in the last decade of the twentieth century as suitable land and water availability restricted future opportunities. Problems of water availability and water quality are likely to increase in the future.

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Biographical Sketch

Peter Cullen died in 2008. He was Chief Executive of the Cooperative Research Centre for Freshwater Ecology, and a Professor at the University of Canberra in Australia. He studied agricultural science at the University of Melbourne and had worked in a variety of fields within natural resource management. He had been a member of the Australian Prime Ministers Science, Engineering and Innovation Council and the Community Advisory Council, of the Murray-Darling Ministerial Council. He was a member of the Lake Eyre Catchment Management Coordinating Group. Professor Cullen was a Fellow of Australian Academy of Technological Sciences and Engineering, a Director of Landcare Australia Limited, and Past President of FASTS, the Federation of Australian Scientific and Technological Societies.