International Association of Hydrogeologists

Strategic Overview Series

FOOD SECURITY & GROUNDWATER

KEY MESSAGES

- food production requires large quantities of water, with groundwater resources providing more than 40% of all water used globally for irrigated agriculture
- groundwater has proved to be a critical input for securing improved crop yields and enabling the 250% increase in food production achieved during the 'green revolution' of 1970-2000
- during the past 30-40 years there has been a remarkable level of investment in private waterwell construction for agricultural irrigation, because groundwater availability allows higher crop yields and farmer returns per unit of water
- groundwater storage is very large but current withdrawal rates for irrigated agriculture in more arid areas are not physically sustainable, resulting in long-term (semi-permanent) depletion of aquifer reserves at rates in excess of 120 km^3/a
- land-use practices affect ground-water recharge rates and quality, with intensification of cropping widely leading to diffuse pollution of ground water by plant nutrients, salinity and some pesticides
- there is a pressing need to mobilise groundwater professionals, together with water-resource managers and irrigation engineers, to identify trans-sectoral governance and management responses for improving resource sustainability

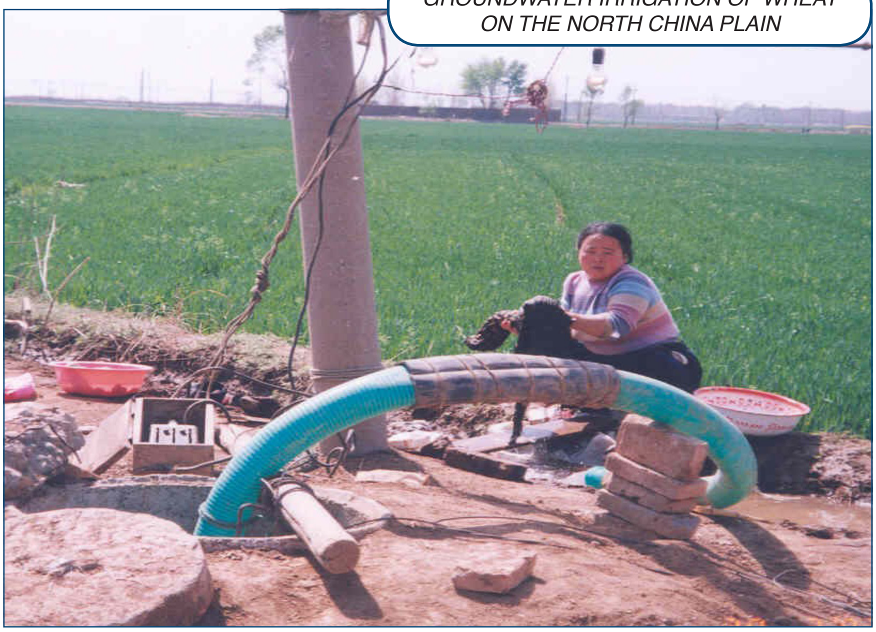
Why are groundwater resources critical for global food production ?

The inexorable growth in world population has led to questions about whether sufficient food can be produced to meet escalating demand - and the concept of 'global food security' arises. However, some 1,400 million of the rural population depend on subsistence agriculture or subsidised food imports (rather than 'food trade') for their minimal nutrition.

Food production, both commercial and subsistence, requires large quantities of water. Thus food security is intimately linked with water-resource security. In some humid temperate regions plant growth is sustained by rainfall alone – but in most regions irrigation is required for optimal production.

The irrigation demand of the agricultural sector already amounts to more than 70% of global water-supply withdrawals and about 85% of global water-resource consumption – and it is estimated that groundwater sources provide 43% of all water used for irrigation. Groundwater has been most intensively developed in South Asia and North America - where it provides 57% and 54% respectively of all irrigation water.

GROUNDWATER IRRIGATION OF WHEAT ON THE NORTH CHINA PLAIN



This Series is designed both to inform professionals in other sectors of key interactions with groundwater resources and hydrogeological science, and to guide IAH members in their outreach to related sectors.

In the past 30 years there has been spectacular growth in the construction of irrigation waterwells – for example they now command some 39 Mha of irrigated land in India, 19 Mha in China, 17 Mha in the USA and large areas of Pakistan and Bangladesh. They have facilitated major benefits for millions of small farmers, with advances in low-cost pumping technology being the trigger for their development.

REGION	GROUNDWATER IRRIGATION AREA (Mha)	VOLUME USED km³/a	propn total
GLOBAL TOTAL	**112.9**	**545**	**43%**
South Asia	48.3	262	57%
East Asia	19.3	57	34%
South East Asia	1.0	3	5%
Middle-East & Central Asia	11.9	76	38%
Europe	7.3	18	38%
North Africa	2.5	16	24%
Sub-Saharan Africa	0.4	2	7%
North America	19.1	100	54%
Latin America	2.2	88	19%
Australia	0.9	3	21%

FAO-UN 2010 STATISTICS ON GROUNDWATER USE FOR AGRICULTURAL IRRIGATION

The exception to this trend is Tropical Africa, where only 1% of the land-area is currently under groundwater irrigation (compared to 14% in South Asia). Even here the potential of managed groundwater development for irrigated agriculture is becoming more widely recognised, but to date, a complex array of factors have impeded its widespread introduction.

Groundwater resources, and the availability of natural groundwater storage, are a key factor ensuring water-supply security for food production. Waterwells have proved to be highly appropriate for meeting widely-dispersed and temporally-variable irrigation demands of both commercial and subsistence agriculture, because of their low capital cost and reliability during extended (multi-year) drought.

SUBSISTENCE IRRIGATION FROM GROUNDWATER IN SUB-SAHARAN AFRICA

The improved access and security of water-supply afforded by groundwater (combined with the introduction of high-yielding crop varieties, fertilisers to improve plant nutrition and pesticides to reduce crop losses) enabled global food production to increase by some 250% during 1960-2000, whilst only using about 15% more land. This major increase was associated with a 300% increase in irrigation waterwell abstraction. Thus groundwater has to be regarded as a critical input for global food security.

What pressures will be put on groundwater by future food demand ?

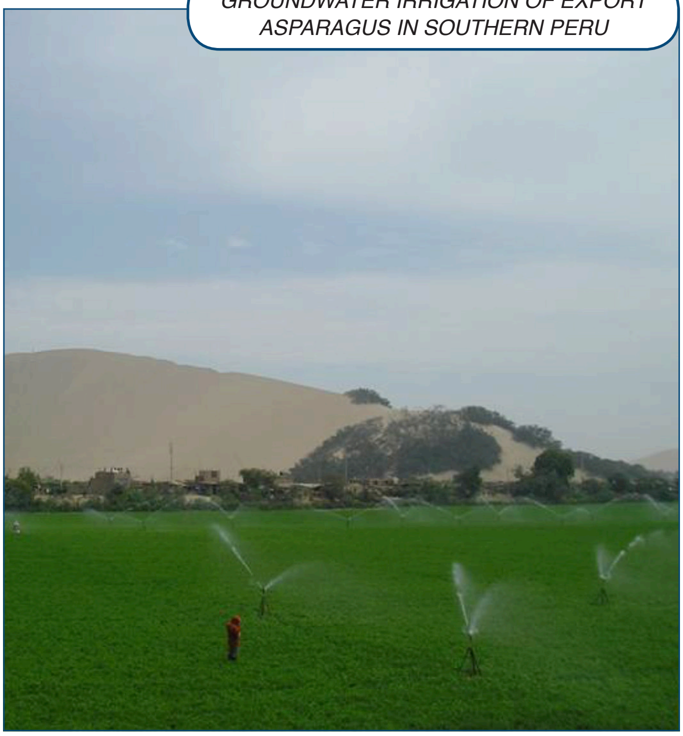
It is predicted that global food production will need to increase a further 60-90% by 2050 to meet the demand created by population growth and changing diets. Crop yield improvements on existing land (mainly in Tropical Africa and parts of Asia) will need to provide about 80% of this increment, since most of the more fertile land is already cultivated. This challenge will be compounded by the impact of global warming, the demand for increased animal fodder, the continued need to cultivate plant fibres and the desire to increase biofuel production.

The intensification of crop production is likely to generate further soil erosion, groundwater depletion and salinisation, excessive nutrient and pesticide leaching, and aquatic ecosystem stress. Farmers will need to maximise water productivity, to cooperate with efforts to conserve land resources and enhance groundwater recharge, and to introduce less water-intensive crops.

There remain opportunities for significantly intensifying cropping and increasing food production on major alluvial plains, where both surface-water and groundwater resources are available. This can be achieved sustainably by conjunctive management to eliminate the negative effects of soil waterlogging and associated salinisation, and of surface-water drought.

Moreover, groundwater has often been the catalyst to engage in higher-value irrigated agriculture, since its availability can enable all-year-round production, more uniform crop quality and compliance with health standards for crops eaten uncooked. This is a trend that will unquestionably continue in the future.

GROUNDWATER IRRIGATION OF EXPORT ASPARAGUS IN SOUTHERN PERU



MAJOR LAND SUBSIDENCE IN RURAL MEXICAN TOWN RESULTING FROM EXCESSIVE WATERWELL ABSTRACTION

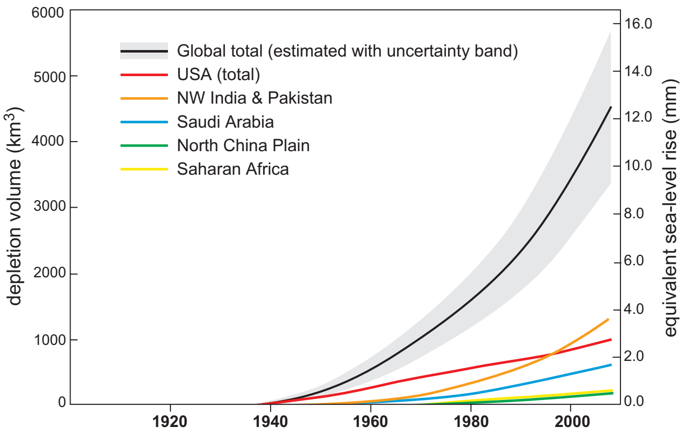
What are the principal threats to groundwater resource sustainability ?

Groundwater storage reserves are very large, and capable of buffering major drought episodes (for climate-change adaptation and economic transformation to less water-intensive activity), but there are absolute limits on their long-term sustainability. It is the work of the professional hydrogeologist to define these limits through scientific assessment of the processes and rates of replenishment of groundwater systems.

There is evidence that current rates of groundwater withdrawal for irrigated agriculture in many of the world's more arid and/or drought-prone areas have for many years have not been sustainable in the long-term – and are giving rise to continuous depletion of aquifer reserves (including those of 21 out of 37 major aquifers globally). This depletion is associated with escalating pumping costs (and its carbon fooprint), land subsidence, aquatic ecosystem degradation and groundwater salinisation.

Globally some 4500 km^3 of groundwater were depleted from subsurface storage reserves during 1940-2008, with the rate of depletion having increased notably since 2000 to 120-180 km^3/a.

Even in regions with regular recharge these groundwater reserves are unlikely to be fully replenished for 100 years or more, and in some cases non-renewable resources are involved – notably in Libya, Algeria & Saudi Arabia, and locally in Australia, China, Egypt, & Iran. Currently about 10% of global grain production (150 M tonnes/a) is dependent upon unsustainable groundwater resources and the cumulative exploitation of non-renewable groundwater since 1940 could be directly responsible for a 15 mm contribution to mean sea-level rise.



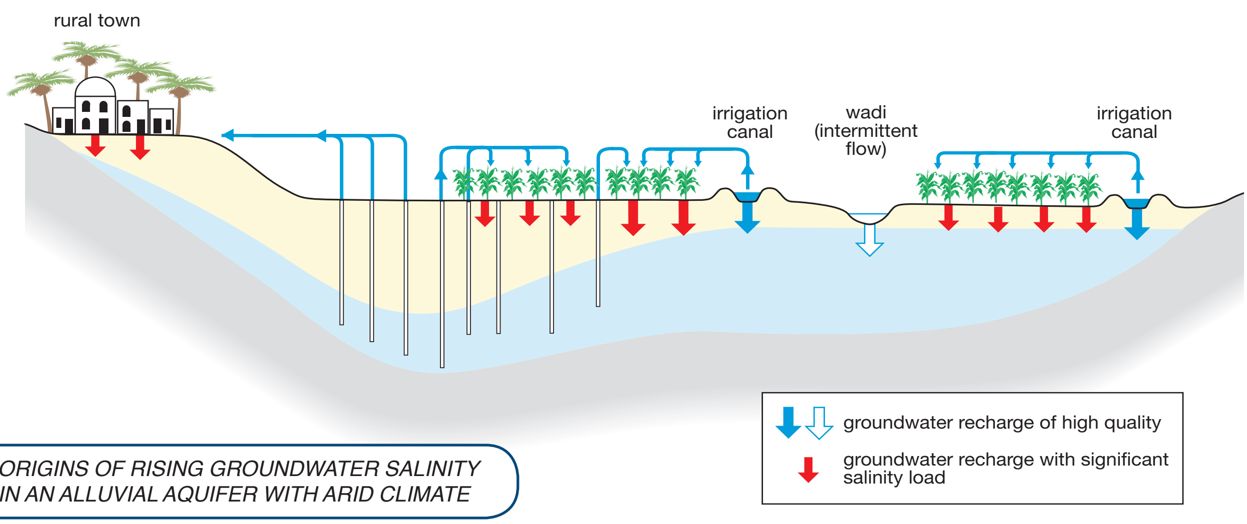
CUMULATIVE DEPLETION OF GROUNDWATER STORAGE RESERVES MAINLY BY IRRIGATED AGRICULTURE

Another phenomena of equally widespread concern is the insidious salinisation of freshwater aquifers resulting from groundwater use and irrigation water management. In numerous areas, when groundwater bodies become depleted and their natural discharge eliminated, they tend to become the 'sink' for salts leached from arid land and fractionated in irrigated soils. In others with shallow groundwater table, inadequate irrigation-water management is leading to excessive infiltration with soil water logging and salinisation. Globally some 10 M km^2 of agricultural land are classified as currently experiencing, or in serious risk of, salinisation.

Current irrigation practices, and the development of new irrigated areas, need to be monitored by groundwater specialists to identify any trend towards groundwater salinisation, which in the long run could destroy agricultural potential.

Are there other facets of food production that impact groundwater ?

The relationship between food production and groundwater is considerably more complex than the issue of aquifer depletion and salinisation. It is the work of the professional hydrogeologist to characterize and quantify the linkages, as a scientific basis for resource management. Large-scale surface-water irrigation schemes generate a major component of groundwater recharge – and in the more arid environments sometimes are the dominant and most reliable



ORIGINS OF RISING GROUNDWATER SALINITY IN AN ALLUVIAL AQUIFER WITH ARID CLIMATE component. This is the case in the Indus Basin of Pakistan and in numerous arid Andean Valleys of Peru, Chile & Argentina. Modifications to canal-water management can radically reduce groundwater recharge and storage reserves available for use during drought.

While pressurised (drip) irrigation is effective for improving agricultural water productivity and reducing unit groundwater pumping cost, it has to be combined with measures to enhance groundwater recharge at times of excess rainfall and surface-water availability. Since farmers depend on groundwater reserves in times of drought, the conjunctive management of groundwater resources with surface-water irrigation is essential for long-term resource sustainability and optimising water availability for irrigated agriculture.

The intimate relation does not end with groundwater recharge from large-scale surface-water irrigation, since all agricultural land-use practices have a footprint in groundwater recharge rates and quality. Moreover, the intensification of agricultural cropping (required to meet growing food demand) can lead to significant, and inevitably persistent, groundwater pollution through the leaching of excess nutrients and some pesticides. More stringent regulation and targeted incentives can help a lot in reducing diffuse agricultural pollution, and avoiding the associated difficulties and greatly enhanced treatment costs for drinking water-supply. Another serious complication occurs in the flood plains of some major rivers (for example, the Ganges) where the shallow saturated soil profile contains arsenic-bearing minerals, from which under certain circumstances soluble arsenic is mobilised contaminating shallow drinking waterwells and entering the rice crop itself.

DRIP IRRIGATION OF HIGH VALUE VEGETABLES FROM GROUNDWATER IN SPAIN

Why must science-based groundwater management be strengthened ?

The critical importance of groundwater for global and local food production and the clear threats to its sustainability comprise an overwhelmimg case for a concerted effort for improved management of land and water resources to meet demands for a reasonable increase in food production in a sustainable way. There is a pressing need to mobilise groundwater professionals with:

- water-resource managers and irrigation engineers, to identify and activate trans-sectoral management responses to improve resource sustainability
- macro-economic planners to recognise water-energy-food linkages and avoid subsidies that encourage use of non-renewable groundwater resources

Amongst the priorities for concerted action are :

- the elaboration and implementation of groundwater management plans (including demand-side and supply-side measures involving irrigation-water management) to stabilise aquifer systems experiencing serious depletion and/or salinisation as a result of existing agricultural practice
- the introduction of conjunctive management of canal-water and groundwater resources on major alluvial plains to enhance crop productivity and diversification, whilst avoiding land drainage and soil salinisation problems

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- trans-sector agreement and agricultural extension services to promote land management measures by farmers, which enhance groundwater recharge rates and avoid excessive leaching of nutrients and pesticides.

INDIAN FARMERS MEASURING GROUNDWATER LEVEL TO INFORM DRY- SEASON CROPPING PLAN

PRIORITY ACTIONS

- **elaboration of sustainable groundwater management plans for aquifers under pressure from irrigated agriculture, including the identification of improved irrigation-water management measures**
- **integrated evaluation and conjunctive management of groundwater and surface-water in major alluvial areas to enhance agricultural productivity and to avoid land drainage problems**
- **careful evaluation and monitoring to ensure that crop irrigation practices and new irrigation developments will not lead to groundwater salinisation problems**
- **promotion of land management measures by farmers to enhance groundwater recharge rates and to reduce nutrient, salinity and pesticide leaching to groundwater**
- **re-aligning government finances (such as crop guarantee-prices, pumping-energy subsidies, waterwell and irrigation hardware grants) so as to reflect limited groundwater availability and the value of lost ecological services - thereby supporting initiatives for sustainable resource management**

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