

WATER CYCLE AND PEOPLE

water for feeding humanity

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Introduction

Many future oriented studies on global food supply tend to take an engineering and mercantile approach: what is probable in terms of food production increase and market responses? In other words taking a forecasting approach. Uncovered food needs - mainly in S Asia and Sub-Saharan Africa are left as "hidden food gap", by 2020 estimated at twice as large as total developing country imports at that time (360 and 190 Mton/yr respectively, Conway 1997). This study takes the opposite approach. If we want the world population in its entirety to be nutritionally well fed by, say, 2025 what would that imply in terms of additional consumptive water use, i.e. taking a back casting approach?

The conventional approach to crop production distinguishes between irrigated and rainfed agriculture. It pays main interest to the former in view of the evident competition with other water uses and users. Most of the global food production, however, originates from rainfed agriculture. Rainwater represents the ultimate water resource, part of which vapourises as part of plant production (so called green water flow), while the rest forms runoff (so called blue water flow). Irrigated agriculture represents some 70 percent of the overall blue water use of altogether 3900 km³/yr. Rainfed agriculture consumes twice as much, however. Huge amounts of rainwater - in fact 2/3 of all the continental precipitation - are in fact consumed in plant production in natural and anthropogenic ecosystems (forests, grasslands, croplands). Moreover, altered plant mass production tends to be reflected in altered runoff production: a land use decision is also a water decision.

There is, however, a broad grey area between the two modes of agricultural water use. From the perspective of the crops, the key is the amount of water available in the root zone, not how the water got there: whether infiltrated rainwater or applied irrigation water. The Green Revolution had its focus on irrigated agriculture. But by dryspell mitigation efforts rainfed agriculture can be upgraded in the tropical regions, doubling or even three-folding the yields (small scale, short-

term protective irrigation based on rainwater harvesting)
(Rockström&Falkenmark 2000).

Water requirements

Let us first look at how much water that will be literally consumed - vapourised - in the food production on an acceptable nutritional level for each individual. Based on crop water requirements to produce different food stuffs, the composition of different diets, and the food needs for a nutritionally acceptable diet, Rockström (2002) arrived at a per-capita water requirement of 1300 m³/p yr in consumptive water use, irrespective of whether the roots get the water from infiltrated rainfall or from applied irrigation water. It should be observed that this corresponds to some 70 times the basic water need on a household level, if taken as suggested by Gleick (1996) at 50 l/p d.

In this back casting approach we are interested in the gross amount of water that will be consumed in producing enough food to feed tomorrow's population. We have therefore to assume 1300 m³/p yr for each additional world inhabitant, but we also have to include the additional food needed to raise the nutritional level of all the undernourished individuals in today's world. Rockström (ibid) arrived at the following global amounts of additional green water needs:

- * by 2025 + 3800 km³/yr
- * by 2050 + 5600 "

On the regional level he got the following increases between now and 2025:

- * Sub-Saharan Africa 3.1 times the present (460 to 1450 km³/yr)
- * Asia (except Soviet) 2.2 times the present (2830 to 6210 ")

Potential water sources

The result suggests that huge additional amounts of green water flow will have to be appropriated for feeding humanity on an acceptable nutritional level. The crucial question is from where will this water originate? There are three basic sources:

- * irrigation, i.e. redirecting even more blue water for meeting green water needs - an alternative that is however strongly opposed by environmentalists who feel the need to conserve most of the remaining stream flow for the benefit of aquatic ecosystems (IUCN 2000);
- * increased 'crop-per-drop' efficiency, i.e. by which losses in current agricultural water use (irrigated as well as rainfed) could be put to productive use, in other words transforming pure evaporation losses from wet surfaces into productive transpiration through the plant - a solution strongly advocated in the international water community debate;
- * horizontal expansion by which green water now used for plant production by natural ecosystems (forests, grasslands), would be used for production of crops instead.

two

Rockström has analysed (ibid) the potential contribution by 2050 from the first sources, resulting in the following possibilities to meet additional green water needs:

- * irrigation: maximum 800 km³/yr
- * crop-per-drop improvements maximum 1500 "
- * horizontal expansion minimum 3300 "

Difficult balancing between water for food and water for nature
As just indicated, there exists a strong opposition from ecological circles against both large-scale increase of irrigation (due to negative effects on aquatic ecosystems), but also of horizontal expansion (due to effects on terrestrial ecosystems). It is evident from the sheer scale of these assessments, however, that informed tradeoffs will have to be made. What problems will have to be addressed? What sort of balancing between man and nature will be needed? And what would the criteria for priority setting be? Let us look closer on the three alternatives.

Irrigation involves redirecting blue water during the growing season, turning it into consumptive green water flow. During the wet season the effect will basically be reduced flood flow. During the dry season the resulting reduction of dry season flow may be more problematic. Current examples of river depletion are offered both by the Yellow river, which in 1997 went dry in the downstream stretch seven months a year, and by the Aral Sea region where the river inflow has decreased to 10 percent of the natural flow, causing the lake evaporation to take over and the lake to shrink dramatically. Through water storages in reservoirs, wet season flow can be stored for use during the dry season.

Improved water use efficiency (crop-per-drop) can be secured in different ways in both rainfed and irrigated agriculture. On the one hand, infiltration possibilities can be improved by soil conservation measures so that more rainwater can infiltrate. This will also reduce the destructive overland flows that tend to cause severe erosion damage in large parts of the tropics. On the other hand, evaporation losses between plants can be reduced by increased foliage, for instance by protecting the plants from dryspell damage to the roots (protective irrigation during dryspells with locally harvested overland flow). Depending on where the harvested blue water was heading - on its way to evaporate or on its way to a local stream - downstream effect may or may not happen. In irrigation systems, losses may be reduced by covering the canal or by lining the canal. In the latter case however groundwater recharge is reduced with possible downstream effects on groundwater-fed wetlands, or wells used for local water supply.

Horizontal expansion, i.e. turning forested land or grasslands into croplands, may have effects on rainwater partitioning and therefore on local runoff generation. In cases where a year-round green water flow from a forest is replaced by a seasonal one from an annual crop, groundwater recharge and/or runoff production may increase. In Australia, where immigrants from Europe cleared the woodlands for croplands, the outcome was a disastrous, regional scale water logging and salinisation (so called dryland salinisation). The hydrological consequences of the other main alternative, i.e. replacing grasslands for croplands, are more complex and difficult to generalise.

The balancing needed between water for existing ecosystems and water for feeding a growing human population will evidently be a difficult one. IWMI (International Institute of Water Management) has brought together a large number of other international organizations, among them IUCN (International Union for Conservation of Nature), initiating a broad dialogue on water, food and environment. The aim is to find the way out of this considerable dilemma, which will need large-scale international attention in the next few decades.

Considerable regional contrasts

The options open for the increased food production are different between different world regions. The two regions where the dilemma is largest are the semi-arid regions in Sub-Saharan Africa and S Asia that were left with large "hidden food gaps" in conventional studies. These are the two regions with largest undernutrition and at the same time the most rapid population growth.

In S Asia horizontal expansion is highly limited: most land is already used and there are no reserves of arable but still unused land. The options are therefore 'crop per drop' and irrigation. To the degree that this will not be enough to feed tomorrow's populations, food will have to be imported.

In Sub-Saharan Africa, however, plenty of unused land remains, mainly under forests. Since 95 percent of the farmers are rainfed and there is only limited irrigation, crop-per-drop in the sense of increased irrigation efficiency will contribute only to a limited degree. There are however considerable possibilities for upgrading rainfed agriculture, provided that dryspell mitigation can be developed on a regional scale and be made attractive among the Sub-Saharan farmers (Rockström&Falkenmark 2000). During the transient process of social change and changing farmer attitudes to risk assessment, food import will probably have to play a central role (largely food aid).

A new research area appears in this connection: the water perspective of food trade, and the future flows of so called virtual water. This is the water involved in the production of food transferred from one region, better endowed in terms of water needed for food production, to a water deficient region with large food needs. Japan has recently assessed its dependence of virtual water flow to almost 20 percent more than all domestic withdrawals (104 km³/yr as compared to 89 km³/yr, Oki 2002).

Conclusions

This backcasting study of the water needs for feeding humanity in the next half century has shown that major changes can be foreseen. The reported fiasco of Johannesburg discussions of future food production should therefore cause serious concern. Already in the next generation, an additional amount of green water will be needed that is equivalent in size to ALL blue water use by humanity today. In the second generation another 60 percent will be needed. The study has also shown that the past approach, limited to irrigated agriculture and blue water needs only, will be highly insufficient. Only some 14 percent of the additional water requirements may be covered.

There will in other words be no food security without a major shift in thinking. A new approach will have to be taken to crop water requirements and the possibilities to meet those requirements. It is no longer the irrigation needs that will remain in focus, but the overall water requirements whether met by infiltrated rainfall or supplied irrigation water. Plant production will have to be addressed by referring to both green and blue water flows.

The crop water requirements represent green water flows. But when these flows change, runoff generation will be influenced and therefore also blue water flow. Conventionally such relations were covered by the concept 'water balance changes' but did not attract much interest,

probably since the evaporative demand in the temperate zone tends to be too low to generate distinguishable streamflow changes. S Africa however speaks of forest plantations as "streamflow reducing activity" for which foresters will have to pay. In a way, therefore, water consequences of land cover change, as experienced in Australia and S Africa, can be characterized as 'arid zone surprises'. Adequate attention has therefore to be paid also to the potential streamflow changes of closing the hidden food gap.

In the new approach, agricultural engineering will have to be complemented with agro-ecohydrology. There will have to be an active bridge-building between ecology and hydrology so that the conceptual void between climate, plant production and streamflow can be filled. Finally, virtual water flows will have to be focused. Today's optimistic references to food import and virtual water when discussing food security in water short regions will have to be complemented with a more realistic analysis of the regional sources for that virtual water. From where will there be enough food to import? Will it be possible to close the global virtual water balance? Or is the world approaching the carrying capacity of the planet - intensively denied in broad circles in the past?

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