Preserving the (water) harvest: effective water use in agriculture

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Abstract  The alternative to increasing the world’s irrigated area by an estimated 30% to secure food security for all, seems to be limited irrigation expansion and consequently higher food prices and probably food shortages. This paper explores other options for ensuring food security. It discusses meaningful similarities between innovative approaches for land and water management in rainfed and irrigated agriculture. The focus is on innovative approaches to increase yields in sub-Saharan Africa and South Asia. Innovative technologies, such as improved tillage practices and water harvesting are important. But at least as important are the processes by which new agricultural practices are developed, improved and extended. In the end it comes down to human inventiveness.

Keywords  Food security; improved agricultural practices; rainfed agriculture; irrigation; human inventiveness

Introduction
The World Water Vision presented at the Hague in March 2000 sketches two equally unattractive scenarios for maintaining world food supplies over the next twenty-five years, both involving large expansions in irrigated area. The first would increase the irrigated area by 30% and requires major investments in water infrastructure, a considerable part of which would have to come through large dams. Implementing this scenario entails serious risks to the environment and would still not alleviate water scarcity. The second scenario, with much reduced irrigation expansion, is expected to cause considerable food shortages and rising food prices if other policies remain as they are today. Neither scenario, therefore, is able to achieve the World Water Vision targets, universally desired, of enhanced food production for a growing world population without food riots or serious risks to the environment. At present, an estimated one billion mostly poor people live and work in situations where their farming, herding or fishing operations cannot benefit from many mainstream agricultural technologies (Altieri and Uphoff, 1999). This workshop, therefore, seeks another scenario for the future, without the adverse effects of the World Water Vision scenarios and one which focuses on those people who did not benefit from the green revolution of the past thirty years.

The ultimate objective of food production is food security. Various definitions of food security have been given but the preferred view was expressed by Pinstrup-Andersen and Pandya-Lorch (1995): the world is food secure when each and every person is assured of access at all times to the food required for a healthy and productive life. It has been argued repeatedly that today the world produces enough food to meet the needs of all. If the supplies were well distributed, there would be no food problem now or in the future, as there is still scope for further expansion of production. In this line of thought the poor, who need food but can’t afford it, are assumed away (Tims, 1995). The difficulty of delivering the food to those who are in need, especially the poor and vulnerable in remote regions, is an essential part of all food security considerations. In a discussion of innovative processes in small-scale agricultural production distribution of food and the economics of the proposed innovations should at least get equal weight with the technological aspects.
Food production is now increasing much faster in the developing world than in the developed world. It is expected that by 2020, the developing world will be producing 59% of the world’s cereals and 61% of the world’s meat (Pinstrup-Andersen et al., 1999). Nevertheless, cereal production in the developing world will not keep pace with demand, and net cereal imports by developing countries will almost double between 1995 and 2020 to fill the gap between production and demand. Hence, many developing countries will not be self-sufficient in grain production anymore. World markets respond to demand not need, which is one reason why malnutrition (also resulting from a diet with insufficient micro-nutrients) will continue among those too poor to get the right type of food.

It has been suggested that one of the ways to bridge the gap between food demand and production is to import the difference. Pinstrup-Andersen et al. (1999) expect that net cereal imports to developing countries will almost double between 1995 and 2020 to 192 million tons in order to fill the gap between production and demand. The Water Vision Document for South Asia (March 2000) estimates by 2025 for Pakistan alone a shortfall of 28 million tons of different food crops. Increasing imports, and hence reducing the degree of self-sufficiency in food production, is not an easy option for many developing countries due to the scarcity of hard currencies, especially when there are other import priorities. This is why the failure of last December’s Seattle meeting of WTO is such a disappointment for the developing countries. Those who stand to lose most if globalization were to be pushed sharply back – what those opposed to WTO appear to desire – are the developing countries, in other words, the poor (Leader in The Economist, December 11, 1999).

Finally, it is important to be reminded that innovation is not just technology and economics. It is also about those curious, unpredictable, inventive and cantankerous creatures, human beings. This paper discusses meaningful similarities between the innovative approaches for using water more effectively in rainfed and irrigated agriculture, and how human beings can make a difference by adapting innovative approaches.

Scope
Innovative thinking about more effective use of water in agricultural production requires attention for the enormous spatial variation in agricultural production systems. Sub-Saharan Africa (SSA) and South Asia (SA) are often bracketed together as the areas with the largest numbers of rural poor. However, in their use of water for agriculture, the two could not be more different. In SSA irrigation plays only a small role: it represents on average less than 8 percent of the arable land, with large differences between countries. Crop yields obtained under rainfed conditions in SSA are not accurately known. National yield data reported by FAO combine the yields under irrigation with those for the same crop when grown under rainfed conditions. Because of the much greater importance of rainfed agriculture, innovative thinking in SSA needs to concentrate on stabilizing and improving crop yields under rainfed conditions.

Variability of rainfed yields is bound to be large. In low-input subsistence farming under marginal conditions, cereal yields are often much below 1 T/ha, and it is likely that some of those data are not even included in the national records. FAO data indicate that for SSA as a whole wheat yields had increased from 982 kg/ha for the average of three years 1969/71 to 1563 kg/ha for 1989/91, an annual increase of 2.35%. Similarly rice yields in SSA increased in those twenty years by 0.8%, maize by 1.0%, millet by 0.8% and sorghum by 0.5% (Alexandratos, 1995). For all but rice, these figures mainly represent rainfed conditions.

In SA rainfed agriculture contributes only a very small proportion of the total food production. While irrigation provides employment to millions of poor farmers where other opportunities for work are lacking, yields are often as low as under rainfed conditions in
SSA. The reasons for these low yields are many, including unreliability of water supplies which keeps farmers from making adequate investments in other production factors, such as fertilisers, soil conservation measures, pest control, good seed, etc. Poor maintenance of the irrigation structures, the absence of drainage and outdated institutional arrangements have compounded the problem. Proper techniques for monitoring the physical performance of irrigation systems are essential for assessing the potential benefits that may accrue from further investments to improve irrigation systems, small and large.

Innovative thinking in SA therefore needs to focus on raising yields to levels closer to those which are presently attained under controlled conditions of experimental fields in SA. Information on how this can be achieved is generally available; the synthesised knowledge, unfortunately, is only too slowly applied. Policy support for institutional development, including far more appropriate cost recovery mechanisms in irrigated agriculture, should be supplied to support all efforts to raise yield levels.

Insufficient plant-available soil water, now generally called green water (Falkenmark, 1995) can be the result of various combinations of factors. It can result from insufficient irrigation (irrigated agriculture) or reduced rainfall (rainfed conditions). But it can also be caused by a change in the partitioning of applied water (rain or irrigation) between infiltration and storage in the soil profile on the one hand and runoff or deep percolation on the other. For example, studies with rainfed pearl millet in Niger indicate that only 4–9% of the rainfall actually takes the productive flow path as transpiration (Rockstrom et al., 1998).

There is no convincing evidence that rainfall patterns in SSA have substantially changed. Rainfall variability in SSA is inherently high. A change in what happens with rainwater once it hits the soil surface is a more likely cause of the noted decline in plant-available soil water and nutrients (Rockstrom, 1995). It is due to human-induced degradation of land and water. Natural resource degradation is commonly associated with deforestation, especially of tropical rainforests. However, over time, forest depletion has triggered a chain of effects resulting in permanently changed flow patterns in rivers systems, causing intermittent flooding and water shortages, soil erosion, sedimentation and siltation of rivers and reservoirs (Vision Document for Southeast Asia, March 2000). Human-induced soil degradation also occurs at farm and field level. Fallow periods, reduced recycling of organic matter to the root zone, and generally low fertility status of the soil all contribute to crust formation, increased runoff and reduced water holding capacity of the soil profile. Analysis of long term records of how rainwater is partitioned, e.g. those by Rockstrom et al. (1998) in Niger mentioned above and for Zimbabwe by Savenye (1998), would help to identify the rate of change in partitioning, and the scale on which it is significant (i.e., field or catchment).

Human-induced soil degradation occurs also on a large scale in South Asia. Irrigated agriculture as practised by a large number of poor farmers in SA suffers from the many shortcomings mentioned above, of which the unreliability of water supplies has probably the most important effect on farmers’ investments and hence on yield levels. Salinity and sodicity on an estimated one-third of the irrigated land of countries such as Egypt, Iraq, Pakistan and India, is often caused by poor irrigation practices. Salinity and sodicity result in surface crusting and low infiltration rates, compounded by long periods of alternate wheat and rice crops, and low applications of fertilizers and organic matter (Kijne, 1994). Optimal soil conditions for good crop growth are often not attained during either wheat or rice cultivation. Inadequate land preparation leads to poor soil aeration of the wheat crop and leaching is insufficient to drain the accumulated salts from the root zone.

It appears then that the management of both soil and water largely governs the effectiveness of water use in agricultural production. From much of the literature on successful alternative approaches we can conclude that the use of locally available resources con-
tributed to success, but that the use of external inputs should not be rejected. But, as has been pointed out by Altieri and Uphoff (1999), farmers cannot benefit from technologies that are not available, affordable or appropriate for their conditions and the purchase of inputs presents problems and risks to less-secure farmers. We should therefore discuss not so much the innovative technologies themselves but rather the processes by which new agricultural practices are developed, improved and extended. It has often been argued that “best practices” should be transferred from one area to another. This may not be appropriate when the transfer takes place from a favored to a more marginal area where one has to deal with much greater variability and risk. Mazzucato and Niemeijer (2000) have recently reported an interesting example of farmers adapting traditional soil and water conservation practices to changing environmental conditions. They found that farmers in eastern Burkina Faso practise an array of soil and water conservation measures, most of which make use of management skills and available plant (residue) materials. Farmers in the study area were found to adapt their management practices during the course of a single growing season. As a result of these adaptive practices farmers have maintained or even improved soil fertility in their cultivated soils, and there is no evidence of land degradation in spite of signs that, according to conventional wisdom, indicate susceptibility to land degradation.

**Innovative processes**

Research from several countries, including SSA, shows significant improvements in crop yields and reduced soil erosion after the introduction of alternative tillage practices, such as ripping, sub-soiling, tied-ridging, pitting, and zero-tillage systems. The key to successful conservation tillage is its integration within the total production system. The change from inverting the soil (with a plough) to only ripping up planting lines, necessitates changes in most farm operations like weeding, application of fertilizers, timing of planting, and pest management. An example taken from Jonnson (1998), illustrates various aspects of the interaction between yields and the management of natural resources. Sub-soiling in trials in a semi-arid part of Tanzania (Babati), where only the plough-pan was broken in one single action, resulted in maize yields 2.7 times higher than in the control. This increase was obtained for a fertilized crop during a rainy season with good rainfall distribution. During a good rainy season but without the application of manure the yield increase caused by sub-soiling was slightly greater (2.8 times) but from a lower yield level in the control (1.3 T/ha versus 1.8 T/ha). In years with poor rainfall during the rainy season, maize yields were at most 1 T/ha and the improvement due to the application of manure of the order of 10 to 20%.

By changing plant-soil-water-nutrient management, the system of rice intensification introduced in Madagascar increased rice yields as much as fivefold even on poor soils while applying less water (Altieri and Uphoff, 1999). The changes compared with traditional paddy production include: transplanting seedlings when they are very young and singly rather than in clumps, and with wide spacing. During the vegetative growth stage, soil is intermittently watered and dried rather than left with water standing on the field all the time. The success of this system of rice intensification is ascribed to a larger root system for each plant below ground, due to better root zone aeration, and more growth of tillers, leaves and grains above ground. A very simple mechanical weeder, pushed by hand has been developed to enable farmers to eliminate weeds easily, quickly and early. It reduces the hard labor of pulling up individual weeds by hand once they emerge. Labor requirements for this system of rice cultivation were found to be about two-thirds more days of labor per hectare during the first few years. But after farmers had become more familiar with the system requirements, especially the transplanting, the labor requirement dropped by about one-third, so that the system required only about 25% more labor per hectare.
Since yields were several times greater, the amount of rice produced per day of work was increased greatly.

I have deliberately not referred to water harvesting yet. For many people, water harvesting is what comes to mind first when thinking about innovative processes that use water more effectively. Successful examples of water harvesting using tanks and earth dams to store water for supplementary irrigation harvesting have been reported from many countries, including China, India and in Sub-Saharan Africa. Conditions for success with water harvesting have been listed by Oweis et al. (1999) as involvement of water users from the early planning stages onwards; realistic understanding by the water users of the benefits of water harvesting; strengthening and updating of existing indigenous water conservation measures, economic feasibility of the initial construction of the water harvesting facility and of the subsequent maintenance costs. Success is more likely if water harvesting is part of a village or regional land use management plan, involving improved agronomic practices and inputs. Many water-harvesting systems have failed because one or more of these conditions was not satisfied. If done successfully, water harvesting can alleviate short-term effects of climatological droughts especially in subsistence farming areas.

Conclusions

Conservation tillage is a promising system for redirecting the components of the water balance in favor of infiltration and thereby crop transpiration. Water use efficiencies can be substantially improved, while at the same time soil productivity is restored. Conservation tillage combined with good soil and water management is equally applicable to irrigated agriculture as to rainfed agriculture. Yields in both types of farming would likely be raised significantly by consistent application of good soil and water management practices, which include conservation tillage. However, as the maize yields in Tanzania illustrate, improved tillage practices are of little or no help to the farmer during dry spells and droughts. The challenge lies in the dry spells when crops suffer from short periods of water stress.

Risk is ever present in farming, and it is always a reason for discounting prospective economic returns. However, economic profitability is not the only criterion affecting farmers’ decisions. Where markets are unreliable or difficult to access, households will continue to regard self-sufficiency as the wisest strategy for food security (Altieri and Uphoff, 1999). However, economic analysis, especially considering labor inputs, is important in evaluating the possibility of adoption (and adaptation) of soil and water conservation measures. Labor in rural communities seldom if ever has zero opportunity cost even where there appears to be under-employment of young men in the villages. Hence the need to assess the returns to labor of the introduction of soil and water conservation measures.

Innovative thinking about more effective use of water in agricultural production requires bridging the dichotomy between rainfed and irrigated agriculture. Supplementary irrigation can make just the difference between crop failure and a worthwhile harvest. There are many similarities between rainfed and irrigated agriculture in terms of measures that can be taken to enhance the proportion of applied water that is effectively stored in the root zone and used for plant growth in crop fields. Simple, low pressure drip irrigation systems with elevated drums for water storage are found to be very suitable for applying supplementary irrigation to small vegetable plots. These systems have been introduced successfully in several African countries.

We may not be able to increase yields on all rainfed or all irrigated lands. Some land is too degraded for productivity to be restored economically. Instead, there we need to concentrate our efforts on the most suitable parts of rainfed and irrigated lands by encouraging higher input agriculture. Higher input can mean more management and labor input, but
does not necessarily imply large scale. But high-input agriculture can make more efficient use of green water through protective irrigation combined with improved agronomic practices. Yield levels and per capita food availability in rural areas should then improve correspondingly. The link between water use and fertiliser use is crucial.

Irrigated agriculture can never on its own enhance food production sufficiently to keep up with population growth, but it needs to be part of the strategy for enhancing food production, even in SSA. Performance accountability in public irrigation systems is rare and it seems unlikely that irrigation staff will make the necessary management changes without incentives to improve performance in a quantifiable manner. Full participation of the farmers themselves in the management and maintenance of irrigation systems should be able to change that.

Policies, institutional arrangements and public expenditure patterns which are counterproductive to integrated water resource management, need be changed so that available water can be used successfully for improving agricultural productivity in irrigated and dryland agriculture alike.

How successful we are in preserving the harvest depends then on our ability to preserve land and water, which make the harvest possible. This is equally true for rainfed and irrigated agriculture. Innovative processes require innovative thinking. This is where human inventiveness enters in. A few months ago, BBC TV showed a program on food production in Britain during the Second World War. Households with small gardens were encouraged to dig up their lawns and rose bushes and plant potatoes and vegetables instead. Government support in the form of seeds, fertilizers and advice made it a great success and much of wartime food was produced small scale in this way. It was urban and peri-urban agriculture before these terms were coined. It is a sign of hope. When people are motivated and given the right type of support, there is much that can be achieved in terms of small-scale food production. Scenarios of large-scale irrigation expansion or food shortages for many need not come true. This workshop is about the alternatives.

References


