ANNEXES TO THE REPORT

of the

AFRICAN PRE-CONFERENCE

"WATER FOR FOOD AND ECOSYSTEMS: MAKE IT HAPPEN!"

ANNEX C-1: Introduction to the Themes

Theme 1

Fostering Implementation: Know-how for Action

Annex C. Introductions to the themes

THEME 1: FOSTERING IMPLEMENTATION: KNOW-HOW FOR ACTION

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INTRODUCTION

Feeding the ever-increasing world population and solving the looming climate and water crisis are intricately linked. Yet the links between land use, crop production, food security, ecosystem protection and water resources management are not well articulated or understood by policy makers. Water is a fundamental resource for agriculture, which is a large consumptive user of water. Irrigated agriculture accounts for 70% of the global total water use; 88% in all of Africa, and over 90% of withdrawals in some developing countries in the arid regions. In Egypt for instance, Agriculture uses 85% of the surface water resources for its present 6.7 million feddans of irrigated farmland, served through an irrigation system consisting of 31,000 km of public canals, 80,000 km of private ditches, 560 pumping stations, and over 22,000 water control structures.

Irrigated agriculture is, of course, more productive than rain-fed production and contributes some 40% of world food production on 17% of cultivated land. For instance, irrigated sugar cane yield in Zimbabwe and South Africa is about 120 tonnes per ha, 240% of rainfed production yield on the lower veld. In Nigeria, irrigated rice yield is 200%, while irrigated tomato and cowpea is 120% of that of rainfed production.

The downward trend in rainfall, runoff and available water resources in West Africa and much of Africa as a result of the back-to-back droughts of the last 35 years vis-à-vis increasing demand for water in agriculture and other sectors of the economies remains a great challenge. El Niño events continue to demonstrate the water shortage impacts in all the regions of Africa, especially, the Horn, Eastern and southern Africa. Yet, it appears that more climatic dramas and their impacts will unfold in the coming decades. Climate variability and change is assuming great proportions but is just one of the major factors that put pressure on the hydrological cycle and freshwater ecosystems. Population growth, landuse changes, the changes in the industrial sector, and demands for ecosystem protection and restoration are all exerting pressures simultaneously with feedback mechanisms. It is noted that water demands are fast approaching the limits of the resources in certain areas, e.g. Sahel and sub-Sahara zones of Africa; some countries actually need to reallocate part of the 80-90% of total devoted to agriculture to other uses, particularly ecosystems. Fortunately, technologies and better management practices exist to boost that level substantially as irrigators in Israel and parts of the former Soviet Union have shown.

Integrated management (taking into account downstream and upstream interests, quantity and quality aspects, ecosystem requirements, socio-economic subsystem with its sectors as well as the basins, which host the sources of these lakes and rivers, is therefore imperative. Without such regional cooperation and integration for effective basin and water resources management, the sustainable development of the economies of the riparian countries may remain elusive. Time seems to be running out as water stress and scarcity as well as inadequate quality is already hurting many of Africa's economies and millions of its population. Fortunately, a number of transboundary organizations have been established and are operating, though under many constraints.

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Although they cover the largest part of the continent, the Northern and Sudano-Sahelian regions of Africa contribute only respectively 1.2% and 4.3% of the total water resources of Africa. The southern region also shows a very low runoff coefficient of 9%[2].

For the continent as a whole, about 85% of water withdrawals are directed towards agriculture but this figure varies considerably from one region to another. Arid regions, where irrigation plays an important role in agriculture, have the highest level of water withdrawal for agriculture. The northern region of Africa accounts for more than half of the continent's agricultural water withdrawals. In contrast, the humid regions show the lowers agricultural withdrawals: 62% for the Gulf of Guinea and 43% for the Central region, where it is the same as domestic use.
The ratio of water withdrawal to internal renewable water resources is an indicator of the importance of transboundary water transfers for some countries. Libya, Tunisia, Morocco and Algeria have almost no transfer from other countries. The rate of utilisation of water resources is high. This situation requires a very strict management of the resources and leads to a competition between the sectors of water use. In Libya, annual water withdrawal is higher than the volume of renewable resources, the difference coming from non-renewable resources (fossil water). Egypt and Mauritania also withdraw more water than is produced on their territory, but benefit from transfer from other countries through the Nile and Senegal rivers respectively. Niger, Somalia, Eritrea and Chad, in the Northern Hemisphere, and Namibia and Botswana in the South, have few internal renewable resources but benefit from important transfers. In these countries, withdrawal is still less than their internal resources, but some of it is already taken from incoming water. Sudan, South Africa and Swaziland have high rates of use of their internal resources, but benefit from important resources and significant amounts of incoming water.

Balancing and reconciling food and ecosystems as competing users of water entails:
Manner of allocation of water in general, and in particular to each these two uses
Making compromises in the use of a shared and finite and vulnerable supply of the resource
Recognizing both as subset ecosystems and managing them as such while reconciling needs and services for both systems: that food systems have attached services while ecosystems also have capacity to produce foods generate incomes that also help to alleviate poverty and hunger.

The paper therefore discusses the subject of this address with the above considerations and attempts to answer the two key questions that have been posed. The paper examines the role of water in the integration of food and ecosystems using local cases where available to illustrate lessons learnt from past experiences and successful approaches as well as make recommendations for future knowledge generation and make the same available to support stakeholder management

The two key questions are:
1. How can one integrate and apply knowledge for managing the intertwined relation between water for food and ecosystems?
2. How can one enhance effective stakeholder involvement?

INTEGRATING KNOWLEDGE

Water requirements of food security and ecosystems – the role of allocation policies and practices?

The amount of water required to grow plant-based food is only about 20% of that for animal-based food (tables 1 & 2). The disparity in the actual water requirements might not be so great, however, when the actual calorie intake is considered (Table 1).
Depending on their diet and where their food is grown, each person is responsible for the conversion of 2000 to 5000 litres of liquid water to vapour each day. The daily amount of water used for drinking

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[2] This is the ratio of annual runoff generated within a country to the total annual rainfall it receives.

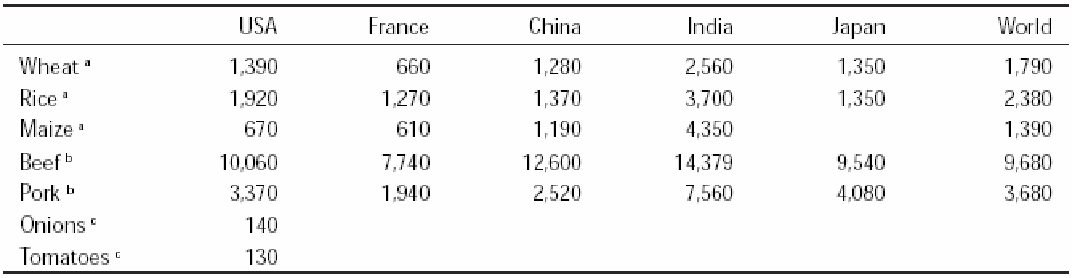
(2 to 5 litters) and for domestic washing, sanitation, and other household tasks (50 to 200 litters per person) seems insignificant when compared to the amount of water we eat (Molden *et al op. cit*.).

In the United States and Europe meat consumption has stabilized at around 25 to 30% of total calorie intake, whereas in African countries it constitutes of less than 10%. In Asia, meat consumption took off in the late 1970s, quadrupling to nearly 15% of total calorie intake in 2001, and it is still rising—much of the increase coming from China (Fig. 1). India remains largely vegetarian, because of cultural and religious reasons.
By 2025, there will be an estimated 2 billion more people to feed. Growing more food means using more water. To produce one kilogram of grain, plants must transform between 500 and 4000 litres of water—depending on the type of crop, the climate, and water and land management practices— into vapour through the process of evapotranspiration.

Table1 Water requirements for food per capita. Source: FAO (see Falkenmark, 1997[3])

Food	Plant-based	Animal-based	Total
Daily amount (kcal)	2300	400	2700
Daily water required per kcal (m^3)	1	5	-
Daily actual water requirement (m^3)	2.3	2.0	4.3
Annual water requirement	840	730	1570
Assume 50% irrigation production (m^3)	-	-	785

Table 2 The amount of water used to grow food (in litres evapotranspired per kilogram).



	USA	France	China	India	Japan	World
Wheat [a]	1,390	660	1,280	2,560	1,350	1,790
Rice [a]	1,920	1,270	1,370	3,700	1,350	2,380
Maize [a]	670	610	1,190	4,350		1,390
Beef [b]	10,060	7,740	12,600	14,379	9,540	9,680
Pork [b]	3,370	1,940	2,520	7,560	4,080	3,680
Onions [c]	140					
Tomatoes [c]	130					

[a] from Fraiture et al (2004) [b]Chapagain and Hoekstra (2003) [c]Renault and Wallender (2000); data for California (see Molden *et al,* 2004).

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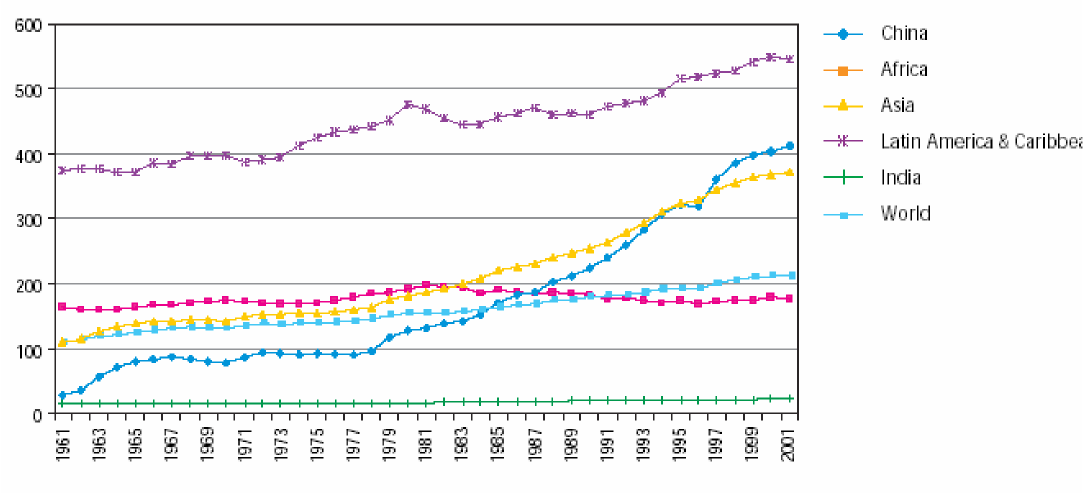
[3] Falkenmark, M (1997) Managing water requirements of an expanding world population. Phil. Trans. Roy. Soc, London, B. 352, 929-936.

Fig. 1 Calories per capita met by meat products.



If modification occurs, wetlands can have "too much" water as well as "too little water" and this can profoundly affect their functions. Due to the importance of wetlands, an environmental flow is required to help them continue providing goods and services. An environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated. Dams are often the most significant and direct modifiers of natural river flows. They are therefore an important starting point to implement environmental flows. Environmental flows provide critical contributions to river health, economic development and poverty alleviation. Yet, pioneering efforts in South Africa, Australia have shown that the process to establish environmental flows, especially when part of an integrated management approach, poses great challenges.

Case of Chad Basin: Logone Wetlands, Cameroon

Analysis of water use in the Logone floodplain reveals huge losses in the traditional floodplain agricultural production in recent decades due to climate variability and human activity. A barrage was constructed across the floodplain in 1979 to create Lake Maga. And supplied irrigation water to some farms. This together with the construction of the Yagoua-Tekele dyke (on the Logone) had had severe negative environmental and social impact on the wetlands and the people. Recession rice cultivation dropped to 75% and cotton to 33%, fish yields collapsed by 90% for lack of inundations (Matt and MacDonald, 1999, Oyebande 2001). Together with collapse of the floating rice farming this had produced a battalion of unemployed Kotoko youths who needed retraining and empowerment to work with other rice varieties and with the collapsible fish cages.
A good example of the achievement stakeholder participation in the Chad basin is the rehabilitation of the Logone wetland in Cameroon in 1993. The embankments of the barrage along the river were modified over eight years. Stakeholders and local community members were involved in the planning and design of the project. Small-scale fishing has recommenced and potable water from groundwater source has been supplied to 33 villages.

Also in Burkina Faso, a new Water Framework Law (*Loi d'orientation sur l'eau*) was adopted in February 2001. This adopted legal and institutional framework for the management of water resources promote integrated basin management, equitable access, water for nature, international cooperation. In its article 40, this framework recognises that "infrastructures which are built on a water course may maintain a minimal flow that guaranties aquatic life..."

Nowadays, there is an increased awareness and emerging policy frameworks regarding environmental flow due to the benefits of aquatic ecosystems, they need to be followed now by accurate information on the amounts of water required to sustain these ecosystems and the different levels of benefits they can provide. In a recent presentation, estimates of environmental flows show that on average some 30% of the annual river flows are needed to maintain ecosystem services and a reasonable level of environmental quality[4].

Added values of ecosystems in terms of water retention, water treatment, erosion control, etc

Irrigation development has often come with a high environmental price tag. These costs range from aquatic ecosystem degradation, fragmentation and desiccation of rivers, and drying up of wetlands. A few widely quoted studies from Barbier and Thompson (1998) and Acreman (2000) show that in some cases the values generated by irrigation proved to be less than the values generated by the ecosystems they replaced. For example, an economic valuation conducted to assess the benefits of the Hadejia-Jama're wetlands in Nigeria. It estimated some of the key direct use values the floodplain provides to the local population: crop production, fuel wood, and fishing (Barbier, Adams and Kimmage 1993). It also provided comparison with the net agricultural benefits of a major upstream development, the Kano River Irrigation project. The net present value of a weighted aggregate of the agricultural, etc. of the floodplain was estimated at US$34 to US$51 per ha or about US$9.6 to US$14.5 per 10^3 m^3 of annual floodwater input into the wetlands. The corresponding value for the Kano River Irrigation Project is US$20-31 per ha or US$0.03-0.04 per10^3 m^3 of annual irrigation water use.

Lake Chad basin is an interesting example. The basin is home for some of the poorest countries of the world. The estimates of annual household income (CFA) from various sources or activities are as follows in order of importance: fishing 26 billion, crops 15.5 billion, animal husbandry 8.6 billion, small irrigation schemes 6.3 billion and large irrigated projects 5.5 billion. However, the World Resources Institute estimates the real value of ecosystem services to twice the gross national product of $33 trillion. The services of highest value (soil formation) are valued at $17 trillion, followed by recreation $3 trillion. Each of nutrient cycling and water regulation and supply is valued at $2.3 trillion, climate regulation (temperature and rainfall) $1.8 trillion, habitat $1.4 trillion, and flood and storm protection $1.1 trillion, food and raw materials production, genetic resources each $0.8 trillion, atmospheric gas balance $0.7 trillion and pollination $0.4 trillion. The values of other resources add up to $1.6 trillion. The habitat thus needs to be protected in order to preserve the values of the ecosystem services.

Freshwater ecosystems (such as ponds, lakes, wetlands and rivers channels) are essential components of the environment. They provide support for the existence of aquatic and terrestrial wildlife, environmental goods (e.g. water, foods) and services (such as flood attenuation, depletion of organic pollution). In West and Central Africa fish are a key element in the social and economic organisation of human communities and are the first source of proteins, and sometimes the only one, especially for the poor. The region's wetland ecosystems in the Senegal Valley, River Niger's interior and coastal deltas in Mali and Nigeria respectively, the Volta basin, and the Chad basin countries of Chad, Cameroon, Niger and Nigeria's extensive north-eastern areas among others, perform vital functions such as flood reduction, groundwater recharge and low flow augmentation. Important products, such as fish, pastureland, reeds, medicines, fuel wood and timber among others are produced in relatively cost-effective manner with minimum damage to the freshwater ecosystems[5]. Thus, for the millions of people, particularly the rural poor who depend directly on natural resources or benefit from ecosystems, providing water for the environment and for people are one and the same. Therefore vulnerability analysis must include information for adaptation policies and help to meet social goals.

How to achieve water productivity gains in agricultural without compromising ecosystem water requirements conservation

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[4] Striking a Balance between Water for Food and the Environment. Third World Water Forum**,** Japan. Secretariat of the Dialogue on Water, Food and Environment, Colombo, Sri Lanka 17 March 2003**.**

[5] Cost-effectiveness and efficient use of scarce water resources

The secret partly lies in agricultural water use efficiency or water productivity, but scales microeconomics to macroeconomics and global economy and decision-making and lifestyles. The production function for a farmer A relying on limited water for irrigation may be written simply as

$$Y^A = Y\,(T^A, K^A, L^A, S^A, W^A, F^A, P^A), \qquad (1)$$

where Y^A is crop yield, T^A land base, K^A capital input, L^A labour input, S^A seed varieties used, quantity and timing of irrigation water received, F^A application rate and timing of fertilizers, and P^A pest management/crop protection strategy of the farmer.

Land productivity usually defined as some yield per ha or so is well known, but it is considered not an adequate measure of efficiency (Oyebande, 2000). All the other input variables are important in order to obtain high land productivity, yield per ha, the very increases that were popularly tagged Green Revolution in the 60s and 70s. As a key ingredient in the Green Revolution, irrigation has helped raise agricultural productivity, particularly in Asia and North America. The steady annual productivity increases of over 2% of the 60s and the 70s have come down to a current and expected 1%.

One reason for the deceleration is that the biological limits for improving high-yielding varieties appear to have been reached and another is that there is less water to fuel productivity increases (Oyebande, 2000). However, plant productivity may be improved over the next 25 years through biotechnology, both through tissue culture and through genetic modifications. The rate at which biotechnology will support productivity increases is extremely difficult to predict and, of course, there is considerable debate over the public acceptability of genetically modified organisms.

Thus there is need for paradigm shift, and a first prerequisite for this shift in focus from land productivity to water productivity will be an effort to measure and monitor water use and water productivity, both in the field and in research and development.
Table 3 shows a summary of approximate water use efficiency of rain fed and irrigated agriculture. Where agriculture is practised on poor land, water use efficiency (WUE) can be even lower. For instance, in typical farmers fields in Niger, the traditionally grown millet plant transpires only about 5% of the available water in West Africa. These very low efficiencies demonstrate the scope for improved food production from rain fed agriculture. If the amount of water transpired could be increased from 5 to 10%, which is a possible target, then dry land yields could be doubled.

Table 3 Estimates of water-use efficiencies of irrigated and rain fed agriculture in semi-arid areas (Wallace & Batchelor, 1997)[6]

Process	Irrigated agriculture: Proportion of available water[a] (%)	Rain fed agriculture : Proportion of rainfall (%)
Storage & conveyance (loss)	30	0
Rainfall & drainage	44	40-50
Evaporation (from soil or water)	8-13	30-35
Transpiration	13-18	15-30

a Rainfall and stored surface or groundwater.

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[6] Wallace, J.S. & Batchelor, C.H. (1997) Managing water resources for crop production. Phil. Trans. Roy. Soc. London, B. 352, 937-947.

Table 4 The effect of soil tillage on runoff from sandy soils in West Africa: Source: Stroossnijder & Hoogmoed (1984)[7]

Year	Rainfall (mm)	Runoff: no tillage (mm)	Runoff: with tillage (mm)
1977	368	155	76
1978	271	104	49
1979	361	141	80
Average	333	133	68

In this case, efforts should not just focus on the 2,500 km3 of water diverted annually to irrigation, but must also include the 4,500 km3 depleted in rain-fed agriculture. Rain-fed agriculture contributes to about 60 percent of cereal production on 70 percent of the global cereal area, and is the primary means of food production in most countries, and the only means of production for many farmers. Consequently, a 1 percent increase in rain-fed cereal production would have 1.5 times more effect than a similar productivity increase in irrigated cereal production (Molden & *et al, op. cit*.).

It is expected that improving water productivity should allow farmers to grow the same amount of food with less water. Increasing water productivity is necessary, but not sufficient. The water that is "freed up" can go to ecosystems and cities, or it can be used to grow more food. In practice, local gains in water productivity provide an excellent incentive for farmers to intensify or expand cultivated area (Molden *et al, op. cit*.). For example, using drip irrigation, a farmer can irrigate more land; get more production and money with the same amount of water delivered to crops. More crops and more production, even with the same amount of water delivered, leads to *more* evapotranspiration, and may lead to further ecological degradation. Therefore, along with water productivity enhancements on-farm, must come rules for allocating scarce resources to make sure that water released from agriculture is used to meet other purposes such as ecological restoration

Of course, water productivity gains do have an environmental cost. They will in many cases require more fertilizers and agricultural chemicals, which can have negative consequences for the environment. These negative consequences can be minimized through better water and land management practices and that the positive benefits for the environment far outweigh the negatives.

Alcamo et al (2000), estimating irrigation withdrawals in 2025 based purely on environmental considerations, found that in order to sustain ecosystems, irrigation withdrawals need to be reduced by 7 percent from 1995 levels. Clearly some tradeoffs between environmental considerations and food production will be unavoidable, but there are various options that have been put forward for minimizing them.

According to Molden *et al, op. cit*.) A rough estimation shows that improving water productivity by 40% on rain-fed and irrigated lands can reduce the need for additional withdrawals for irrigation to 0 over the next 25 years. The amount of grain that farmers get per cubic meter of water consumed (evapotranspired) ranges from 0.2 kilograms—typical of rain-fed systems in sub-Saharan Africa— all the way up to 2.5, found in highly productive rain-fed systems in Europe. In a review of 40-irrigation systems, Sakthivadivel et al (1999)[8] found a 10-fold difference in the gross value of output per unit of water consumed by evapotranspiration. Differences between countries are also notable, but many rain-fed and irrigated systems in the EU, USA, China, most of the Mediterranean region, and Brazil are already operating at high water productivity levels. Systems in Asia and Africa with low-productivity

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[7] Stroossnijder, L. & Hoogmoed, W. B. (1984) Crust formation on sandy soils in the Sahel. II. Tillage and its effects on the water balance Soil Tillage Research 4, 321-337.

[8] Sakthivadivel, R.; de Fraiture, C.; Molden, D. J.; Perry, C.; Kloezen, W. 1999. Indicators of land and water productivity in irrigated agriculture. International Journal of Water Resources Development, 15(1/2):161-179.

and a high incidence of poverty should receive priority for productivity improvements. In sub-Saharan Africa, doubling or tripling yields is quite feasible with improved tillage and supplemental irrigation.

Cases such as Water conservation and waste water disposal in Robertson town (South Africa), Critical analysis of river basin management in the Great Ruaha (Tanzania) and Developing Community Management for Small Dams and Irrigation in communal lands in Midlands and Masvingo Provinces (Zimbabwe) illustrate a win-win strategy to achieve water productivity gains in agricultural without compromising ecosystem water requirements conservation (www.gwpforum.org, IWRM toolbox).

Technologies are available for ecosystem design, engineering, and rehabilitation: How effective are they in improving ecosystem functioning, services and productivity?

Several practices and technologies on rain-fed and irrigated land can lead to improved water productivity. The technical basis for this improvement is through increasing the amount of water made available to plants and/or increasing the efficiency with which transpired water produces biomass. According to the approach by Gregory *et al* (1997)[9], the water-use efficiency (WUE) of a crop can be written as

$$WUE = e_{w} / \{1 + (L + E_{s} + R + D)/E_{t}\} \tag{2}$$

Where WUE is the amount of biomass (*W*) produced per unit of water resource (be it rainfall, surface or groundwater). *L* are the losses in storage and conveyance, E_s is evaporation from the soil (or open water in paddy rice, etc.), R is runoff, *D* is drainage from the crop root zone and E_t is the crop transpiration, e_w is the transpiration efficiency or the water us ratio, the ratio of the amount of carbon fixed by a plant per unit of water transpired (W/E_t). A range of engineering, hydrological and agronomic techniques and microclimate manipulation can be used to increase $e_{w.}$

Four ways of potentially increasing transpiration are:

- Reduce *L* (storage and conveyance, in irrigated agriculture) using a range of engineering or management techniques to increase infiltration i.e. reduce runoff); and
- Reduce *R, E*, and *D* (in both irrigated and rain fed agriculture).

The specific techniques for achieving those desired objectives are well known, but the suitability and net effect of a particular approach in a given environment requires further study. For example, tillage practices ranging from contour bunds to terracing. The effect of bunds has been demonstrated in Zimbabwe in different soil types. In West Africa simple surface tillage using local hand tools halved the amount of runoff through increased surface storage and/or soil infiltration rate (Table 3).

At farm and field scales, improved crop varieties and improved soil fertility boost yields and water productivity. More precise irrigation application using sprinkler or drip technologies or improved surface systems, such as laser levelling, can also enhance yield, and require less diversions of water, because of reduced direct evaporation.
In dry areas, deficit irrigation—applying a limited amount of water but at a critical time—can boost productivity of scarce irrigation water by 10 to 20 percent.
Giving farmers better access to water for irrigation through groundwater development and small-scale technologies can increase productivity and reduce poverty in both irrigated and rain-fed areas. In northern Nigeria, small farmers with access to water account for more than 70% of irrigated land.
Within basins, allocating supplies to various uses to enhance values improves water productivity.
Modifying the landscape, for example livestock grazing practices of changing land use, influences water flows (Falkenmark 2003) and thus water productivity.

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[9] Gregory, P.J., Warren, G.P., Simmonds, L.P. (1997) Interactions between plant nutrients, water and carbon dioxide as factors limiting crop yields. Phil Trans. Roy. Soc. London, B. 352, 987-996.

In addition to technical solutions, strong supporting policies are needed. For example, agricultural subsidies in rich-countries may discourage farmers in Africa from investing in productivity-enhancing inputs because crop prices are too low for them to get a return on their investment. Firm land and water rights are needed so people will invest in long-term improvements.
Good governance and water management along the principles of IWRM, are necessary for water productivity improvement increases.

ENHANCING EFFECTIVE STAKEHOLDER MANAGEMENT

Mobilizing existing groups and networks to contribute to the further development and implementation of an integrated approach to the management of water, land and diversity?

Water use in agriculture affects ecosystems and the services they provide (Gordon and Folke, 2000) not just by reducing the amounts of water available, but also by polluting water, altering river flow patterns, and reducing habitat connectivity by drying up parts of rivers and streams. Co-managing water for agriculture and the ecosystems can minimize these impacts. Steps in co-management include (Molden *et al*, 2004):

- Assessing the value of fisheries and other ecosystem services and their role in livelihood strategies
- Assessing environmental flow requirements—the flow amounts and patterns needed to sustain desired ecosystem characteristics and services.
- Creating forums for dialogue and negotiation between parties with different interests—for example farmers and fishers—based on knowledge of tradeoffs and potential impacts of water management decision. In some cases, however, the same persons wears both caps, as in Lake Chad basin in north-eastern Nigeria – many former fishermen became farmers as their water bodies dry out or in years when artificially aggravated floods prevent the poorly equipped fishermen from fishing in deeper waters.
- Allocating water to sustain ecosystems taking into account all of the above.

Reorienting irrigation planners and managers to appreciate the needs of multiple water users, not just farmers, can both lessen environmental impacts and improve the productivity of irrigation systems. For example, with appropriate water management, irrigation systems can also sustain fisheries, substantially boosting food production from the system and contributing to livelihoods and nutrition. Fortunately, the era of single-purpose dams has yielded place to multi-purpose designs. The real need is to use the dams effectively as designed. In many cases, there are simple but effective ways to lessen irrigation's impact on biodiversity in aquatic and terrestrial ecosystems—for example, providing "corridors" for movement of animals and fish, maintaining a diversified landscape instead of promoting huge mono-cropped tracts, and reducing off-site drainage to reduce the flow of water polluted with agro-chemicals into rivers and wetlands.

Cases such as Community Management in Lake Victoria Drainage Basin (Kenya) and The role of water users' associations (WUAs) in reforming irrigation (Egypt) illustrate a win-win approach through decentralization of basin management and effective stakeholder participation (www.gwpforum.org, IWRM toolbox).

The Egypt case illustrates how we can raise the capacity of stakeholders to increase their knowledge on water and to use it for food and ecosystems in their decision-making processes. The water users association provide a cooperative avenue for the ownership of projects, training in operational and maintenance and fulfilling the individual's commitment in terms of payments of water charges, etc. It also provides a veritable avenue for making information available to that important segment of the stakeholders.

Major constraints of achieving Water productivity among farmers

Much of Africa's food is wasted – farmers lose 15-25% of their crop in the field and another 15-20% after harvest to pests because of poverty or lack of the means and skills to protect the food crops in the fields and after harvest through proper processing and storage. There could be much difficulty in getting more production from rain-fed agriculture, as lack of empowering policy incentive may discourage future growth of rain fed production in much of Sub-Saharan Africa, where farmers are unlikely to invest, even if they can afford it, in inputs (fertilizers, crop protection measures and good quality seed to raise land productivity. Fertilizer application in Sub-Saharan Africa in 1988/90 was only 11 kg per ha compared to world figure of 62 kg.

How can we meet the water needs of both people and the ecosystems? There seems to be an ever increasing need more water to feed people, more water to reduce poverty, and more water to sustain natural ecosystems. Though relatively negligent compared to agricultural water needs, water demands for cities and industries are also increasing rapidly, particularly in developing countries, and there is less water to go around. The options that have been put forward for solving this dilemma can be divided into six basic pathways (Molden *et al, op. cit.*):

1. Influencing diets towards less water-consuming foods
2. Increasing food trade from water-abundant countries to water-short ones ("virtual water")
3. Using alternative sources of water such as wastewater or saline water
4. Improving irrigation efficiency
5. Increasing water productivity ("more crop per drop") on both rain-fed and irrigated lands
6. Upgrading rain-fed systems through the introduction of supplemental irrigation and better land and water management practices.

While any lasting solution will most likely involve multiple pathways, of these six we consider a combination of the last two—increasing water productivity and upgrading rain-fed systems seems to have the most potential to improve food security and reduce poverty at the lowest environmental cost. Any solution will require supportive policies and institutions to make it a reality.

Need for restoration of degraded lands and reversing ecosystem deficits

Currently soil erosion, nutrient depletion, salinisation and other forms of land and water degradation are putting the brakes on water productivity gains in many areas. World-wide 40 percent of agricultural land is moderately degraded and 9 percent is highly degraded—reducing global crop yield by as much as 13 percent (Wood et al. 2000)[10]. In rain-fed agriculture, land productivity is declining on an estimated 40 percent of cultivated area (Hansen and Bhattia 2004)[11]. Without reversing these trends, increasing water productivity will be impossible in large parts of South Asia and sub-Saharan Africa—regions particularly vulnerable environmental degradation. But as with water harvesting and supplemental irrigation, we need to know more about how to spread positive examples. Research supported by the Comprehensive Assessment is looking at "bright spots"—where communities have managed to reverse both land and water degradation— to determine the major drivers of success. In some cases, farmers may need incentives to make long-term investments in soil conservation and other land management practices—particularly when results from such investments do not have an immediate or direct impact on their incomes. Social and institutional factors such as land tenure also affect farmers' willingness to invest.

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[10] Wood, S.; K. Sebastian; S. J. Scherr. 2000. Pilot analysis of global ecosystems: Agroecosystems. Washington, D.C.:International Food Policy Research Institute, and World Resources Institute. 110 pp.

[11] Hansen, S. and R. Bhatia. 2004. Water and Poverty in a Macro-economic Context. Paper commissioned by the Norwegian Ministry of the Environment in preparation of CSD12, April 19-30, United Nations, New York.

CONCLUSION & RECOMMENDATIONS

Conclusion

IWRM should be the guiding principle for balancing and reconciling water for food security and ecosystem integrity. It has been shown that rain fed agriculture is by far the greatest user of water. Therefore both irrigation and rain fed agriculture enter the water-food-ecosystem equation, and both are required to produce enough food to feed the teeming world population.

Recommendations

Further development of the concept of virtual water trade – particularly international trade in food and fibre – should focus on environmental, social, economic and political implications of using virtual water trade as a strategic instrument in water and food security policies, including WTO negotiations.

The concept of environmental flow requirements needs to be further worked out and applied at the basin level to provide a basis for balancing water for food security and ecosystem integrity.

A target should be adopted for water for productive use to complement the existing water supply and sanitation targets. An appropriate target was formulated by the Prince of Orange in No Water No Future www.nowaternofuture.org): *"Increased food production to achieve target for decreasing malnourishment and rural poverty without increasing global diversion of water to agriculture over the 2000 level"*.

Role of research such as Comprehensive assessment and Challenge Programme (CGIAR program on Water and Food, a major research and development initiative to increase water productivity for food, and livelihood in a manner that is environmentally sustainable and socially acceptable www.waterforfood.org) inform policy and investment decisions in agriculture, livelihoods and ecosystems? The Comprehensive Assessment of Water Management in Agriculture takes stock of the costs, benefits, and impacts of the past 50 years of water development for agriculture, the water management challenges communities are facing today, and the solutions people have developed. Through a process of research synthesis, review, and dialogue, the Assessment is bringing together scientists from over 90 institutes worldwide with policymakers, development professionals, and water users. The results of the Assessment will enable farming communities, governments and donors to make better-quality investment and management decisions in the near future and over the next 25 years (www.iwmi.org).

Other research programmes in Africa such as the African Monsoon Project, START/PACOM fulfil similar roles for African scientists and technocrats as well as policy makers in climate, hydrology, ecology, and associated land and water resources. START, the global change SysTem for Analysis, Research and Training, co-sponsored by the International Geosphere-Biosphere Programme, the International Human Dimensions Programme on global environmental change, and the World Climate Research Programme, seeks to enhance the scientific capacity of developing regions to conduct global change research. START promotes regional collaborative research networks, which conduct research on regional aspects of environmental change, assess impacts and vulnerabilities to such changes, and provide information to policy-makers. START mobilizes resources to support infrastructure and research programs on environmental change within developing regions and provides a variety of capacity building programs to global change scientists within these regions.
Through its various activities, START enhances the scientific capacity of developing countries to address the complex processes of environmental change and degradation.

PACOM, the Pan-African Committee for START, serves as a regional coordination body for START's activities in Africa. PACOM is comprised of scientists and policy-makers who are actively engaged in activities addressing issues related to global change and its relation to sustainable development. The Pan-African START Secretariat, based at the University of Nairobi, serves as the coordinating office for START's activities in Africa. START website (www.start.org).

Dialogue: the dialogue on Water, Food and Environment is an initiative established by ten international organizations to improve water resources management by bridging the gap between the food and environmental sectors through open and transparent dialogues and knowledge building base and sharing (www.iwmi.cgiar.org/dialogue/index.asp). It is helpful to present and share experiences from a number of country and basin dialogues in different parts of the world. It is also necessary to discuss the context, issues, constraints & difficulties, strategies for fruitful dialogues processes on water/food and ecosystems with different cases.

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Table 5. Regional Distribution of water resources

Region	Area	Precipitation	Internal renewable resources			
	(1000 km^2)	(km^3/yr.)	Km^3/yr.)	(mm/yr.)	% of total for Africa	% of ppt
Northern	5 753	411	50	8.7	1.2	12.2
Sudano-Sahelian	8 591	2 878	170	19.8	4.3	5.9
Gulf of Guinea	2 106	2 965	952	452.0	23.8	32.1
Central	5 329	7 621	1 946	365.2	48.8	25.5
Eastern	2 916	2 364	259	88.8	6.5	11.0
Islands (I.O.)	591	1 005	340	575.3	8.5	33.8
Southern	4 739	2 967	274	57.8	6.9	9.2
Total	30 025	20 211	3 991	132.9	100.0	19.7

Table 6 Regional distribution of water withdrawals

Region	Withdrawals by sector					
	Agriculture	Communities	Industries	Total	As % of total	As % of internal resources
	X $10^6 m^3$/yr	x$10^6 m^3$/yr	x$10^6 m^3$/yr	x$10^6 m^3$/yr	%	%
Northern	65 000 (85%)	5 500 (7%)	5 800 (8%)	76 300 (100%)	50.9	152.6
Sudano-Sahelian	22 600 (94%)	1 200 (5%)	300 (1%)	24 100 (100%)	16.1	14.2
Gulf of Guinea	3 800 (62%)	1 600 (26%)	700 (12%)	6 100 (100%)	4.1	0.6
Central	600 (43%)	600 (43%)	200 (14%)	1 400 (100%)	0.9	0.1
Eastern	5 400 (83%)	900 (14%)	200 (3%)	6 500 (100%)	4.3	2.5
Islands (I.O.)	16 400 (99%)	200 (1%)	20 (-)	16 620 (100%)	11.1	4.9
Southern	14 100 (75%)	3 000 (16%)	1 800 (9%)	18 900 (100%)	12.6	6.9
Total	127 900 (85%)	13 000 (9%)	9 020 (6%)	149 920 (100%)	100.0	3.8

Source: FAO (1995)