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Background paper:

Water governance challenges: Managing competition and scarcity for hunger and poverty reduction and environmental sustainability

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Abstract: The report addresses the growing water challenges in developing countries, distinguishing between two different categories of water resources problematique. In the irrigated Green Revolution countries, an urban/rural blue water competition is emerging, driven by population growth, urban expansion, industrialization and new lifestyles. The problems are especially demanding in regions with depleted rivers and overexploited groundwater aquifers. For the billions of poor in the semiarid savanna regions, where rainfed smallholder farming dominates agriculture, a new type of agricultural revolution is called for, harvesting the potential of green water in the soil through conservation farming and rainwater harvesting. Due to this dichotomized problematique, water governance has to shift its focus from blue water and incorporate also green water linked to land use, and see rainfall as the manageable freshwater resource. To secure environmental sustainability, special efforts are called for to clarify water-related trade offs in balancing between human and ecosystem wellbeing.

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1. Introduction – setting out the challenges

As a consequence of socio-economic advances, demographic trends and high-level pledges to eradicate extreme poverty and hunger, the pressure on freshwater resources is bound to increase. Globally, some 70 percent of water resources withdrawn are used for irrigation, some 10 percent goes to households and the remaining part to industries. For most agricultural economies of developing countries, water use by agriculture is much higher and reaches in some countries well over 90 percent of total water withdrawals. To get access to or to make sufficient water available to increase food production is thus a major challenge to lessen hunger and poverty. For example, the achievement of the Millennium Development Goals (MDGs) related to hunger and poverty alleviation, improved water supply and sanitation and sustainable environmental development will require that more water be utilized in combination with more efficient water use. In addition to the massive need for an improvement in livelihood for the poor, a growing middle class, with cash and loans to spend, articulate their wants by demanding more goods and services. Both the needs of the poor and the wants of the growing middle class have to be catered for from the same, basically finite, erratic and vulnerable water resources. At the same time, water plays a crucial role to sustain ecosystem functions and in aesthetic terms, during busy hours and leisure.

1.1 Expanding water depletion and dilemmas of equity

Socio-economic advances and demographic changes, such as increasing urbanization, imply that water resources within a basin become increasingly diverted, controlled and used. In many river basins the water resources are already close to or already overcommitted in the sense that the streamflow has been depleted beyond what is needed downstream for flushing, dilution and sustaining aquatic ecosystems. It has been indicated that such overcommitment has already spread over 15 percent of the land area hosting 1.4 billion inhabitants (Smakthin et al 2004).

The fact that streamflow is increasingly depleted as irrigation continues to expand should be no surprise (Falkenmark and Lannerstad 2005). The more intensive the irrigation is in order to increase crop production, the lesser are the ”losses” and the larger the part of the water withdrawn that is productively used for evapotranspiration in the photosynthesis process.

When a basin approaches closure, water allocation has to be modified so that a certain minimum so-called environmental flow remains in the downstream river. This situation currently characterizes large parts of the irrigated tropical regions. One consequence is that further expansion of irrigated agriculture can only be very limited.

Increasing water scarcities are at their core socially and politically induced challenges. The water challenges are essentially about how we, as individuals, and as parts of a collective society, govern the access to and control over water resources and their benefits. It is clear that in many places, particularly in tropical zones, challenges include improved equity and efficiency and striking trade-offs between human and ecological water use. Improved water governance will thus be critical to meet challenges related to increasing water scarcities and competitions.

The complex dilemma of equity, resource stewardship and environmental sustainability entails competition and conflicts, which require effective and just policies. Water typically transcends political and administrative borders and boundaries and must be shared between individuals, economic sectors and, many times, between countries. One of the basic challenges for governance is that competition is not between equals but rather between interests that exercise different power and which are at odds with each other; the poor *vs.* the rich, urban *vs.* rural sectors, economy *vs.* ecosystems; yet they all rely on the same resource. There is no other conceivable strategy but to *both* use and conserve the water resources in the most worthwhile and productive manner. The entire water resource – literally from drops of rain to discarded drains - has to be included in a strategy that deals with multiple objectives. Improved management, in a wide sense, is a key to achieving "more crop per drop". Increasingly, it is also recognized that co-management is required, for livelihoods and for healthy ecosystems. Hence, it is vital to adhere to additional objectives; "more care per drop", "more jobs/income per drop", "more collaboration per drop", etc. Equally important, but formulated differently, a strategy must include "less wastage per drop" or "less harm per drop".

1.2 The blue and the green water

Many of the irrigated countries in the tropics/subtropics are approaching the bottom of the blue water barrel. This is most obvious in the Middle East and North Africa region. As noted by Allan (2002) this region ran out of water for food self-sufficiency already in the 1970s. Also, some countries in Southern Africa display worrying water scarcity trends. Irrigated agriculture accounts for more than 70 percent of global freshwater withdrawals and 40 percent of world food production (Rijsberman and Molden 2001). It is thus evident that the average peasant in, for example, Sub-Saharan Africa has to rely on rainfed agriculture as the livelihood mainstay. The Green Revolution's strong emphasis on irrigation came with a whole package of related investments to increase the withdrawal of blue surface and groundwater, research and development of high-yielding crops and extension services. The long-standing emphasis on irrigated agriculture has largely had the side-effect of neglecting potential and substantial improvements of the productivity of rainfed agriculture. In fact, and as will be maintained throughout this report, there exists huge opportunities within rainfed agriculture, on which most poor farmers rely, to increase food production.

Of the continental global precipitation, some 65 percent forms green water in the soil (soil moisture), to be consumed in biomass production by global forests, grasslands, wetlands and croplands. The remaining 35 percent generates blue water (surface and groundwater), out of which only 10 percent is withdrawn to meet societal needs for settlements, industry, irrigation and hydropower. The precipitation over land generates two types of water (Figure 1):

- Green water in the soil from naturally infiltrated rainfall, accessible to plants
- Blue water in rivers, lakes and aquifers, that can be withdrawn for human use

It is evident that the green water constitutes a source that remains largely unclaimed and ready to be utilized. By using the green water more productively within rainfed agriculture, it can yield positive returns in crop production. It also has the potential of "freeing-up" blue water that can be used for non-agricultural economic activities as well as maintaining required streamflows to sustain aquatic ecosystems.

The ensuing section 2 analyses the forecasted increases in water demand and multidimensional aspects of increasing competition for blue water. Section 3 looks at green water requirements to feed a growing population with increasingly new food preferences in urban areas. The links between water competition and scarcity and human and ecosystem wellbeing are analyzed in section 4. Section 5 brings attention to the move towards a multiple water crisis by conventional approaches. It also puts forward the concept that the true overall water resource is the rain over the catchment. Section 6 brings to forefront some of the governance and technological responses to increased water scarcity and competition.

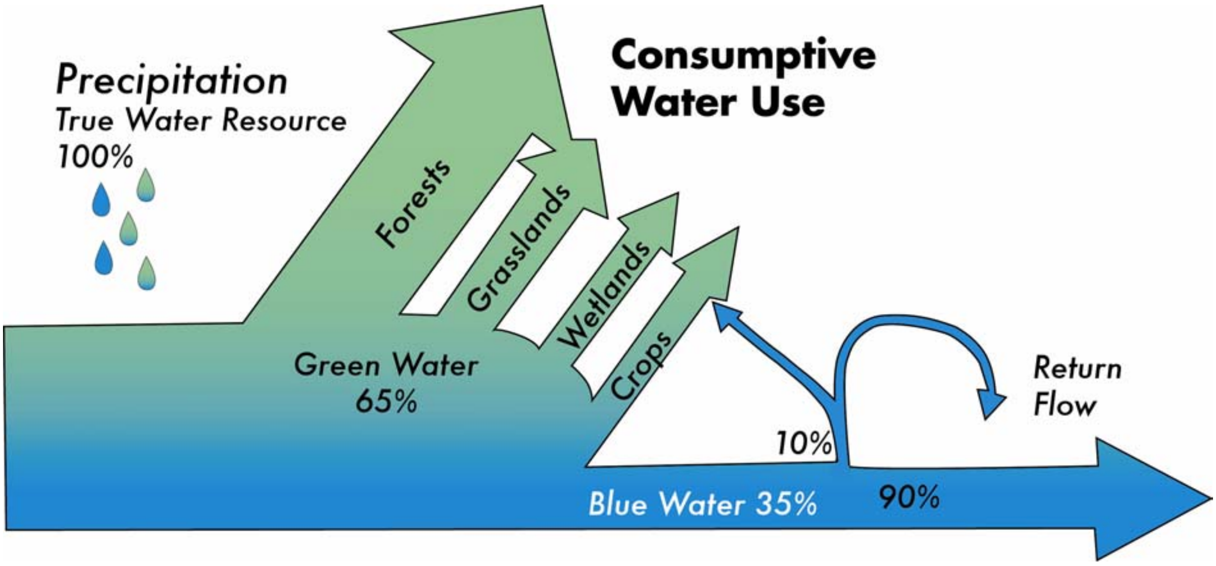


Figure 1. Green and Blue Water

2. INTENSIFIED BLUE WATER COMPETITION

2.1 Rising water withdrawals

As a consequence of demographic trends and improvements in standard of living for large segments of the world population, the demand for water as well as other resources has increased. To illustrate the magnitude of the pressure and the pace in the growth in the demand on water resources, a comparison with the pace of population increase is illuminating. During the last century, the rate of withdrawals of blue water resources was about 2 – 2.5 times more rapid than overall population increase (see figure 2).

This simple comparison may be interpreted in different ways. In addition to an escalating demand emanating from an increased number of people, the augmented withdrawal during the previous century illustrates either (i) that withdrawal and supply has been quite liberal and/or (ii) that the per capita use of water has increased rapidly. Figure 2 also illustrates that it is primarily the water in rivers, lakes and aquifers, referred to as "blue water", that has been exploited. This water is only a small part of the precipitation that falls over a country. For various reasons, an effective conservation and use of the rains is seldom seen as a water resource management task. One reason is probably that it is much more easy - although quite expensive – to exploit blue water resources. Another more interesting explanation is that green water management, i.e. harvesting the rains and better use of the water that is stored as soil moisture, requires an integration and land/soil and water management. As will be discussed further below, the potential to better utilize the green water resource must be explored.

Whatever the true cause behind the curve for withdrawals of water, it is clear that an extrapolation in the withdrawal of water is neither possible nor desirable. But the demographic curve will continue to grow and by 2050 a most likely scenario is that another two billion people have been added to the world's population. Since the available water is more or less constant over time, although with considerable variations between seasons and over space, the competition has naturally increased and it will continue to increase. Some of the important questions are: what are the drivers behind the rapid increase in withdrawal/demand; how can the increased competition be handled through institutional and other arrangements and what roles do authorities, donors and users play in this regard?

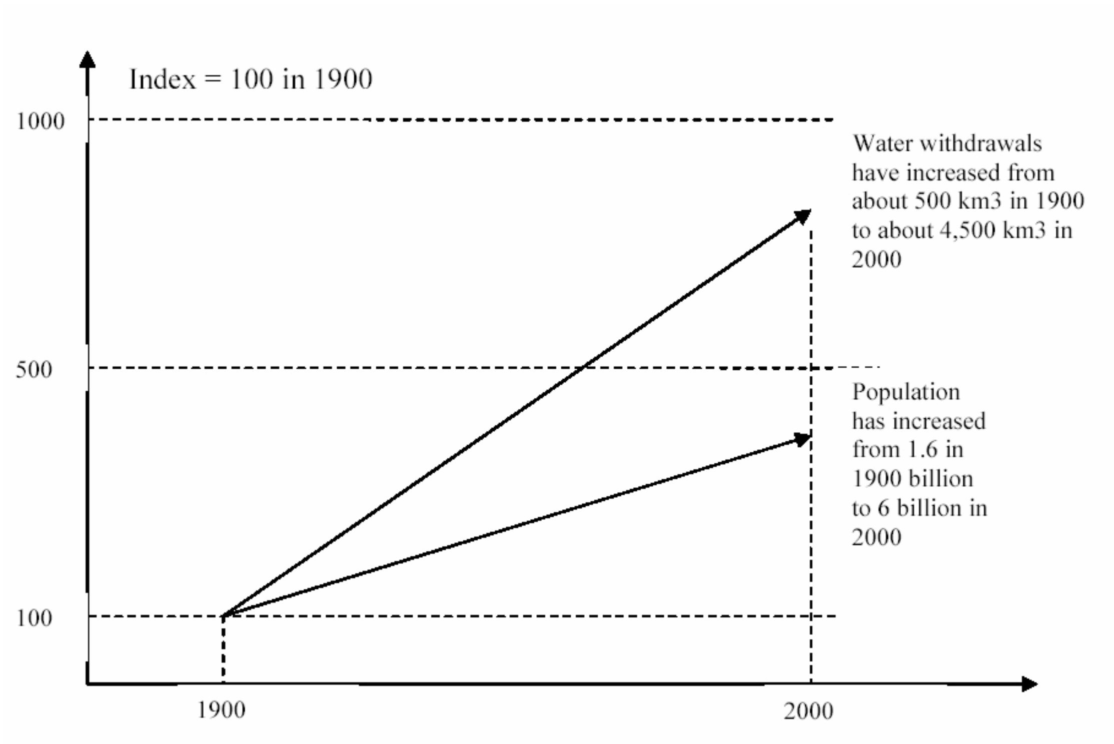


Figure 2. Rate of water withdrawals and demographic change in previous century

Increasing competition for finite water resources has been associated with two diametrically opposite consequences. On the one hand, it is seen as an important cause for increasing tensions and conflicts, which result in distortions in a rational resource allocation and use. The public discourse on transboundary waters has often been based on this underlying assumption. At the national and local level, there are many conflicts between water users, particularly at lower levels, due to an "unfair" or poor access to water. Tensions between farmers in irrigation schemes, for instance, between top-enders and tail-enders are common and in recent years, a number of conflicts between farmer, hydropower and urban interests have surfaced (see Case 4). Many of these conflicts are violent, with human casualties and breakdown of structures and property as a result. Another contentious dimension refers to clashing interests of environmentalists and those who want a further exploitation of water resources. More generally, a lingering Malthusian concern is still another type of pessimistic perception of an imbalance between demographic trends and capacity to cope with difficult odds. No doubt, the water situation is alarming in many parts of the world and the situation is also worsening in some respects, for instance, in terms of water quality (see below).

Competition and dwindling resources are also seen as a driver towards a more efficient use of resources and to collaboration between different stakeholders. Where demand exceeds supply or availability, people and societies at large can simply not afford to practice "business as usual". Equally important, they have to rely on the efforts of other people. Scarcity and competition will force or stimulate people to develop new practices and partnerships, or to look for substitutes -- provided they are wise enough to refrain from fighting for a larger share of the available resource. The seminal work of Ester Boserup (1965) concerning innovations in agricultural practices as a result of increased demographic pressure is a good illustration of the dynamics of human ingenuity.

There are many studies which support the hypothesis that the path towards more efficient utilization and also collaboration is the more common strategy. In the case of transboundary waters, Wolf (1998) has convincingly shown that collaboration is the rule and violent conflict is the exception. Similarly, many other authors have illustrated that collaboration is the most common strategy, e.g. Jägerskog (2003). Even in the most water scarce region in the world, e.g. the Middle East, efforts to collaborate over water are common (ibid.).

Contrary to a widespread belief that increasing competition over water in transboundary basins may lead to "water wars", a close look at historical and contemporary contacts between riparians reveals that cooperation is, by far, more common than hostile acts. It should be emphasized though that collaboration is more of an intent character; there are relatively few examples of concrete and joint activities.

2.2 Multidimensional water competition

In contrast to most other resources, there are no substitutes for water and the basic challenge is therefore to improve its governance, i.e. to have a clear strategy and policy for how to develop, conserve and utilize the resources and to ensure that the necessary institutional and technical arrangements are in place to implement the policy.

But how is increasing competition at national and sub-national levels affecting policy and management? Is increasing competition at national and local levels also resulting in improved management and increased collaboration?

As indicated above, competition over water is multi-dimensional. Some of the dimensions are summarized below:

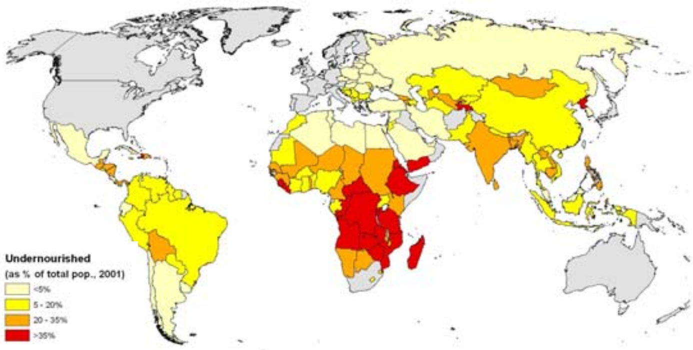
1. How are the poor affected by the increased competition? How can the objectives to "eradicate extreme poverty and hunger" (MDG, No 1) be handled in a context where the same resources are demanded for other socio-economic gains and environmental sustainability?
2. Urban expansion is one of the most striking features of change in the South. It will increase competition for water and other resources. For many decades, rural areas and especially the irrigation sector enjoyed a "privileged" situation, i.e. it was allocated liberal volumes of subsidized water on a priority basis. The contemporary situation is quite different. While the rural sector was seen at that time as the pivotal component in development process, the urban centers and their industrial and service sectors are now perceived as engines of economic growth and innovations. In this context, a prime task for water governance is to facilitate water provision to growing urban centers. How can this new task be combined with the tremendous challenge to ensure food and environmental security?

3. While competition over quantity of water has been a major challenge for a long time, the threats emanating from degradation of quality are now increasing. What kind of governance options are possible and effective to cope with this largely “invisible” threat?

2.3 Poverty reduction in the context of increasing competition

Extreme poverty and hunger is very much an interlocked problem. Extreme poverty is often defined as being forced to live on 1 dollar or less per day. Among other things this means that the purchasing power and the effective demand is minute. The poor in rural as well as in urban areas cannot access food and other goods and services that they need. The pressure on water and other resources is therefore less than would be the case if basic human needs would be met. As shown in Figure 3, there is a high correlation between proportion of hungry people and the percentage of people living on a dollar per day. The situation is especially grave for Sub-Saharan Africa, where extreme poverty has increased during the last decade according to UN statistics.

Geography of undernourishment and poverty



Percentage living on < US$ 1/day

	1991	2001	
Developing countries and transition economies	27.9	21.3	+
Northern Africa and Western Asia	2.2	2.7	-
Sub-Saharan Africa	44.6	46.4	-
Latin America and the Caribbean	11.3	9.5	+
Eastern Asia	33.0	16.6	+
Southern Asia	39.4	29.9	+
South-Eastern Asia and Oceania	19.6	10.2	+
Transition countries of south-eastern Europe	0.2	2.0	-

Source: UNStat, 2005

Figure 3. Geography of under-nourishment and poverty

Reducing poverty does presume an improvement in two regards: income for those who need more food and other goods and services (but who do not produce it themselves) and better prices or wages for those who produce the food and other goods and services. Poverty in urban areas and, generally, poverty among a growing number of consumers in society is closely linked to poverty among the producers, i.e. the small farmers and farm workers. The farmers cannot increase prices of their products because those who need to improve their food security cannot afford to pay or buy more and those who are better-off have already reached a “saturated level” in terms of food. A general trend is that the demand for staple food items is reduced, while the demand for meat, dairy products and fruits is increasing. The new demand pattern has implications for water pressure since the production of food items from animals is more water intensive per energy unit (SIWI and IWMI, 2004; SIWI et al. 2005; SEI, 2005).

Governments in Least Developed Countries (LDCs) also tend to keep prices of staple products at a low level to cater for the poor. Increasing prices of basic food items have led to serious riots and most Governments are therefore very sensitive to the voice of growing numbers of urban poor. Procurement prices paid by the government to farmers in India for rice, for instance, have been at about the same level for several decades while prices for inputs in production and for most industrial goods and societal services have steadily increased.

Eradication of poverty presumes an increase in income and livelihood opportunities for both producers and consumers. The net result is that the pressure and competition for water resources will increase. There is no simple governance formula which can be applied to deal with the complex challenge. Obviously, it is necessary to produce "more drop per drop" of water withdrawn. There is also a need to deal with both consumption and production patterns. Current trends in the composition in the diet, for instance, more meat and dairy products, means a more heavy pressure on water resources. This trend is warranted for the poor from a nutrition point of view (SIWI and IWMI 2004; SIWI et al, 2005). However, there is a considerable wastage in the food chain, "from the field to the stomach". Much more is produced as compared to what is actually consumed or what is required from a public health perspective (see e.g. Smil, 2000).

2.4 Urban expansion and new lifestyles

The rapid urban expansion is the most thorough force of change and driver of various processes in society and in the minds of people. The previous urban minority is becoming the new majority (see figure 4).

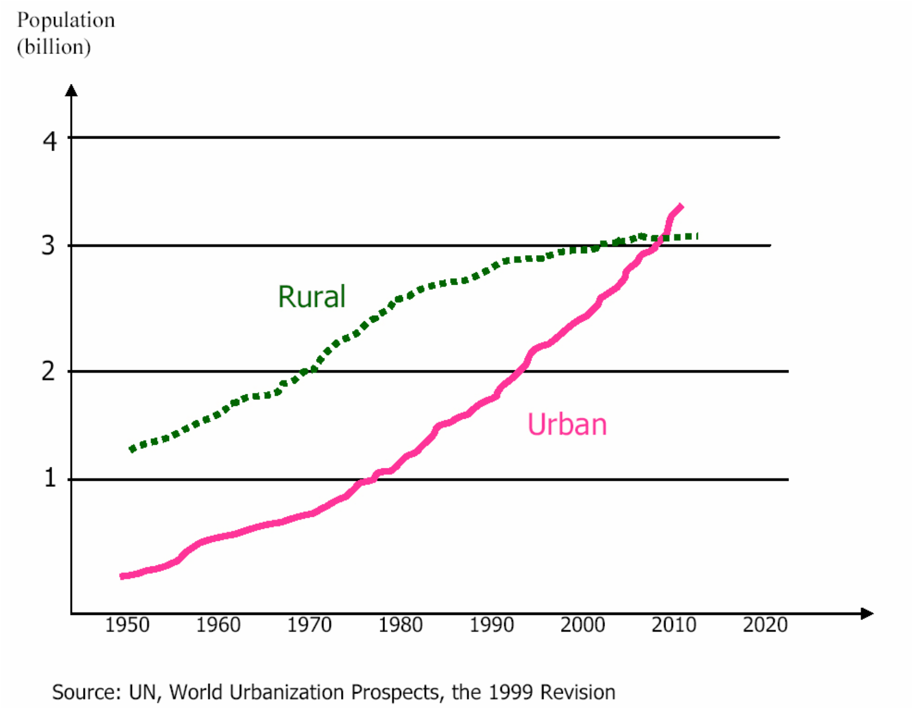


Figure 4. The emerging urban majority

Urban centers are the hotspots of problems and opportunities While the direct water use in urban centers is comparatively modest, around 15 – 20 percent in most developing countries, the actual pressure on water resources from the urban sector and from the population therein is substantially much higher (See case 1 in annex). The case of the Pangani River in Tanzania shows the complexity of competing water claims by farmers, urban uses and the hydropower industry in the country (see case 4 in annex). What is produced in rural areas is increasingly consumed in urban areas. Urban centers are the potential outlets for agricultural produce. Urban centers are also demanding – and getting - an increasing share of the blue water resources in the basin or from wherever water may be withdrawn. Interbasin transfer to urban centers is common, while it is hardly conceivable for irrigation or hydropower purposes.

One crucial implication of the dynamic change in urban centers is that consumption patterns will drive production in rural areas, among other things in food production, but in terms of resource use in a broad sense. Water management is not only about production but also about consumption.

2.5 Water quality degradation increases competition for freshwater

The prevailing focus on water management has been to supply water to different sectors in society. Comparatively little attention has been paid to how water is actually used, i.e. how efficient and prudent farmers, households, industrialists and other users apply it in the fields, in factories, etc. Similarly, little concern has been devoted to what happens to water after use. Disposal of wastewater, which is untreated in many parts of the world has resulted in considerable and negative impacts on the environment and on human health. Recently, it was officially announced in China that household water for some 300 million people comes from heavily polluted sources. At initial stages of industrial growth, production technologies are usually both inefficient in terms of resource use and chemicals and other pollutants and by-products are not contained within the factory premises. A rapid industrial growth in semi-arid regions, where the dilution effect is limited, is particularly problematic since relatively large volumes of water are required and since the volume of effluents is correspondingly large.

There are three principal governance tasks. One is to push for the building of treatment plants, which may be characterized as an "end-of-pipe solution". A much better approach would be to stimulate introduction of "clean production technologies". This would both reduce resource pressure, i.e. water competition since these technologies are generally more efficient, and it would reduce the risk that "free riders" do not dispose their wastewater to treatment plants. Usually, there is a fee connected to wastewater treatment and it is therefore tempting to dispose wastewater at night into any recipient or in other ways escape treatment costs. A third principle that is discussed and practiced in some areas, is to move industries to areas where dilution is better or to sites where common treatment is cheaper and easier to monitor.

Water quality degradation is consequently a serious threat to environmental sustainability and public health, and it will also reduce the use options of the water that is available. In reality it means that the amount of freshwater is reduced and thus that the competition for "good water" is pronounced.

3. WATER FOR FOOD PRODUCTION

It is important to recognize that competition primarily refers to blue water resources. A better use of green water – *as a substitute for further pressure on blue water* - is thus a win-win governance option. Blue water may be spared and may instead be used for other sectors of society (which cannot use green water). Better green water use may therefore reduce the competition for the water that is available in rivers, lakes and aquifers. It may also increase the possibility to reserve a certain flow in the river that would improve the conditions for aquatic ecosystems, i.e. to satisfy the environmental flow requirement.

3.1 Green revolution achievements

Table 1 illustrates the increasing amount of food that is produced. The prospects for food security in the world have dramatically improved in terms of increased productivity, both per unit area and per unit water. Food production per capita as well as total amount of food produced has been possible through a combination of agronomic, technical and institutional improvements (SIWI and IWMI, 2004; SIWI et al. 2005).

Table 1*. A summary of the tremendous improvements in total food production, yields and water productivity during the last decades (Source: various FAO and IWMI documents).*

	1960s	**1990s**	**today**
Total cereal production (billion tons)	0.94	1.7	2+
Per capita availability			
- developing countries	145	175	230
- global			325
(kgs/capita, day)			
Average yield (tons/ha)	1.4	2.8	3
Water footprint (m3/capita,day)	6		< 3

Productivity improvements have been important both in efforts to feed a rapidly growing population, but also in an environmental sense: "....if Asia's average rice yields of 1961 (930 kgs/ha) would have been maintained, the world would have needed nearly an additional 600 million hectares of the same quality to realize the total harvest of 1997"
(Norman Borlaug, International Herald Tribune, March 15, 2000).

The contrast is striking between the optimistic trends in the Table above and the deplorable livelihood situation and undernutrition as shown in Figure 3. It shows that alleviating poverty is a complex task. It is hard to imagine that poverty can be alleviated, let alone eradicated, as stated in the MDGs, without additional pressure on available water resources and, hence, increased competition for finite water resources.

3.2 Particular water challenges in the poverty and hunger hotspot region

Conway (1997) has shown that projections of future food production, based on plausible irrigation development, would leave whole food deficit regions as "hunger gaps", primarily in South Asia and Sub-Saharan Africa. These regions basically have a savanna-type climate and will not achieve food self sufficiency through blue-water based approaches. While the Green Revolution basically involved irrigated agriculture, most of the so-called "top and high priority countries" indicated in the Human Development Report 2003, that are of special interest for the MDG efforts, are dominated by rainfed agriculture. What will be essential is instead an upgrading of rainfed agriculture by less costly ways to reach crop water security (SIWI and IWMI 2004, SIWI et al 2005).

For this purpose, the water-related problematique typical for the savanna zone has to be properly understood. The situation in Sub-Saharan Africa has been characterized in terms of four challenges that have to be coped with (Falkenmark and Rockström 2004):

- long dry period and a wet season interrupted by dryspells (green water challenge)
- infiltration problems linked to crust-forming soils (green water challenge)
- low runoff production, leaving small water courses empty except during heavy rains (blue water challenge)
- recurrent drought years linked to i.e. the *El Nino* phenomenon (both green and blue water challenges).

There is a large potential to upgrade rainfed agriculture even in the semiarid tropics (SIWI et al 2005). It has been shown that just by meeting the soil and plant deficiency challenges, crop yields may be doubled or even tripled (Rockström 2003). It is therefore fundamental to realize that the crop production potential in the savanna zone is considerable, and that the necessary knowledge already exists (SEI, 2005). The thresholds to be overcome are therefore in the realm of land and water-related governance.

3.3 Water required for long-term hunger alleviation

MDG 1 aims to halve the relative number of those in extreme poverty and hunger by 2015. Most of the rural poor in developing countries depend on agriculture for their food and income, both of which have clear water implications, however, because of the consumptive water use linked to the photosynthesis process in crop production and the income raising potential of cash crop production.

Water challenges involved in long-term alleviation of hunger (not just the extreme hunger stated in the MDG 2015) were recently assessed by SIWI, IWMI and IFPRI in reports to CSD 12 and 13 (2004, 2005) and by SEI (2005) in the Swedish contribution for the Millennium +5 Summit in September 2005. One of the conclusions when comparing long-term water requirements for food production (FAO 2003) with available blue and green water resources is that "crop per drop" water productivity increases and irrigation expansion will cover no more than half the long-term global water requirements for ensuring a food supply that ensures food security to the ultimate 2050 population (assuming a food production level of 3000 kcal/p d; 20 percent animal protein). The remaining half will call for making better use of local rain by water harvesting for protective irrigation, horizontal expansion of croplands, and diet adaptations, in particular the meat component (see Figure 5).

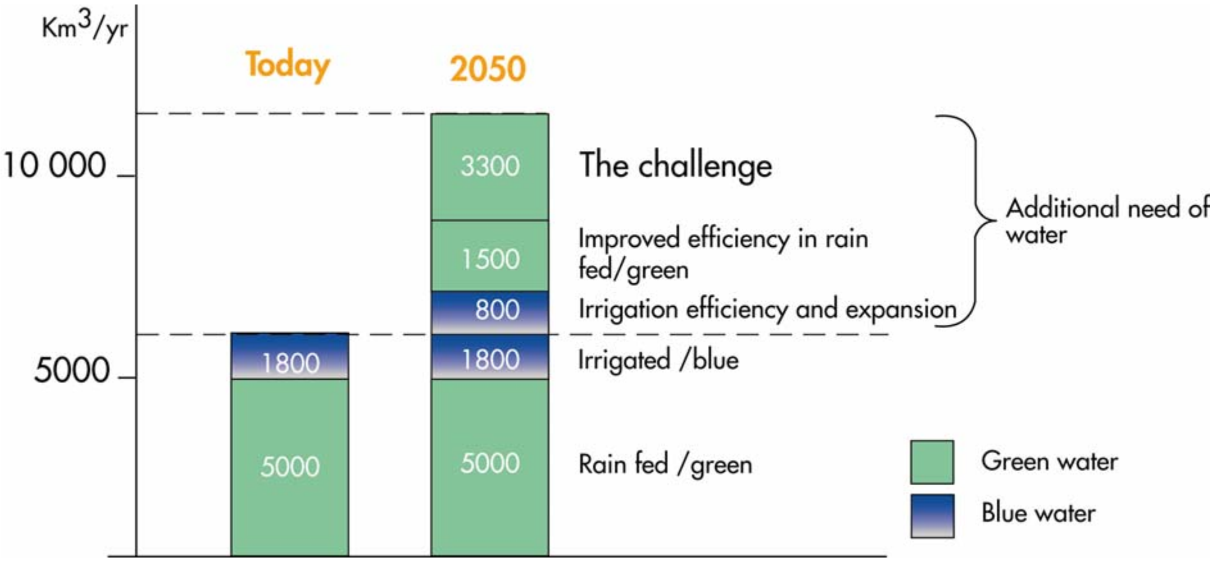


Figure 5. *Comparison of consumptive water use involved in today's food production and the challenge in terms of additional requirement to feed humanity by 2050. From SIWI et al 2005*

4. HUMAN AND ECOSYSTEM WELLBEING

The report aims to find out how to manage water competition and scarcity for poverty reduction and environmental sustainability, The focus in Section 2 was on expected increases in blue water demand and competition as seen from different perspectives, and in Section 3 on green water required for feeding humanity. This section will link water competition and scarcity to human and ecosystem wellbeing by addressing ecosystem stress and the MDG 7 goal of environmental sustainability in the sense of not undermining the life support system (Report from MDG Task Force 6, cf Melnick et al 2005). Particular interest will be paid to regional differences, benefiting from the rich statistical material in the publication "The wellbeing of nations - A country-by-country index of quality of life and the environment", by R.Prescott-Allen in cooperation with IUCN, IIED, FAO and UNEP (Island Press 2001).

4.1 Environmental sustainability challenges

The analysis of country-level wellbeing was based on quantification of human wellbeing and ecosystem wellbeing, each based on and averaging over a set of indices. Ecosystem wellbeing was quantified based on indices referring to land (diversity and quality); water (river conversion, water withdrawal, water quality); air; species and genes (wild and domesticated diversity); and resource use (basically energy). The outcome has been presented as global maps and sustainability diagrams. The sustainability diagrams show the relation between the human wellbeing index (HWI) and the ecosystem wellbeing index EWI (see Figure 6), distinguishing between areas with:

- ecosystem deficit (human wellbeing good or fair)
- human deficit (human wellbeing low, i.e. medium, poor or bad)
- double deficit (both human and ecosystem wellbeing low)

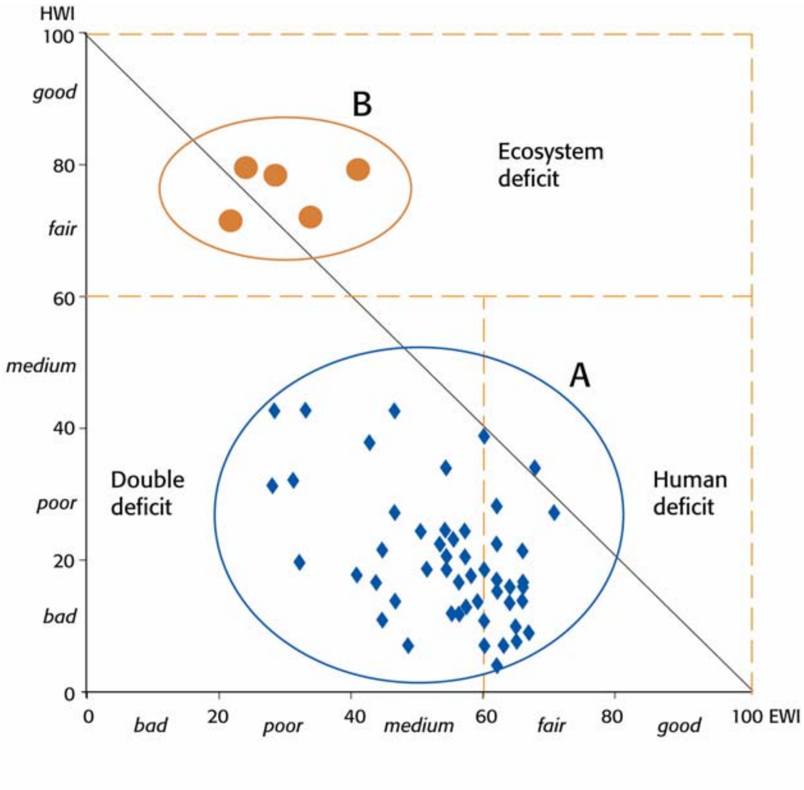


Figure 6. Sustainability diagram showing the relation between human wellbeing (HWI, vertical axis) and ecosystem wellbeing (EWI, horizontal axis), each characterized by a set of indices on a scale between 0 and 100. (Based on data from Prescott-Allen 2001)
A = "top and high priority countries" (Human Development Report 2003)
B = a set of highly industrialized countries (HIC)

It is worth noting that NO country is even close to environmental sustainability as defined in that study: the ratio of human wellbeing to ecosystem stress should amount to at least a factor 4, while for the best cases it is only around 1. Ecosystem stress is the opposite of EWI (e.g. 100-EWI).

It is clear from the Figure -- showing the relative positions of a set of countries -- that the socio-economic development process towards higher human wellbeing has involved a decrease of ecosystem wellbeing, i.e. increased ecosystem stress. At the same time countries tend to move along different sides of the diagonal. Some manage to secure relatively less ecosystem stress, i.e. stay on the right side, while others distance themselves from the line on the left side, i.e. with proportionally larger ecosystem stress.

The best situation is noted for highly industrialized countries with similar human wellbeing but different positions relative to the diagonal: Northern Europe has the best ecosystem conditions by being on the right hand side, while Southern Europe is on the left with larger ecosystem stress.

The "top and high priority countries" tend to have higher EWI with the poorest situation found in Sub-Saharan Africa with low HWI, and an EWI on the left hand side. Most of these countries share a joint challenge: savanna zone climate and rainfed agriculture.

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4.2 Hydroclimatic observations

While the temperate zone HICs have high human wellbeing and low ecosystem wellbeing (high ecosystem stress), many of the “top and high priority countries” identified in the Human Development Report 2003 (Figure 7) are arid zone countries with a savanna climate. Whether or not the hydroclimatic preconditions in the savanna zone offers a plausible explanation of the low human wellbeing achieved, an increased human wellbeing in the Sub-Saharan Africa will depend on a capability in that region to master a set of particular hydroclimatic challenges: short rainy season with intervening dryspells, intermittent drought years and very high evaporative demand with low runoff generation as a result.

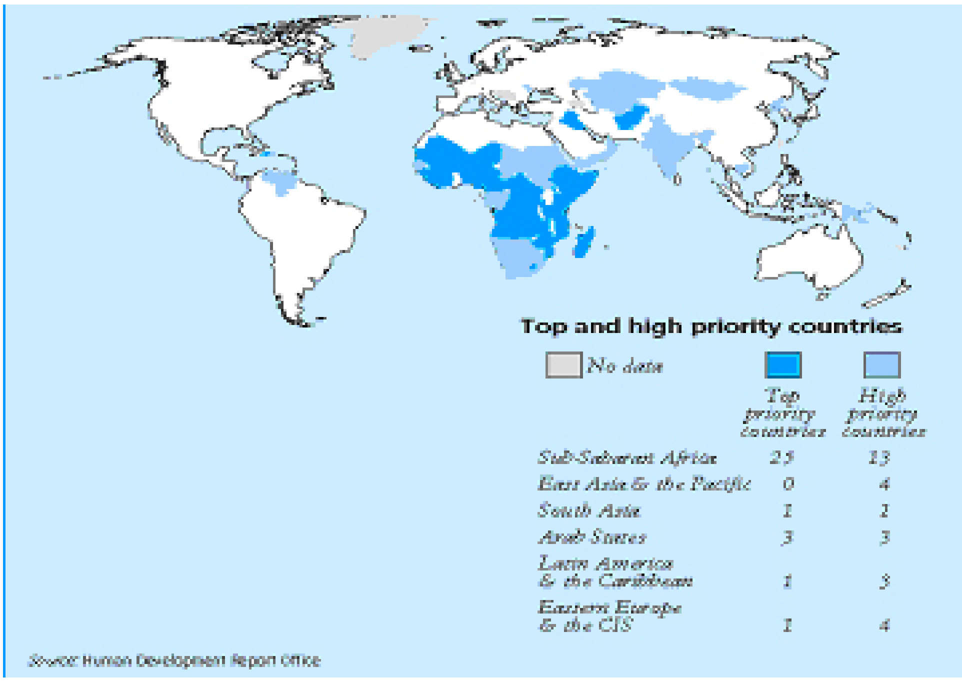

Figure 7. *Top and high priority countries. From Human Development Report 2003. (Copyright 2003 by the United Nations Development Programme. Used by permission of Oxford University Press, Inc.)*

4.3 Balancing water for humans and nature

It is important to develop a more structured thinking around what can be done to move towards higher ecosystem wellbeing and less ecosystem stress:

- to what degree can countries in the human deficit section of the sustainability diagram increase their human wellbeing while avoiding an increase in ecosystem stress - this will probably turn out to be an issue of striking trade offs
- to what degree can countries with a double deficit achieve a parallel increase of human wellbeing and a decrease of ecosystem stress, especially if they are located in the region with savanna climate
- how can developed countries with ecosystem deficits reduce the ecosystem stress? What role will water pollution abatement play? What are the implications of the fact that irrigated crop production involves unavoidable water losses to the atmosphere, reducing the blue water flow? For this situation the minimum residual streamflow to support

downstream aquatic ecosystems has to be identified, the so-called environmental flow (see below).

Due to the genuine water dependence of both human society and ecosystems, water can be seen as the common denominator for humans and nature (Falkenmark, 2003). This opens possibilities for coordinated management in a river basin/catchment context since:

- water use modifies streamflow and water quality,
- land use change modifies generation of runoff and recharge of groundwater.
- terrestrial ecosystems consume green water, and
- aquatic ecosystems suffer from blue water changes.

In other words, an integrated catchment-based approach to land use, water and ecosystems is needed.

The Prescott-Allen study reveals interesting conceptual aspects of ecosystem wellbeing. Ecosystem wellbeing is based on averaging indices for land, water, air, species and energy use. Figure 6 showed the tendency that ecosystem stress increases as human wellbeing grows. The water index includes water withdrawal as one of the factors behind ecosystem stress. Irrigation has been essential for the Green Revolution and involves withdrawals as a key component. It is therefore desirable to develop the ecosystem wellbeing concept further so that it will be possible to incorporate an understanding that some phenomena are unavoidable (such as irrigation in arid regions) while others are avoidable (such as pollution and land degradation, at least to a certain degree).

It has to be realized that environmental sustainability does not refer to unchanged ecological conditions but to a protection of the viability of the ecosystems (Folke 2003), by securing protection of their resilience against unavoidable change. Ecosystem change can in other words be accepted but not that the functioning of the life support system be undermined. ”Accept change, manage for resilience” (ibid).

5. MEETING A MULTIPLE WATER CRISIS

Conventionally, water availability has been thought of as a more or less static resource, offering a certain amount of water per year to be allocated for different uses. In reality, the resource is mobile and dynamic, and represented by a flow through the catchment from the water divide to the mouth and from the soil back to the atmosphere.

5.1 Conventional approach

When limited to the water quantity aspect of the crisis, it is evident that developing regions with a dry climate are moving towards a multiple water crisis reflected in i.e. the following phenomena:

1. Closing river basins due to large-scale water withdrawals but escalating water competition, due to rapid urbanization,
2. overexploited groundwater, difficult to bring under control (Shah et al 2003), and
3. food production problems due to low water productivity in savanna regions with rainfed agriculture.

Blue water scarcity conditions are generally expressed as high water withdrawal in relation to overall water availability (*use-to-availability ratio*). When demands rise, the two conventional degrees of freedom have been:

- floodflow mobilization through storage in reservoirs, often meeting counterarguments due to past experiences in terms of negative environmental and social impacts of dams;
- reduction of losses in water infrastructures both in water supply pipes and in irrigation canals.

The use-to-availability ratio has to be limited by the demand for a residual streamflow needed to secure healthy aquatic ecosystems, the so called *environmental flow.* This concept has brought a new dimension in the debate about the value of in-stream functions of blue water and the relevance of paying due attention to aquatic systems. The value derived from withdrawing water from streams and lakes in terms of increased agricultural production, industrial development, etc., has been perceived as more important and higher as compared to the value of the goods and services derived from aquatic systems. This is, however, a somewhat simplified understanding.

Water scarcity has also to be seen in relation to the population pressure on the water resource. This can be expressed in terms of a (blue) *water competition or water crowding* index (people per flow unit of blue water, or inverted as per capita water resource, Falkenmark 1986, 1989, 1997). In closing river basins, this index will be increasingly relevant in view of its implications. When water crowding increases, the risk increases for rising water pollution and rising tensions and conflicts of interest.

As already stressed, the conventional conceptualization has neglected a large unnoticed resource: the infiltrated rain in the soil that supports all plant production, including rainfed agriculture, i.e. the green water resource (Falkenmark and Rockström 2004). *Green water scarcity* is manifested as both soil problems (permeability and water holding capacity problems) and plant problems (dryspell damage). Rainfed agriculture in this region is characterized by low crop yields, which can be related to restricted crop water access (Rockström and Falkenmark 2000) with three possible water deficiencies:

- Rain deficiency to be met by irrigation,
- soil deficiency to be met by soil conservation measures and fertilization, and
- plant deficiency to be met by dryspell mitigation, in terms of protective irrigation during dryspells based on rainwater harvesting.

Green water scarcity problems are reflected in terms of difficulties of green water access for crops, rather than to a resource that is low compared to the demands. In savanna climate regions, crops easily get damaged by frequent dryspells, reducing the capacity of the roots to take up the green water in the soil (Rockström and Falkenmark 2000). There may in other words be water, but the roots are not able to take it up efficiently. The solution is therefore protective irrigation rather than “reallocation” of blue water.

5.2 The way out: rain is the true water resource

Accepting the view that the true overall resource is the rain over the catchment - this water input is being partitioned at the ground surface into two parallel water resources:

- the green water taken up by the roots and consumed in the plant production process (forests, grasslands, rainfed croplands, etc.), and

- the blue water in rivers and aquifers, generated from the surplus rain, accessible for societal use in water supply to households, industries and irrigation, and evaporated from wetlands and irrigated croplands.

Accepting rain as the basic water resource makes it possible also to include in water balance considerations the water used by natural ecosystems: terrestrial ones supported by green water, and aquatic ones supported by blue water. In tomorrow's water resources management, it will become essential to pay adequate attention to what happens to blue water after use; whether water withdrawn returns to the blue water system in the catchment as return flow (and carrying pollutants), if it is literally consumed/evaporated and thus leaves the system and depletes the river. In other words, a distinction must be made between consumptive water use and throughflow-based water use, where the water after use either returns to the atmosphere in the former case, or forms return flow that can be reused again further downstream in the system in the latter case.

5.3 Growing water challenges

Turning from there to the main focus of this report, the key challenge to be addressed is how to manage water competition and scarcity while paying attention to poverty reduction and environmental sustainability. The key governance challenge is therefore to develop appropriate tools for benefit sharing of the rain input to a catchment and to secure hydrosolidarity between all its different stakeholders.

Blue water competition tends to be largest in highly industrialized countries and Green Revolution countries with dry climate due to high water dependency of human welfare, materialized in large water withdrawals for irrigation, increasing both water competition and ecosystem stress (by the way the latter is being defined). Part of this stress is, however, unavoidable by being biophysically inseparable from the crop production process. The competition is intensified by the ongoing urbanization discussed in section 2 and the fact that many river basins are already closing in response to large-scale irrigation. All in all the key governance challenge is managing water competition by water allocation and increased water productivity.

In poor tropical countries with a semiarid climate, the key governance challenge is very different: coping with the particular savanna climate. This will involve managing multiple water scarcities and links between land use and water: blue water scarcity manifested as ephemeral rivers (rainfed areas) or depleted rivers (irrigated areas), and green water scarcity manifested as both soil problems (permeability and water holding capacity problems) and plant problems (dryspell damage).

Based on the above extended water resources conceptualization, it is possible also to see the water crisis and its links to ecosystem stress in a clearer light. As regards the already indicated quantity-related water crises, a few phenomena need to be stressed:

- streamflow depletion, already covering 15 percent of the continental land (Smakthin et al 2002), reduces the available blue water resource and contributes to an escalating water crowding (more and more people per flow unit of blue water) and to severe problems for aquatic ecosystems which are reported in the last 30 years to have suffered a 50 percent loss in biodiversity (Living Planet Index, created by WWF and UNEP) - to what degree can it be remedied?
- overexploited groundwater with a decreasing water table, making access more and more difficult, and with consequences for groundwater dependent wetlands, which get deprived

of their water supply: how can better control of groundwater withdrawal by millions of small-holder farmers be achieved?
- difficulties in terms of plant access to available green water, due for example to dryspell damage of roots, explaining the extremely low crop yields typical for rainfed agriculture in small-holder crop production: how can a water-secure, small-holder based agriculture be rapidly put in place where that knowledge already exists?

6. Governing water: From rain to gain

As shown in previous sections many developing countries are facing multiple water competition challenges, within sectors as well as between sectors, of how to allocate increasingly precious water resources and resolve disputes. The key challenge that needs to be addressed through improved water governance systems is: How to manage water competition and scarcity to reach societal objectives of poverty reduction and environmental sustainability? This section will look into examples of water policy responses as well as technological responses to come to grips with poverty alleviation and environmental sustainability. In essence, the argument put forward is that current institutional and technological responses are only focusing on the blue water, particularly surface water. The "invisible" groundwater is typically subject to weaker legislation and regulation as compared to the "visible" surface water. Even though countries must continue to improve management of surface- and groundwater, the path of making better use of green water largely remains unexplored. Production and productivity gains in rainfed agriculture can make a major contribution towards poverty alleviation

6.1 Technological responses

A major paradigm within the water sector has been, and still is to a large degree, to make more water available as demands and populations are increasing. In such cases various kinds of technologies (both supply- and demand side management) have been applied to ease situations of water scarcity. The technology responses are broadly divided into: 1) harnessing and increasing the availability of water resources; 2) more efficient water use; and 3) water re-use.

A typical response has been to *harness and increase water storage capacities* through constructions of dams, river diversions, desalination, etc., of the blue water. Improved water storage capacity can be required in locations with big rainfall variations, such as low-income tropical countries. The Sub-Saharan region is subject to substantial rainfall variability and has the lowest per capita water storage to even out rainfall within and between seasons. The rainfall variability of Australia and Ethiopia is similar. The per capita water storage capacity in Australia is over 4,700 cubic meters, whereas the same figure for Ethiopia is 43 cubic meters (World Bank, 2004). According to proponents of increased damming and water diversion there is thus a need for improved water storage capacities in some countries. However, they frequently fail to point out alternatives to the capital intensive large-scale infrastructure, such small-scale water harvesting or more efficient use of green water. Desalination is normally considered a last resort for those wealthy countries that can afford it. Countries in the Gulf region, such as Saudi Arabia, Kuwait, the United Arab Emirates and Oman, are experiencing a rapid increase in water demands. The Gulf region is already witnessing extremely limited surface water and renewable groundwater sources. Some of the countries, like Saudi Arabia and Kuwait, use large quantities of non-renewable fossil groundwater, causing depletion of these resources. As a response, the oil-based economies of the Middle East and Israel are desalinating seawater. For most countries this is far too expensive and not realistic to apply for agriculture in a bigger scale. Although more conventional water resources such as renewable groundwater and surface runoff are available in countries like Oman, the United Arab Emirates and Saudi Arabia, these resources still need to be properly developed in an integrated water resources planning context.. There is also a potential for collecting more blue water through rainwater harvesting and more green water through conservation tillage and soil conservation.

More small-scale rainwater harvesting technologies have been used since ancient times and are still used in both urban and rural areas. Despite its long history, the technology remains greatly ignored and underutilized. Rainwater harvesting systems have been ignored in favor of modern and supposedly better alternatives. Still, many communities depend on a variety of rainwater harvesting technologies. These can be include, simple clay lined reservoirs, low walls diverting water runoff from hillsides onto fields, and so on. Many of the rainwater harvesting practices were abandoned with the introduction of the Green Revolution and large-scale water schemes. In India, irrigated agriculture typically went from surface to ground water irrigation. Rainwater harvesting is also done in urban areas through, for example, roof tanks. And for many urban dwellers this is an important complement to other water sources. Rural rainwater harvesting initiatives in places like Gansu, China, and Northeast Thailand have shown that rainwater harvesting technologies can be upgraded and scaled-up in order to provide affordable and sustainable supplies (Gould, 1999). Considering that hundred of millions of people harvest rainwater, it is surprising that so little attention has been paid to develop the technologies further. If fully developed, rainwater harvesting could provide an important sustainable and environmentally benign water source for supplementing other water supply options in a wide variety of circumstances.

Gansu province, located in a very dry part of northern China, has a population of 26.7 million. Here, rainwater harvesting has a thousand-year tradition, and several projects to scale up the investment in rainwater harvesting techniques are in place. The Rainwater Harvesting Irrigation Project is funded by the government and covers 2.9 million ha of cultivated land and 17 million people in the province. Farmers can receive funds or credits for investment in greenhouses, cement slabs and tanks. Water is collected from roads, courtyards, playgrounds, etc., and stored in underground tanks. The water is applied in a similar way to drip irrigation, consuming 7.5 mm/ha per application, compared to 90 mm/ha per application for conventional irrigation schemes. Harvests have increased with 40 percent, and the use of greenhouses has made it possible to grow cash crops and fruit trees previously not grown in the region. The economic return for the farmers has sometimes improved by 100 percent. The investments made by the farmers, from funds or credits, are low, as much of the equipment and material can be shared by whole communities (SIWI, 2001).

Other types of technological responses are more *efficient water use* and *water re-use*. The first one typically comprises technologies to get more “crop per drop” of water withdrawn, that is to increase water use efficiency within agriculture, such as through drip irrigation and developing crops that require less water inputs, or minimize unaccounted for water, such as through seepages and “water theft” in urban and rural water provision systems. According to FAO (2003), there is in general higher water use efficiency in countries where water availability is lower. In Latin America, for example, it is only 25 percent, compared with 40 percent in the Near East and North Africa and 44 percent in South Asia. Within agriculture more efficient water use often goes hand-in-hand with development of high-yielding crop varieties and biological engineering. Water re-use, such as through wastewater treatment and the re-use of grey water for irrigation is increasingly used in many places of the world.

Large-scale and capital intensive technological responses – typically a part of Green Revolution technologies - have been beneficial to increasing food production. But it has also implied heavy costs for detrimental social and environmental effects, such as displacement of people, intensified water competition, groundwater depletion and degraded ecosystems. Perhaps the most well-known example of negative social and environmental impacts of river diversions can be illustrated by the dramatic shrinking of the Aral Sea due to diversions of Amu Daryar and Syr Daryar river water. Many localities in the Middle East, Asia and Sub-Saharan Africa have come to learn the hard way that making more blue water available is hardly possible anymore (see e.g. Tropp and Jägerskog, 2006). It is expected that many countries will continue on this unsustainable path. Projections for developing countries imply a 14 percent increase in water withdrawals for irrigation by 2030. One in five developing countries will face water shortages (FAO, 2003).

The World Bank has recently made a push for increasing investments in large-scale multipurpose water infrastructures. This may be useful in countries where hydraulic infrastructures are underdeveloped, particularly in monsoon climates, where it can help in coping with rainfall variability and contribute to long-term water security. This should be viewed with caution as there are alternative ways of investing in improved uses of the blue and green water. Water-related investments need to be considered within the broader framework of both irrigated and rainfed small-scale agricultural technologies and practices, ecosystem services and demand side management. As demonstrated, watershed programs and conservation farming have great potentials of increasing food production, generating incomes and maintaining natural resources and ecosystems. The financing of scaling-up of small-scale alternatives, for example linked to local rainwater harvesting, can be more economically realistic alternatives for many farmers relying on rainfed agriculture. Another factor that should be weighed into investment decision is improved management of ecosystems. The IUCN has pointed at that wetlands and other types of ecosystems can have similar functions as infrastructures, such as water purification, and that decision-makers must take this into account in making investment decisions (Emerton and Bos, 2004.).

It is critical to continue the path of technological developments particularly when it comes to environmentally and economically sustainable and appropriate large- and small-scale technologies. Current technological responses have had a strong focus on the blue water. The application of these technologies and the economic benefits they can provide is very much related to issues of governance and financing structures as well as hydrological conditions. Many developing countries, particularly the Highly Indebted Poor Countries (HIPC) in the tropics, cannot afford to invest in large-scale infrastructure development, and it would thus in many cases make more sense to intensify and scale-up local farming technologies and practices linked to, for example, rainwater harvesting and watershed management. Technology is also about governance. Why are certain technologies chosen? How are they applied? Are there institutions and management tools in place to cater for proper operation and maintenance? These are some of the relevant questions that must be posed in technology choices and their application. Despite an increased emphasis on decentralization, participation etc., the water sector is still a stronghold for hydraulic engineering, hence providing even greater reason for placing technology within a framework of governance.

6.2 Water governance responses: An avenue for alleviating water scarcity and competition

The ways societies govern their water resources impact profoundly on urban and rural peoples' livelihood opportunities and environmental sustainability. Yet governance and capacity building have not received the same investment attention as technical issues and infrastructure development.

Water decisions are anchored in governance systems across three levels: government, civil society and the private sector. Facilitating dynamic interactions – dialogues and partnerships – among them is critical for improving water governance reform and implementation. Water governance addresses among other things (see World Water Development Report, 2006, forthcoming):

1. Principles such as equity and efficiency in water resource and services allocation and distribution, water administration based on catchments, the need for integrated water management approaches and the need to balance water use between socio-economic activities and ecosystems.
2. The formulation, establishment and implementation of water policies, legislation and institutions.
3. Clarification of the roles of government, civil society and the private sector and their responsibilities regarding ownership, management and administration of water resources and services, for example: inter-sector dialogue and co-ordination, stakeholder participation and conflict resolution, water rights and permits, price regulation and subsidies and tax incentives and credits.

Issues of power and politics are decisive for governance of water. They play an important role in shaping governance and involve the characteristics of actors and policy processes. Politics can both hinder and facilitate water policy reform and implementation. Politics and the choice of management tools and technology are closely knitted. The representation of various interests in water decision-making and the role of politics are important components in addressing urban and rural food security and governance dynamics. Some of the current governance responses which are typically a part of ongoing water reforms in developing countries are looked at below, .

6.2.1 Ongoing water reforms

Progressive reform is taking place in many countries around the world. Kazakhstan is currently on the verge of implementing its new water strategy that, among other things, includes the implementation of river basin organizations. Other Central Asian countries, like Tajikistan and Kyrgyzstan, are also in the process of reforming their water sectors. Reform is also taking place in other Asian countries and in Latin America. Reform work has been progressive in many Sub-Saharan African countries, like South Africa, Zimbabwe, Botswana, Namibia, Mozambique and Ghana. But the implementation has many times suffered due to insufficient political backing, weak economies and public budgets and political turmoil, such as in Zimbabwe. The middle-income country South Africa in particular has been able to start implementing its water reform, however, with a somewhat mixed implementation record. The water legislation in South Africa contains some very interesting features, such as acknowledging the right to water – lifeline quantity of water - and balancing human and ecosystem water needs.

As a part of national and international water agendas, many countries are currently responding to water governance challenges by developing and implementing national integrated water resources management (IWRM) plans and strategies. The content of such plans and strategies varies, but some common features can be traced: they typically include reform of decentralization (including setting in place new administrative water units -- river basin organizations), privatization of water services, multistakeholder participation and water rights. Many developing countries are currently in the phase of formulating such strategies or are in the process of implementation (see for example GWP, 2003 and Arab Water Council et al., 2005).

6.2.2 Economic incentives: Water pricing in irrigated agriculture

Water for irrigated agriculture has so far been treated as a special case in almost all developed and developing countries. It has been shown that farmers in Spain, for example, pay less than 20 percent of the total costs for irrigated agriculture. The heavy subsidy to irrigated agriculture of the western parts of the USA is well known. In most developing countries the charges for water to irrigated agriculture are very low and the true costs outweigh by far the actual price on water for irrigated agriculture (Bruns and Meinzen-Dick, 2000). The special treatment for water use in irrigated agriculture is largely due to the welfare of rural sectors, providing cheap food to urban consumers and the perceived importance of food self-sufficiency. In many places there is a low social acceptance to price water and related services. Therefore, particularly for the Green Revolution countries, water for irrigated agriculture is a heavily politicized issue that cuts to the heart of development.

Many countries are introducing water supply pricing mechanisms for irrigated agriculture to come to terms with increasing water scarcities. The theory behind water pricing, either through public administrations or private markets, is that it can improve water allocations and distributions and impact positively on water conservation. The basic rationales are found in: 1) improved water use efficiency; 2) increased cost recovery; 3) water is allocated to sectors that provide high economic value-added; and 4) improved equitable use. According to Johansson (2000) there is disagreement in both developed and developing countries regarding the impacts and applicability of various pricing regimes. During recent years it has been observed that the cost of irrigation (and subsidization) has risen dramatically in South and South-East Asia in particular. In India and Indonesia for example the real cost of irrigation has doubled over the last 30 years. Similar trends have also been witnessed in Thailand and Sri Lanka. The reasons behind this are not yet clear, but contributing factors can be: loss of irrigated land to salinization and urban expansion and increasing water competition between urban and rural sectors.

The various pricing regimes that can be applied differ with regard to their costs and benefits as well as between efficiency and equity. Johansson (2000) distinguishes between three main water pricing regimes: 1) volumetric; 2) non-volumetric (per output basis, per input basis, per area basis, crop choice, based on land value); and 3) market-based methods, including tradable water rights.

Volumetric: This way of charging water use is in theory pretty straightforward – each farmer pays according to how much water he or she uses. There are also varieties, such as through time-based charging. Volumetric charging requires that there are means of measuring the actual water use. In most developing countries this is difficult, as water meters are few and far between. Groundwater is normally not subject to volumetric charging – the price for extracting groundwater is determined by costs of drilling, power supply for pumping and equipment. In other words, volumetric charging requires mechanisms for actually measuring water use and since this is lacking in many developing countries it may under current water management regimes be a less viable option. In irrigation systems where costs are based on charging for time of delivery, it is possible to overcome the constraint of actually measuring water quantities used. Blomqvist (1996) has shown that in the case of South India, under a time-based price regime, it was common that local landlords, following a patron-client logic, exerted pressure on and sometimes bribed field-level employees of when, to whom and how much water that should be distributed. Hence, it is clear that even though pricing regimes look good in theory, their application has not been sufficiently effective to make any major impacts on water use efficiency and equitable distribution. What Blomqvist (1996) is showing is the difficulty to implement pricing regimes without addressing local politics and power structures.

Non-volumetric: Area pricing is the most commonly used regime for irrigated water pricing. A study found that as many as 60 percent of farmers worldwide are charged on a per unit area basis (Johansson, 2000). Under this regime farmers are charged for water used per irrigated area, often taking into consideration crop choice, irrigation method and season. In Pakistan and Northern India it is fairly common to combine volumetric and per area pricing. Levy pricing is used to capture the indirect value of irrigation by charging water tariffs per area, based on increases in land value. Additional ways of charging for water use is through actual crop production or amount of fertilizers used. Pricing regimes based on per output basis, per input basis, per area basis, or based on land value can be very difficult to implement since farmers tend to underestimate their farming area or crop production, for example. There will normally be heavy transaction costs involved in monitoring area cultivated or how much output each and every farmer is producing, especially for small-scale farmers. Yang et al. (2002) has shown that in Northern China farmers tend to underestimate the arable land; the estimated irrigated areas are somewhat smaller than the actual areas. As a result the actual water use per unit of irrigated area may be less than the assigned quota. Consequently, by tampering with size of land plots, agricultural outputs and inputs, this particular system faces difficulties in allocating water in efficient and equitable ways. In fact such practices can even be counterproductive and imply that more surface water is being tapped, impacting negatively on ecosystems and/or downstream uses. Groundwater is normally subject to non-volumetric charging. As seen above the price is the cost for power supplies, etc.

Market-based methods: It is increasingly argued by market proponents that water markets, including tradable water rights, can provide an effective avenue for allocating water in more efficient and equitable ways. For such markets to work there needs to be rights that can be bought and sold. Importantly, the water right does not imply ownership of water resources *per se* but the right to make use of a particular water source or a particular quantity of water. The debate on tradable water rights continues to stir up emotions. Some perceive this as an unhealthy commodification of a public good. Others recognize that tradable water rights are fundamental to provide people the proper incentives for sustainable development. Recent cases where trade of water rights are occurring, such as in Chile and Australia, have shown that implementation is not as simple as theory suggests. For example, in Chile it has been necessary to adjust water markets due to counterproductive results, such as hoarding of water rights by private hydroelectric companies. Australia seems to be going the other way by actually deepening private water rights reforms which initially where rather cautious (see section on water rights). In many countries water trade takes place within informal water markets. In any South Asian city informal water vendors are common, and it is typically farmers selling excess water to urban households and institutions. It is now also fairly common that farmers can make a better profit by selling water than using it for irrigation. The price ratio between publicly supplied water and the prices charged by private informal water vendors can be staggering. For example, in Manila, the Philippines, the cost for publicly supplied household water is USD 0.11/cubic meter, while the informal sector charges USD

4.74/cubic meter. This equals a price ratio of more than 40 (WWDR, 2003). Control and monitoring of private water vendors' water quality by local regulatory authorities is weak, thus exposing consumers to high risks for water-related diseases. For such reasons some governments are now considering introduction of tradable water rights to make the informal sector formal and to regulate unrestricted water use (Marino and Kemper, 1999).

6.2.3 Water pricing: efficiency and equity

The current application of water pricing regimes for irrigated agriculture in developing countries suggests that there in practice has been fairly little impact on improving efficiency and equity. For example the theory behind marginal cost pricing (sometimes called the opportunity cost pricing, including fee collection, O&M, extraction costs, externalities, social costs and benefits, etc.) provides that water can be allocated efficiently according to a Pareto-optimal, solution, that is, you cannot make anyone better off without making someone else worse off (see for example, Ostrom, 1990). But a major difficulty is to assess all the marginal costs and benefits, especially since they vary across the seasons as well as over the years (Johansson, 2000). It has also been observed that volumetric pricing in combination with opportunity cost pricing can have detrimental effects on lower income groups. Water scarcities will consequently lead to higher marginal cost for water and that such pricing can lead to negative social effects (Thobani, 1998). Due to the nature of surface and groundwater systems they are inherently difficult to monitor and police. It has been noted that transaction costs are high in fee collection and monitoring of use and to exclude those without the right to use. For example, Ostrom (1990) noted that keeping "free-riders" out of the irrigation system requires heavy transaction costs that may outweigh benefits.

The equity concern is often vaguely defined but normally refers to "just and fair" allocation of water and can include cost recovery from users, income redistribution and subsidized food production. According to Tsur and Dinar (1995) water pricing is in general not a very effective mechanism to redistribute incomes, as equity effects of pricing are dependent on land endowments. Others have noted, however, that water pricing and water markets can redistribute income between agricultural and non-agricultural sectors, as well as between various irrigation districts (Diao and Roe, 1998). At times and with the aim of income redistribution there can also be a trade-off between equity and efficiency. It can for example be politically motivated to subsidize irrigated water use of certain low income groups in society at the expense of efficiency.

In a case from Northern China, Yang et al. (2003) demonstrated that despite rapid increases in irrigation costs and thus higher water prices (based on per area) this had no effect on water conservation. On the contrary, the shift to more water intensive high-value added crops led to an intensification of overexploitation of groundwater. In this case, which is a rather typical case for many developing countries, the cost for using groundwater was equal to power supply costs for pumping and equipments. Due to current water governance systems, there were instead incentives to continue to increase water use, such as government agencies wanting to increase their budgets through intensified water use and very lax monitoring of groundwater regulations.

The theories behind water pricing and water markets are normally based on assumptions of perfect information, no externalities and rational economic behavior from actors. But in reality information is far from perfect, and irrigation and damming externalities – third party effect on return flows, etc. -- occur frequently, affect downstream users or decrease the environmental flow of rivers.

6.2.4 Water pricing in the wider context of governance and technology

Experiences suggest that the introduction of pricing regimes for improved irrigation efficiency must go hand-in-hand with wider application of water-saving technologies and improvements of water governance systems, such as clearly formulated and enforced water rights and improved management efficiency. Effective pricing mechanisms seem to be difficult to apply in developing countries due to:

- Must be tailored to specific local conditions. This means that even within countries there must be various pricing regimes, such as between groundwater and surface water or between hydroclimatic sub-zones and, if socially motivated, also between income groups.
- Increasing costs for water - *ceteris paribus* - will mean that rural incomes are decreasing. In regulated food markets, it is politically very sensitive to allow for dramatic price changes of main staples as it will affect both rural producers and urban consumers. From a political viewpoint this means that it is most convenient to preserve *status quo*.
- Many countries lack appropriate capacities and institutions to effectively implement pricing mechanisms.

Participatory irrigation management (PIM) through water user associations (WUAs) can reduce the costs for fee collection and monitoring and policing if irrigated systems, as well as more efficient irrigation. Various studies have pointed out that PIM can bring many benefits. Cases from Mexico demonstrate that the transfer of operation and maintenance to the WUA has been fairly successful. The WUAs have improved revenue collection and local management systems. Similar economic benefits have also been experienced in parts of Turkey and India, where case studies show that water is used more efficiently and increased rates of revenue collection. It should be noted that the WUAs are also facing difficulties in considering ecosystems, and from the cases provided here it is unclear to what extent they have impacted ecosystem improvements. It has also been reported that increasing water prices has led to local tensions and that problems of free-riding occurs on frequent basis (for more detailed information see case 3 in annex on PIM and WUAs). The Pangani-Rundugai case illustrates that negotiations will be frequently required to meet competing water demands (see case 4 in annex).

It is imperative to create a direct link between irrigation pricing and water conservation by reforming the current water governance system. As noted by Yang (2003), it is critical to impose effective regulatory powers and effective water extraction restrictions for groundwater and surface water. This can be done through effective water licensing that limits the total volume of water withdrawal. Clearly defined and legally enforceable water rights and platforms for dialogue and negotiations and responsibilities of both public water agencies and farmers are important for the adoption of water saving technologies and practices.

6.2.5 Unclear water rights: A source of tension and inefficiency

Ambiguous water rights are a frequent source of local tension and conflict. It ultimately results in poor decision-making on water use efficiency and equitable water use. In many developing countries formally legislated and customary water rights are at odds and also within formal legislation there are many times ambiguous and conflictive distribution of water licenses and permits.[2] Access to water normally follows land tenure and those who can access land can also more easily access water resources. Water rights define who has access to water and in what ways the user can take part in local water decision-making. Water rights also specify roles and responsibilities regarding operation, maintenance, monitoring and policing. In this sense, water rights manifest social relationships and local power structures of who is included or excluded from the benefits of water and what the various rights and responsibilities include. Water management practices in, for example, the Andes have shown that social and political inequalities can prevent successful collective action, but it also showed that collective management of water can lead to more equitable water distribution as well as strengthening the bargaining position of weaker stakeholders (Boelens and Hoogendam, 2002). The importance of clear and coherent water rights is not unique to localized contexts, such as small-scale agriculture or indigenous systems, but equally relevant to society at large for how water is allocated to various economic sectors.

Setting in place well-defined and coherent water rights is fundamental to deal with increasing competition between water users:

- It can promote improved access to water by groups that previously have been denied formal or informal water rights and equitable water use between existing user groups, through socially motivated water allocation re-distribution, such as in South Africa.
- It can render other governance measures more effective, such as the application of pricing mechanisms.
- It can improve the efficiency of existing water supply allocations. Those requiring additional water resources, such as growing cities, can increasingly meet their needs by acquiring the water rights of those who are using water for low value purposes.
- It promotes the willingness of farmers and urban water users to take economic risks to make necessary investments in improved water management and practices. It can also reduce the pressure on water resources as it is likely that those with water rights have incentives for sustaining water.

In most developing countries, water rights are placed within a legal context strongly characterized by pluralism. Water management has moved from a predominantly pre-colonial local collective activity to a publicly and/or privately regulated resource under the influence of colonial law to the benefit of a small minority. Some countries are currently addressing water inequalities. For example, the objective of re-distributing water resources among ethnic groups features prominently in the water legislations of Zimbabwe and South Africa.

Most governments' legislation and regulatory authority powers largely ignore customary water rights. In most developing countries specialized government agencies are in charge of large-scale irrigation networks and the distribution of water permits. But in a parallel track, water rights are still considered by many local farmers and other water users a common property where communities manage water based on customary rights. Unclear water rights and management of related infrastructure can lead to confusing and conflicting situations of roles and responsibilities among government agencies and water users of who is entitled to what water, when and how, as well as unclear guidelines on operation and maintenance of infrastructure. Water resources and related networks and infrastructure can in practical terms end up being pretty much equal to open access property (no one's property) that can result in

[2] According to Beccar (2002) water rights is defined as "…authorized demands to use (part of) a flow of surface water and groundwater. Including certain privileges, restrictions, obligations and sanctions accompanying this authorization, among which a key element is the power to take part in collective decision making about system management and direction."

a “tragedy of the commons”. The ultimate consequence is breakdown of management systems where no water user or government agency feel responsible for sustaining surface and groundwater resources (both water quantity and quality) and related infrastructure. It is thus important that water reform increasingly acknowledges the multiplicity of water rights, which would offer better and more realistic ways to minimize tensions and conflicts and improve current water allocation and distribution.

Despite progresses in water rights reform during the past decades, the legal development is still lagging behind that of land, forest and energy resources. There are, however, increasing pressures from local to international levels to continue reform in water rights and a need to further clarify its content. For example, villagers in Rajasthan, India, have claimed their right to rainwater (rainwater harvesting). The need for continued reform is well illustrated by water rights reform processes in Australia and Chile. In both places, formal water markets, including tradable water rights, have existed since the early 1980s. Both countries found it necessary to make major reform adjustments. In Australia it was seen as necessary to extend and deepen what were initially relatively modest reforms. In Chile it was required to adjust for the hoarding of water rights by hydropower companies and a need to integrate the water markets in a river basin management framework (Briscoe, 1997). The privatization of water rights is in many contexts perceived as a very controversial issue. Some perceive it as an efficient way of allocating water, while others perceive it as socially unhealthy commodification of a common resource. But irrespective of this discussion, the success of water rights reform in a given country is in part dependent on the formal legislation’s ability to adjust to customary ways of allocating water. Also in this context it is critical that continued reform work takes into account a river basin management framework, as well as reflecting a need for regulations that are effective and flexible enough to reflect the continuum of formal and informal water rights.

6.2.7 Customary water rights

Customary water rights are based on community tradition and norms. Customary water rights govern a number of water related local social and economic activities, such as irrigation, household water, fisheries, livestock, plants and animals, funeral practices and the environmental services provided by water (Beccar, 2002). Local custom and tradition are thus important factors in defining community water management, allocation and conflict mediation. A case study from the Pangani River in Tanzania revealed that out of 2,265 water abstractions, only 171 were based on formal water rights (Hodgson, 2004). This can lead to clashes between formal and informal rights and rules and render legislation and development projects less effective. Enhancing local decision-making capacities and reflecting customary water management and rights in formal legislation in relation to irrigation practices and other water-related activities can create a more genuine way of recognizing local customary water rights and management systems (Beccar, 2002).

Table 2. Example of water rights for irrigated agriculture

Operational rights	**Right to take part in collective decision-making**
Right to use part of the water flow	Rights to take part in decision-making about management/system operation: Defining details about water distribution, irrigation schedules, flow rates, organizational posts and responsibilities etc.
Right to use the water intake and conduction and distribution infrastructure to get the water to a certain	Right to take part in decision-making about inclusion/exclusion of members:

community or plot	Defining who can and who cannot be system members
Right to be eligible and to occupy positions in the water user organization, and to implement decisions regarding water distribution and system management	Right to take part in decision-making about changing or expanding the hydraulic system and irrigation technology Right to take part in decision-making about transferring rights to use part of water flow, the source itself or the hydraulic infrastructure

Source: Beccar, 2002.

Table 2 provides an example of water rights in a localized context. As seen, water rights imply not only rights to use part of water flows and related infrastructures but also can come with a whole bundle of rights to take part in decision-making of how to utilize water, inclusion/exclusion of members, etc. There is sometimes a tendency to "idealize" communities as being homogenous and that decentralization and community customary rights and rules automatically will resolve issues of inequity. It has frequently been noted that customary ways of allocating and managing water resources can mirror unequal local power relations (Hodgson, 2004 and Blomqvist, 1996). The lesson to be learned is that it is impossible to fully tap the potential benefits from water projects and management without taking into account customary water rights and local ways of managing water resources. Changes in water use and management practices due to water reform and/or specific water interventions should thus not only acknowledge but also take into account local norms and needs through for example stakeholder participation. Taking into account local water practices should form a part of any water reform to minimize the social and economic cost that can be associated with local opposition to water reforms and development projects.

6.3 Governing the green water

A basic distinction that must be kept in mind in discussing governance responses is: the green water (soil moisture) is used for plant production, while the blue water is withdrawn by humans from lakes, rivers and groundwater aquifers for irrigation and other purposes. Current water reforms in developing countries are predominantly focusing on the blue water. Governance responses to blue water are essentially about: allocation of water resources between sectors; more efficient water use within irrigated agriculture, other economic sectors and households; putting restrictions (through regulations and/or economic incentives) on water use; improving environmental flow, etc. With the purpose of obtaining goals linked to water allocations and uses, various responses have been applied, including, for example, improving regulatory frameworks, the provision for clearly defined water rights, pricing regimes, increased stakeholder participation, etc. Can similar responses be applied to green water, or is it required to develop new types of governance responses?

Rainwater harvesting in both urban and rural areas is receiving increased interest. For example, in the city of Chennai, India, the local government has enforced legislation that urban households should carry roof tanks to collect rainwater. In rural areas in India, a number of groundwater recharging zones have been developed where groundwater is kept easily accessible by pumping when needed. While this has had positive impacts on household water supplies and small-holder farmers, it is as of yet uncertain to what extent it has impacted positively on the productivity of urban and peri-urban agriculture and the environmental benefits.

The green water production potentials have yet to catch the eyes of most water managers and have only marginally been subject to legislative measures or other types of political and managerial responses. There is currently increasing focus linked to conservation farming, watershed management and rainwater harvesting in rural areas. It has been shown that conservation farming can lead to improved plant production through decreased run-off as well as improving groundwater recharge. Studies in India by ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) showed that increased productivity in rainfed agriculture was largely due to reduced run-off and increased rainwater use efficiency (65 percent). Moreover, the integrated watershed management programs showed a potential of doubling the productivity on farmers' fields in rainfed areas while sustaining the natural resource base (Wani et al. 2003). Watershed programs are recognized as a potential engine for agricultural growth and development in fragile and marginally rainfed areas.

A comprehensive review of 311 case studies on watershed programs in India by ICRISAT revealed that the watershed program is "silently" rejuvenating the rainfed areas with the mean benefit-cost ratio of 2.14 and the internal rate of return of 22 percent. The watershed programs also generated employment opportunities, augmented irrigated area and cropping intensity and conserved soil and water resources. The returns were higher in medium and low income states in India (Wani, 2003 and 2004).

These cases from India show that improved rainfed agriculture can involve many environmental and economic gains that have the potential to be sustained in the long run, that is, *going from rain to gain*. The cases interestingly showed that there is also interface between blue and green water and that measures of improving rainwater use had positive impacts on groundwater recharge and irrigated agriculture (see further in case 2).

Some of the management practices applied to blue water seem irrelevant to green water. For example, the application of various pricing regimes will be ineffective since the green water is coming from the rain, which falls directly onto the land. It is basically the size of the land and soil quality that determines the availability of green water, and it becomes irrelevant to use economic incentives for allocating water. The economic incentives that can be applied are more in the form of micro-credit schemes for promoting water and land/soil technologies and management practices, such as supplementary irrigation to protect the crop root zone from getting damaged by prolonged periods of drought. As a part of getting access to investment capital, the secure tenure of land and water will continue to be an important factor on which farmers calculate the risks of investing in improved practices, as well as for lending institutions. Since farming practices to improve the use of green water tend to be management intensive and focusing on integrated approaches, strong focus must be put on local processes of participatory approaches, decentralization and national legislations and institutions that can facilitate inclusiveness and access to credits, etc.

As has been explained in previous sections, the water and land/soil interface is critical to improve the use of green water for increased food production. A land use decision is also a water decision since land use changes can influence the partitioning of the rainfall. Land use will also affect various components of the hydrological cycle, such as runoff, infiltration and evapotranspiration. Within the water sector the concept of integrated water resources management (IWRM) is well established, even though its implementation in practice has been difficult. From an administrative point of view, land and water are normally separated. Most government ministries, such as irrigation, agriculture, environment and water resources, have been set up to address specific sectors like land, water, forests, energy, etc., long before the need to coordinate them was fully appreciated. Most of these government agencies tend to work in uncoordinated parallel tracks, which in some cases even promote contradictory policies and regulations. A typical divide is one between a ministry of irrigation – staffed by engineers concerned only with pumping stations, canals and pipelines, and water distribution systems down to farm level – and a ministry of agriculture – staffed by agronomists, concerned only with crops, fertilizers, mechanization and extension, with little to offer in on-farm water management. Similar sector-based divisions occur in international donor and support organizations. The need to integrate land and water issues has been captured by Duda (2003), who in the context of fragmented environmentally related international conventions proposes that the proper terminology should be "integrated land and water resources management" (ILWRM).

It seems like there is little need to invent entirely new governance response mechanisms, similar concepts regarding participation, decentralization, etc., can be applied to green water, however with a shift in content. It will also be a question of more effective implementation of water reforms related to increased stakeholder participation, decentralization, etc. There will naturally be much less of a need to look at pricing as a mechanism to allocations and uses of water. In case it is relevant to charge a price for water use, it can be linked to supplementary irrigation of predominantly rainfed agriculture. There is vast potential of improved rainfed agriculture which could be harnessed by adopting integrated approaches to water and land/soil management. More investments in rainfed areas through integrated approaches to water and land has a great potential to enhance food security not only through increased production, but also through increased incomes for the rural poor. Some governance responses for green water have been pointed at, but it is clear that the concept of governing green water needs to be further unpacked with regard to its content and application, such as providing incentives and enabling environments for shifting on-farm practices to catchment-based management and conservation farming in rainfed agriculture. There needs to be improved strategies for the scaling-up of successful practices.

In conclusion, most of the current blue water governance responses, such as participation, decentralization, etc., will be just as applicable to green water and that it is rather the content of the response that matters than the governance response mechanism itself – water tariff interventions seems to be an exception to this. It also seems likely the certain regulatory mechanisms, such as water permits/licensing will not be as important unless for supplementary irrigation and for water quality control. In other words, governance responses to green water will need to shift the focus from blue water allocation to more efficient use of rainwater and intensify the integration of water and land/soil management.

7. Conclusions: Meeting human and ecosystem water requirements

Many developing countries will face increasingly stiff water competition and scarcity. So far much of the governance and technological responses have not been sufficient to address challenges of reducing hunger and poverty or even coming close to sustainable use of water resources and ecosystems. For many countries it is still a "race to the bottom of the water barrel".

In the Green Revolution countries, irrigated agriculture will continue to be an important source of food production and income generation. Technological advancements and the scaling up of the application of existing blue water technologies will not be sufficient to cater for growing water demands, particularly as the number of "closed" river systems increases. It will thus be increasingly difficult to strike a balance between water for humans and water for ecosystems. Decision-making systems will increasingly have to deal with tough trade-offs between human demands and ecosystem needs. Under such circumstances it is critical that governance processes linked to water and other natural resources are inclusive, transparent and provides for a just and effective decision-making to minimize social tensions and conflicts.

It is clear that the various types of governance responses, as well as technological, must take into account measures to provide for hunger and poverty alleviation and environmental sustainability. If improved water uses are not applied more effectively for the blue water, and if green water potentials are not fully explored, it will not be a question of balanced decision-making but rather a matter of making the tough but required trade-offs between water for human uses and ecosystem requirements.

7.1 Human wellbeing

In terms of water competition and scarcity problems, there is thus a fundamental difference between on one side the core governance challenges for the irrigated regions dominated by the water-related consequences of the so called Green Revolution, and on the other side the poor "top and high priority" countries dominated by savanna type semi-arid climate and rainfed agriculture.

A main challenge in the former is biased water allocations, closing river basins, overexploited groundwater and severe water pollution, and therefore the need to increase blue water productivity -- getting the most out of blue water availability. A main challenge in the latter is the semiarid climate with its large rainfall variability, and therefore the need to increase green water productivity -- making the most of green water availability, i.e. soil moisture. The production potential is large, provided that plant productivity problems due to dryspells, etc., can be alleviated by soil/water management measures (green water problems). Affordable, small-scale technologies and approaches for farmers hold tremendous promise for improving local livelihoods. Poor rural populations have the capacity to assimilate these technologies.

<u>Blue Water Recommendations:</u>

For those countries that rely heavily on irrigated agriculture, it is important to continue the path of improving the use of blue water regarding allocation efficiency and equity. The application of various pricing regime to use water in irrigated agriculture more efficiently and equitably have so far proven to be difficult. At times it can even have counterproductive effects. Results also indicate that governance responses in the form of regulatory capacities, decentralization, participation, water rights, etc., need to be strengthened and clarified. Recommendations include:

- More effective pricing would require that pricing regimes are seen within frameworks of improved water governance and technological development to have desired effects.
- Further clarification of water rights and responsibilities, such as by introducing customary rights in national formal legislations.
- Enhanced involvement by user groups to more effectively enforce pricing mechanisms and clarification of water rights.
- View technological change within the framework of water governance, since technological applications require systems of operation, maintenance, clear financing structures, etc.

<u>Green Water Recommendations</u>:

The green water does not primarily require tools for water allocation. Governance and technology responses should thus be directed towards making better use of the green water in rainfed agriculture, moreover it should:

- Support innovations by supporting the development of a green-green-green revolution (green for productivity increase, for rainfed approaches and for environmentally sustainable approaches).
- Secure adequate extension facilities to support the motivation and willingness of farmers.
- Intensify integrated water and land/soil management approaches.
- Apply the water governance response repertoire, such as improved participation, more effective decentralization, incentives for access to credit, etc. This will also apply to improved rainfed agriculture, even though focus should shift from blue water allocation to more efficient use of rainwater, such as through, for example, conservation farming and watershed management.

7.2 Environmental sustainability

The way it has been defined, ecosystem wellbeing tends to decrease with increasing human wellbeing. This is partly an unavoidable phenomenon since some processes incorporated in the definition are unavoidable, such as consumptive water use in irrigation. The overarching challenge towards environmental sustainability is to find out how to securely live with unavoidable changes involved in poverty and hunger alleviation efforts. Key relevance for environmental sustainability is ecosystem resilience.

Water pollution, a serious and to a large extent avoidable threat to environmental sustainability, is particularly worrisome in arid climate regions.

Recommendations:

- Stimulate water pollution abatement measures to reduce resource pressure and threats to aquatic ecosystems
- Clarification of key action needed to protect ecosystem resilience to make vital ecosystems more immune against unavoidable change in land and water use.
- Clarification of water-related trade offs in balancing between human and ecosystem wellbeing

Annex: Case Studies

Case 1: Urban expansion implies a new dimension in water competition[3]

Virtually all population growth, now around 70 million each year, ends up in urban areas. Most of the growth is caused by the migration of poverty-driven rural people to urban areas, particularly in Asia and Africa. To some extent, urban expansion is fictitious in the sense that administrative boundaries are changed and previously rural communities are labeled as urban. Definition of what is urban also varies between countries. Ironically, the poorest countries are those that are urbanizing at the fastest pace. The less affluent a country, the more water is a determining factor in the economy, and the less society's capacity to cope with problems caused to the environment — including those related to water.

A crucial issue that is missing largely in the contemporary debate on water is the informal sector and consequently the informal institutions. Institutions provide the rules for the society. Their various functions range from legislative, juridical and administrative to different informal aspects such as culture, religion and ethnicity. The former ones are often called formal institutions, whereas the latter ones are known as informal ones.

Pushed and pulled migrants

It is one thing if a migrant with a basic education and access to a formal-sector job and the possibility of higher education is "pulled" to a city, but quite another if he or she is "pushed" out of rural areas with no education or other means of making a decent living. Traditional skills are of little avail in a big city.

The division of society into formal and informal sectors is most evident in the rapidly urbanizing centers of developing countries. Besides presenting a major challenge to any aspect of water and infrastructure development, it equally involves issues of safety, revenue collection, health issues and employment and job opportunities.

The hope tends to be that the growth of industry and urban services will somehow absorb the excess immigrant labor force. However, this usually remains a pipedream for all but a handful of people. Even in the most successful countries in this respect, such as Brazil and Thailand, only one fifth of the population is engaged in industry. The informal sector has to absorb 20 to 70 percent of the urban workforce (Todaro 1997). According to Langman (2003) eight of ten new jobs in Latin America are in the informal economy. In the Gambia, the informal sector employs 30 percent of the rural workforce and 60 percent in the cities (Esim 1996). The Gambia's urban population grows by 6.8 percent a year, and most of it has no option but to be part of the informal sector.

Both rural and urban poverty is massive and increasing, but poverty is more explosive, quantitatively and politically in urban settings. Whereas the number of urban poor in the world is reckoned to be about one billion today, it is expected to double by 2030. After the 2004 HABITAT conference, the humble UN target defined in the Millennium Development Goals of halving the number of slum dwellers is likely to remain a dream. What seems more likely is that the number will double. Slum upgrading policies, particularly in bigger urban agglomerations are therefore expected to become very important in the coming decades, with major implications for the water sector.

In fact, UN HABITAT (2003) defines a slum dweller in a very interesting way, as a combination of the lack of the following: improved water supply, improved sanitation, sufficient living area, durable housing and secure tenure. The provision of water and sanitation services is, therefore, one of the keys to upgrading slums and reducing poverty.

Water for informal city dwellers is not only pipes, cans or bottles in the urban areas as such. It is also required to produce food and fiber for urban dwellers. Improved food security in urban areas has direct consequences for rural areas and for the use of water resources there. Food must be produced somewhere and to overcome both rural and urban poverty and to reduce the flow of outmigration from rural to urban areas. Today, the trend is rather that food required in Third World Cities is produced in the developed countries (FAO, 2004)

Water is also affecting large parts of the urban population in a harsh, tangible manner. According to the IFRC (2002), the number of humans exposed to floods tripled between the 1970s and 1990s, and stands at about 2 billion today. This is chiefly due to the concentration of people in the floodplains of big rivers or cyclone-prone coastal areas, particularly in Asia. Wuhan, Dhaka, Mumbai and Bangkok are examples of rapidly growing cities that are extremely flood-prone. The informal settlements of cities are particularly vulnerable.

[3] Case provided by Olli Varis, Helsinki University of Technology.

Connection to rural development

Because most of urban population growth is due to migration from rural areas, one efficient way of reducing urban problems — including those involving water — is to promote rural development. China is an interesting case in this respect. For several decades, the government restricted urbanization, but recently the policy has been relaxing. At the same time two parallel processes are taking place.

On one hand, the urban areas are witnessing unforeseeable economic growth that allows massive improvements in livelihoods and infrastructure; very large numbers of people have emerged from poverty. On the other hand, similar progress has not taken place in rural areas, and subsidies — which used to be very high — have been reduced. Rural areas are short of financial institutions services, and other market infrastructure. They also have to compete with heavily subsidized food production in OECD countries, which is in the order of 350 billion US$ annually.

As a result, the expanding cities have started to import food from the world market and the new urban wealth fails to trickle down to the rural economy. Urbanization continues apace, and informal settlements have started to become considerable in size in Chinese cities. The sustainability of agro-ecosystems and rural livelihoods are also in question. Some recent studies reveal that the number of unregistered, mainly young migrants in Chinese cities is soaring, which results in a rapidly growing informal sector (Söderlund 2005).

Case 2: An Innovative Farmers' Participatory Watershed Management Approach to Improve Livelihoods through Better Rainwater, Land and Crop Management in Semi-Arid Tropics[4]

Drought prone arid, semi-arid and dry sub-humid (rainfed) areas in Asia and Africa, emerge as the hot spots from the water for food perspective as well as for poverty, hunger, equity, development and growth. Currently in the SAT (semi-arid tropics) rainwater use efficiency for crop production is only 35 to 45 percent. Global warming and the associated climate change will increase variation in the rainfall and also the drought occurrence frequency in the tropics. Rainwater and land management is the key issue for enhancing the productivity of the rain-fed systems and improving livelihoods in the tropics.

For example, recent assessment of land use with remote sensing in Madhya Pradesh in central India endowed with Vertisols and associated soils along with assured rainfall (700 to 1200 mm y^{-1}) revealed that 2.02 million ha area was left fallow during the rainy season mainly due to inappropriate rainwater and land management. Sustainable average productivity of 4.7 t ha^{-1} per year from rainfed Vertisols with improved rainwater and land management at ICRISAT, in India over a 28-year period, as compared to 1 t ha^{-1} per year with the farmer's traditional practice. Increased productivity was largely due to increased rainwater use efficiency (65 percent), reduced runoff (from 91 to 20 mm ha^{-1} y^{-1}) and reduced soil loss (from 6.64 to 1.5 t ha^{-1} y^{-1}). Moreover, the integrated watershed management programs have shown the potential of doubling the productivity on farmers' fields in rainfed areas while sustaining the natural resource base (Wani et al. 2003).

Innovative consortium model

Watershed programs are recognized as a potential engine for agricultural growth and development in fragile and marginally rainfed areas. An exhaustive review of 311 case studies on watershed programs in India by ICRISAT revealed that the watershed program is silently rejuvenating and revolutionizing the rainfed areas with the mean benefit-cost ratio of 2.14 and the internal rate of return of 22 percent. However, a large number of watersheds (62 percent) showed less than average B:C ratio and rate of return (47 percent). The watershed programs generated enormous employment opportunities, augmented irrigated area and cropping intensity and conserved soil and water resources. The returns were higher in medium and low income states in India (Table 1).

The ICRISAT-led consortium has developed an innovative farmers' participatory consortium model for integrated watershed management (Wani et al, 2004). The important components of the new model, which are different from earlier models are:

- Collective action by farmers and participation from beginning through cooperative and collegiate mode in place of contractual mode.
- Integrated water resource management (IWRM) and holistic system approach through convergence for improving livelihoods as against traditional compartmental approach.
- A consortium of institutions for technical backstopping (Fig. 1).
- Knowledge-based entry point to build rapport with community and enhanced participation of farmers and landless people through empowerment.
- Tangible economic benefits to individuals through on-farm interventions enhancing efficiency of conserved soil and water resources.
- Low-cost and environment-friendly soil and water conservation measures throughout the top sequence for more equitable benefits to larger number of farmers.

Table 1. Returns were higher in medium (2000-4000 Rs. Ag GDP) and low (<2000 Rs. Ag GDP) income states.

[4] Case study provided by Suhas Wani, ICRISAT.

Indicator	Particular	Unit	Per capita income of the region High	Medium	Low
Efficiency	B/C ratio	*Ratio*	1.98 (16.86)	2.21 (12.28)	2.46 (7.73)
Equity	Employment	Person days/ha/year	132.01 (4.14)	161.44 (5.29)	175.00 (4.66)
Sustainability	Irrigated area	Percent	40.34 (9.73)	23.01 (6.24)	36.88 (4.19)
	Cropping intensity	Percent	77.91 (8.67)	36.92 (11.99)	86.11 (7.64)
	Rate of runoff reduced	Percent	12.38 (5.31)	15.82 (3.39)	15.43 (6.01)
	Soil loss reduced	Tons/ha/year	0.82 (40.32)	0.88 (37.55)	0.69 (4.60)
Extent of people's participation			High	High	Low

Note: Figures in parentheses are the t-values

Figure 1. An innovative consortium model for integrated watershed management

Increased productivity, water use efficiency, incomes, and marketable surplus

With improved cultivars and technologies farmers obtained 2.2 to 2.5 fold more maize yield of sole maize (3.2 to 3.9 t ha^{-1}) and four fold more pigeon pea yields along with other crops also (Table 2).

Table 2. Average yields (kg ha^{-1}) with improved technologies in Adarsha watershed, Kothapally 1999–2004.

Crop	1998 baseline data	1999	2000	2001	2002	2003	2004
Sole maize	1500	3250	3750	3300	3480	3921	3420
Intercropped maize (Traditional)	-	2700 700	2790 1600	2800 1600	3083 1800	3129 1950	2950 2025
Intercropped pigeonpea (Traditional)	190	640 (200)	940 180	800 -	720 -	949 -	680 -
Sole sorghum	1070	3050	3170	2600	2425	2288	2325
Intercropped sorghum	-	1770	1940	2200	-	2109	1980

Further, a detailed survey of the farmers' fields in different states of India showed wide spread deficiency of boron, zinc and sulphur along with N and P in 80 to 100 percent of the farmers' fields. Amendments with B, Zn, and S increased yields of various crops (soybean, sorghum, maize, pearl millet, groundnut, castor, pigeonpea, green gram and black gram) substantially (30 to 70 percent) enhancing rainwater use efficiency in different states in India over the farmers' practice along with net income also.
Improved water availability in the watershed resulted in a significant shift in area under high-value cereals, cash crops, vegetables, flowers and fruits.

Farmers in the developed watershed marketed more quantity as well as earned more income through sale of surplus produce (Figure 2). Watershed development benefited farmers not only during normal rainfall years but also benefited during drought years. In fact, during a drought year such as 2002, the total amount as well as value (15500 Rs ≈ US$ 345) of produce marketed was significantly higher as compared to the non-project village (9500 Rs ≈ US$ 211) (Fig. 2).

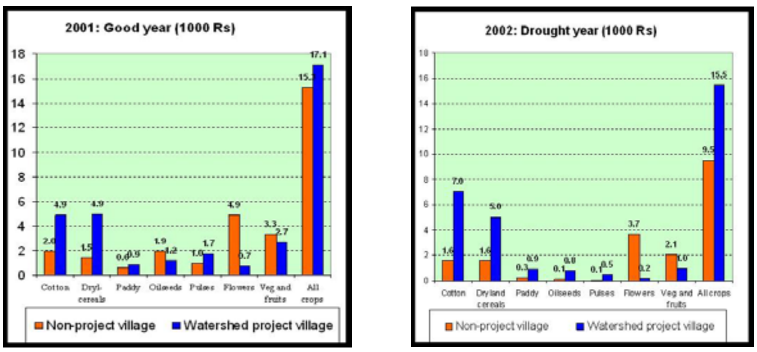

Figure 2. Effect of watershed management on amount marketed value, good and drought year)

Improved groundwater and reduced soil loss and runoff

There was a significant improvement in the yields of most wells, and with additional groundwater recharge, a total of 200 ha were irrigated in the post-rainy season and 100 ha in post-rabi season, mostly vegetables. Significant reduction (45 percent) in soil loss and 29 percent reduction in run-off volume were recorded than the untreated area. Improved groundwater in the watersheds resulted in increased private investments from the farmers. A case study of Rajasamadhiyala watershed in Gujarat showed substantial private investments in digging of open and bore wells, electric and diesel pump sets as well as irrigation equipment such as pipes and sprinklers. However, such large-scale investments could result in overexploitation of the groundwater resources, and there is an urgent need to develop groundwater policies for sustainable development.

Increased household incomes

For cereals, the returns to family labor and land (net income) are 45 percent higher even with irrigation, while the net returns on rainfed cereal crops have more than doubled. Similarly, for pulses, income in the watershed is more than doubled mainly because of a watershed development approach based on integrated genetic and natural resource management. Development of the watershed also provided stability and resilience for income even during a drought year such as 2002. Total household income during drought year was reduced by 23 percent to 29000 Rs (US$ 644) from 37700 Rs (US$ 822) in a normal year. In non-project villages reduction in income during the drought year was 26 percent to 21600 Rs (US$ 480) from 29200 Rs (US$ 648) in the normal year of 2001. The drastic impact of drought on crop income was observed in non-project villages as the share of crop income in total household income decreased to 18 percent in a drought year from 44 percent in a normal year. In a watershed village, the share of crop income in total income during a drought year was reduced to 40 percent from 44 percent in normal year (Fig. 3).

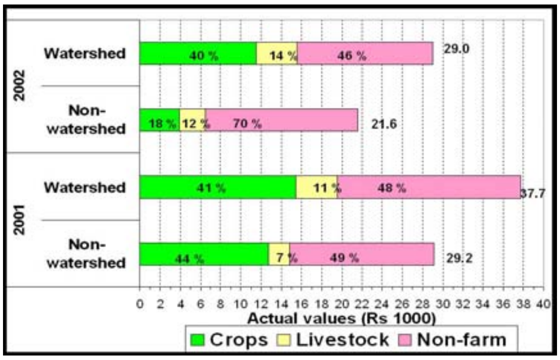

Figure 3. Income stability and resilience effects, Kothapally, AP, India

In conclusion, there is vast potential of rainfed agriculture which could be harnessed by adopting integrated water resource management along with land and crop management. More investments in rainfed areas through IWRM and land management will enhance food security not only through increased production, but with increased incomes for the rural poor in Asia and Africa. It is well established that once watershed development assures improved water availability, a lot of private investment from individual farmers comes and also from the industries. The large untapped potential of rainfed agriculture could be tapped through win-win, pro-poor-public-private-partnerships (5Ps).

Case 3: Participatory Irrigation Management and the role of WUAs[5]

Participatory Irrigation Management (PIM) refers to the participation of irrigation users in all levels and aspects of management of irrigation schemes. The system of PIM shows large flexibility in development of the management method; the approach is that it is the users who are best suited to manage their own water.

Mexico

The term PIM was first used at a World Bank Institute seminar in Mexico in 1995, organized to share the lessons learnt by the Mexican irrigation reform (Peter, 2004). Most farming in Mexico is irrigated, as the conditions for rainfed farming only exists in very limited areas of the country. Since the end of the World War II water services in Mexico have been provided by the central government (Johnson III, 1997) and, according to the Federal Water Law of 1971, all irrigation districts should be managed by the federal government (Palacios, 1999). By the end of the 1980s the government was subsidizing 75 percent of the operation, maintenance and administration of the districts. This was not a sustainable system (Palacios, 1999). The country then went through extensive agricultural reform, where the management of the irrigation districts was transferred to Water User Associations (WUA) (Johnson III, 1997). The responsibility for the irrigation systems was to be shared between the WUA, which would operate and maintain the secondary canal intake and onward, and the newly formed National Water Commission (CNA), which would manage the main canal and the water source (Johnson III, 1997). The transition of the new irrigation modules to WUA was successful, with 88 percent of the module areas transferred during the first ten years, 1989-1999 (Palacios, 1999). The WUA was thought to become financially self-sufficient, and also generate enough resources to cover the costs of the CNA. This has not been possible, and the costs of the CNA are still covered by a ministerial fund (Johnson III, 1997).

The degree of self-sufficiency of the irrigation systems has increased considerably since the reform started. In the Bajo Rio Bravo Irrigation District the degree of self-sufficiency increased from 36 percent in 1989 to 100 percent in 1994. The water fees have also been raised, sometimes by over 100 percent (Bajo Rio San Juan, water fee increase of 180 percent between 1992-1994) (Johnson, 1997).

Even if the Mexican reform has been successful in transferring the irrigation Operation and Management (O&M) to the users, there are problems with the new policy. The WUA does not have a volumetric right of water; instead the concession of the module entitles them to a share of the available water supply which volumetrically varies every season (Palacios, 1999). As the economy of the WUA is dependent on the water fees collected, this can become problematic in many ways. Conflicts arise as farmers are not receiving the amount of water they need, and if the allocated water to each module is too low, the WUA goes bankrupt (Johnson, 1997). A way of solving the financial situation of the WUAs is to introduce a water user tariff, which is not dependent on the volume of water the user receives (Palacios, 1999). If there is a water shortage the priority is given to human consumptions, according to the new Water Law. There is no consideration of the ecosystems need of water in the new law. During dry years this could then seriously affect the foundation of the irrigation system, the natural environment (Palacios, 1999).

Turkey

In Turkey two government agencies are responsible for management of soil and water resources, the State Hydraulic Works (DSI) and the General Directorate of Rural Services (GDRS). The DSI is responsible for large-scale irrigation and water infrastructure, while the GDRS is the agency working with on-farm development and small irrigation schemes (Antipolis and Burak, 1999). Since the 1960s water scarcity has been a problem in Turkey, and the O&M of the country's irrigation was a financial and institutional burden for the government. It was difficult to collect revenue and the water use was very high (Antipolis and Burak, 1999). Even if some transfer of O&M of irrigation schemes had taken place in Turkey, the government officials were reluctant to lose the control and power the central government had of managing the country's water facilities (Antipolis and Burak, 1999).

In 1993, with the support of the World Bank, the central government started a process of transferring even large-scale irrigation schemes to WUAs to reduce the costs of O&M for the central agencies (Antipolis and Burak, 1999 and Döker et al., 2003). Turkey has used the experience gained from the Mexican transfer and trained DSI staff in Mexico. By 1997, 1 350 000 ha of irrigated land was transferred to WUAs (Antipolis and Burak, 1999) and in 2002 87 percent of the DSI developed irrigation projects had been transferred to WUAs (Döker et al., 2003). The main contributions to the fast development of the PIM model was; the increasing costs of irrigation schemes to the central government; on the job training programs in Mexico and the US; commitment of DSI staff; clearly defined goals and selection of pilot projects; and the success of the pilot projects (Döker et al., 2003).

[5] Case compiled by Rebecca Löfgren, SIWI.

The system of PIM is supposed to lead to the transfer of all irrigation schemes, independent of size and location to the users. For this reason the transfer is not restricted to any certain type of user organization, but there is room for individual solutions to the management of the schemes (Döker et al., 2003).
The collection of water tariffs is done differently by different WUAs, the most common methods being area and crop-based tariffs for gravity irrigation schemes and cubic meter-based tariffs in pumping schemes (Döker et al., 2003).
The PIM has lead to better and more efficient use of the water resources; investment in new techniques increased; the collection rate for water user tariffs increased from 42 percent in 1993 to 80 percent in 1997; savings in energy costs has been approximately 25 percent; and a non-political process of water allocation through the WUAs has lead to a more equitable distribution (Antipolis and Burak, 1999). For a continued effective transfer of irrigation O&M to the WUA, the legal framework needs to be updated.
The legal status of WUAs needs to be defined and obligations of central agencies to provide technical and administrative assistance in the beginning of a transfer have to be clarified (Antipolis and Burak, 1999 and Döker et al. 2003).

India (Andhra Pradesh)
The irrigation schemes in the state of Andhra Pradesh in India have experienced serious trouble mainly due to several factors, including low performance despite large investments, declining infrastructure and low agricultural productivity (Raju, 2001). In 1996/1997 new policy reforms came into place to better deal with the situation of irrigation in the state. Among the reforms that took place was a three-fold increase in the charges; the creation of WUAs and capacity building of WUAs' members across the state. The transition to a PIM system in Andhra Pradesh was supported by the World Bank (Raju, 2001). Some researchers have criticized the PIM reform in Andhra Pradesh for being more of a top down program than an effort from the farmers (Jairath, 2000).
After adopting new legislation in 1997, several institutional reforms had to be made: creation of farmer–government partnership in irrigation O&M; consolidation of irrigation management transfer; new methods of cost recovery; expenditure prioritization; and capacity building for WUAs and the state agencies' staff (Raju, 2001).
Each WUAs was divided according to hydraulic boundaries and varied in size between 200 and 3 300 ha. The board members of the WUAs are elected by the users within its boundaries. The transfer of management to the user groups has lead to a strong feeling of ownership and ability to influence one's situation among the users. It has been expressed in some villages that the establishment of the WUA has just increased the number of organizations in charge of different aspects of the community, and that it would be better if the village government handled it. This feeling, however, is often not shared by the water users (Raju, 2001). In Andhra Pradesh the WUA have received funds from the development fund established by the World Bank and from the user tariffs. The collection of water tariffs increased from 54 percent to 65 percent the first year of implementation of PIM, 1998-99 (Raju, 2001). The WUA's management of the irrigation canal has lead to a more effective use of the water; in the Tungabadra High Level Canal area an additional 52 361 ha could be irrigated in 1998 (Jairath, 2000 and Raju, 2001).
There are several constraints to the new management system in Andhra Pradesh: the power supply is still very limited in rural areas; the water supply is less than the designed discharge levels; it is difficult for users to predict the future activities of the WUA in their area; and many WUAs are still completely dependent on governmental funds (Raju, 2001). One of the problems before the reform was the unequal distribution of water, where the downstream users ended up short. Even if the available water has increased this pattern is not broken and the inequality persists in many areas (Jairath, 200). But there are also many positive results: increased land area under irrigation; increased agricultural productivity; increased carrying capacity of canals by approximately 20-30 percent; increased collective action to maintain and develop the irrigation schemes by the users; and a drastic drop in farmer complaints (Raju, 2001).

Case 4: Pangani River Basin[6]

The Pangani River Basin is situated in the northeastern part of Tanzania (with 5 percent in southern Kenya). The basin drains the two highest peaks in the country, Mt. Kilimanjaro and Mt. Meru. The basin is one of Tanzania's most productive areas for both agricultural products and hydropower production (17 percent of the national power grid capacity). Some 80 percent of the population in the basin is directly or indirectly dependent on irrigated agriculture for their livelihood (Sarmett et al., 2005). The watersheds of the basin have a high precipitation, but most of the river runs through the arid Maasai Steppe, where the rainfall rarely exceeds 500mm/year (Lankford and Mwarunvanda, 2005).

The Pangani Basin is a water-stressed area where the supply does not meet up with the 1000 user water rights. In addition there are more than 1800 traditional abstractions that do not hold formal water rights (Samrett et al., 2005).

There are several large and strong water consumers in the basin. Large-scale plantations, including sugarcane, sisal and flowers, use huge quantities of water, as do the growing urban areas of Arusha, Moshi and Pangani. The Tanzanian Electric Supply Company (TANESCO) has a hydropower plant with the capacity of 45 m^3/s, but often receives as little as 15 m^3/s (Samrett et al. 2005). In the competition for water, small-scale users -- both with and without water rights -- have a hard time making their voices heard. The basin also has a large community of pastoralists, the Maasais, which traditionally water their animals in the river. This group seldom has formal rights to the water, and with an increased use of the resource, conflicts arise (IUCN, 2003).

The water rights, or permits, for the use of water for irrigation is paid as an annual fee and are expressed in quantitative flow units. To be eligible for water permits the WUA must be registered as a legal entity and only WUA can apply for water rights for irrigation (IUCN, 2003). Traditionally, water has been allocated through customary agreements between users and regulations; today, there is no system for dealing with these informal agreements, which is problematic (Lankford and Mwarunvanda, 2005). There are more than 2000 extraction schemes in the basins and most of these are unregulated. The large amount of unregulated abstractions makes the control function of the basin authority, the Pangani Basin Water Office (PBWO) very difficult (IUCN, 2003).

The conflicts in the Pangani basin can be described in three categories: conflicts of scale, tenure and location.

***Conflict of scale*:** The large, powerful water users in the Pangani, like the urban water and sewage companies, the TANESCO and the plantations with highly modern and efficient use of the water, contrast greatly to the small-scale users, with an efficiency rate of as low as 15 percent in some irrigation schemes. Even if both large- and small-scale users have water permits, it is common that the water is not enough, either because one user is abstracting more than its share, because the basin is experiencing a dry year or because other unauthorized users upstream are abstracting water for production (Samrett, 2005 and IUCN, 2003).

***Conflict of tenure*:** Government authorities have encouraged the creation of local natural resources management organizations, like the WUA, and this has been successful. The management by the newly formed local institutions have not been frictionless, though. Many of the already established institutions, like village councils, or organizations for other types of resources, come into conflict on who is really in charge of dividing the resource. The WUA have also had problems with collecting water fees from the users to pay for the water rights. Water has always been perceived as a common asset or "gift from God", and to pay for it seems illogical to some farmers. The regulation system has not been updated to handle these kinds of conflicts between WUA and traditional allocation systems (IUCN, 2003).

***Conflict of location*:** Users upstream in the basin have by location more favorable conditions, and the downstream users are dependent on the how much water the upstream users pass on. As the population increases the amount of water diverted for irrigation increases rapidly, both in the mountain areas and further downstream on the arid lowlands. Conflicts between upstream and downstream farmers are common, but also with other industries. An example is the TANESCO, which runs the New Pangani Falls Hydropower facility, and often only receives about 30 percent of its capacity. This affects the entire country's power supply, and the conflict goes well beyond the borders of the Basin (IUCN, 2003).

Pangani - Rundugai case study

The Rundugai irrigation scheme is situated on the Moshi lowlands below Mt. Kilimanjaro. The irrigation scheme holds five villages, where Rundugai being the most upstream. The scheme has been experiencing conflicts over the water resources due to overlapping and competing responsibilities in the area (IUCN-EARO, 2004).

Actors with mandates in water allocation in Rundugai include:

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[6] Case compiled by Rebecca Löfgren, SIWI.

- Furrow leaders: regulating the diversion of water to the individual users. Leaders of the informal Water User Groups (WUG) of users along a single furrow/branch.
- TEGEMEO: the formal Water User Association of Rundugai. WUGs will receive their formal right to water from TEGEMEO.
- Village Government: the authority that held the formal water allocation right before the establishment of TEGEMEO.
- Elders: the village elders receive mandate based on respect for their age and experience. They are often in position of land rights and might have been part of the building of the first canals.

Most of the WUG members of TEGEMEO come from the downstream villages. The downstream users are by location worse off, and have felt that they are not receiving their share of the water resource in the past. It has been easier for them to invest their trust in a new organization. In the upstream areas of the scheme the users are more skeptical of the legitimacy of TEGEMEO. They feel that the mandate of allocating water lies with the village government, as it traditionally has. The furrow leaders are torn between the village governments and TEGEMEO when deciding how much and when to allocate water to different furrows and fields (Pamoja, 2003).
To address the problems in the scheme, TEGEMEO have had support from a local NGO, Pamoja, and the Pangani Basin Water Office to increase its own capacity and to create a dialogue with upstream farmers and the village governments. Through the stakeholder dialogue the users have understood how the legal rights to the water resource is achieved (IUCN-EARO, 2004). A crop calendar has been prepared by the farmers to make the water use more effective and fair between upstream and downstream users (IUCN-EARO, 2004). TEGEMEO have made improvements on the irrigation scheme through rebuilding the intakes and construction of water division boxes in concrete. This has improved the relationship between the users and the organization and made them more willing to accept TEGEMEO as the formal institution holding the water rights (IUCN-EARO, 2004).

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