Water, Food and Poverty: Global-and Basin-Scale Analysis

Rationale: water and food systems support development within a global environment

The global environment currently supports around seven billion people through a range of ecosystem services that include food production, water supply and sanitation. By 2050, the global population is projected to increase to over nine billion (UN 2009) with concomitant increase in the demands on the natural environment. There is evidence that, in reacting to meet some of these demands, human societies are damaging the environment's capacity to satisfy other demands. In river basins, this is manifested through the inequitable sharing of finite water and land resources.

We chose river basins as the environmental entity with which to study this problem since this is the only way to understand flows and exchanges of water. The global picture translates into very different outcomes within individual river basins. Ten river basins were chosen for study in the Basin Focal Projects (BFPs) CGIAR of the Challenge Program on Water and Food (CPWF). These 10 basins are in developing countries where the disjunct between poverty, water and food is particularly acute. Altogether, they host 1.5 billion people and half of the billion poor who leave with less than $1.25 per day.

Components of the problem: Organizing information to help explain conditions in river basins

The problem is made up of aspects of poverty and development: water resource management, agriculture and institutions. Poverty is described within basins according to measures of income, consumption or livelihood assets. Of course, poverty and food insecurity are related and we understand from Byerlee *et al.* (2008) that food security is a necessary if not sufficient basis for poverty alleviation.We consider poverty to be a dependent variable, which represents the degree to which people are not supported by the development of water and food systems.

A framework to analyze conditions in basins

Conventionally, analysis of development in river basins has approached the problem from the hydrologic perspective, with scant reference to the activities of the agricultural systems that operate within it. In this approach, water flow is analyzed, using water-use accounts, or "finger diagrams" to identify where water flows within basins, and to which uses. In contrast, agricultural research has focused strongly on aspects of the farming systems, with little reference to their interaction with water systems. Land productivity is the normal focus of agricultural research, with the individual aspects of agricultural systems usually studied separately. Food-systems approaches analyze the different components without accounting for water use. There is therefore a clear disconnect among the three approaches.

The Food and Agriculture Organization of the United Nations (FAO) predicts that 70% more food will be required by the year 2050 (Bruinsma 2009). Due to evolving diets, especially for growing urban populations, demand for animal products is estimated to increase by 74%. FAO estimates that over 900 million people currently go hungry. Domestic and industrial demand for electric power will increase by about 50%, of which hydropower is expected to supply about one third (EIA 2010). Most of the increased food production is forecast to come from intensification of production systems, but about 15% is expected from extension of the agricultural area. Urban populations will expand from a current estimate of 3.5 billion (50%) to 6.3 billion (69%) by 2050 (UN 2010). The impacts of these changes will be compounded by other factors, in particular global climate change, which imposes major uncertainties on future water availability, environments of crop production, and disease (IPCC 2007).

From the development perspective, neither the water nor the food-systems approach is sufficient to explain how either system interacts with the other to produce livelihood outcomes. Focusing only on the food system provides no insight into the implications of variations in use of a shared water resource. Focus on the water productivity of food systems takes no account that livelihood systems gain support from a wide range of support mechanisms. Water may flow through to a final benefit by many different processes, which operate in parallel or serially. Moreover, benefits may substitute one for the other, for example, people may be supported by food from irrigation, by livestock feed from rainfed grassland, by fish that live in the aquatic environment that the irrigation water might otherwise support, or by the benefits of non-farm employment enabled by hydropower. A focus only on agricultural production can therefore omit important off-farm contributions.

Molden (2007) provides the Comprehensive Assessment of Water Management in Agriculture, which was a major program of research describing a wide range of aspects of the water and food systems. The Assessment provides valuable general advice to policy makers but it does not, however, attempt to assemble these components within specific basins. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT-Water) model of Rosegrant *et al.* (2002) and the Policy Dialogue Model (PODIUM) of de Fraiture *et al.* (2001) both assemble selected components of food systems within river basins, but these models do so at a relatively broad level of generalization at a country scale. This paper drew upon the logical structure of nine projects in river basins to provide observations according to a single analytical framework (Fisher and Cook 2010) (Figure 1).

Insights from basins

Water influences development in many different ways. It does so indirectly through its impact on irrigated or rainfed agriculture, through its support of aquatic systems, and also through the provision

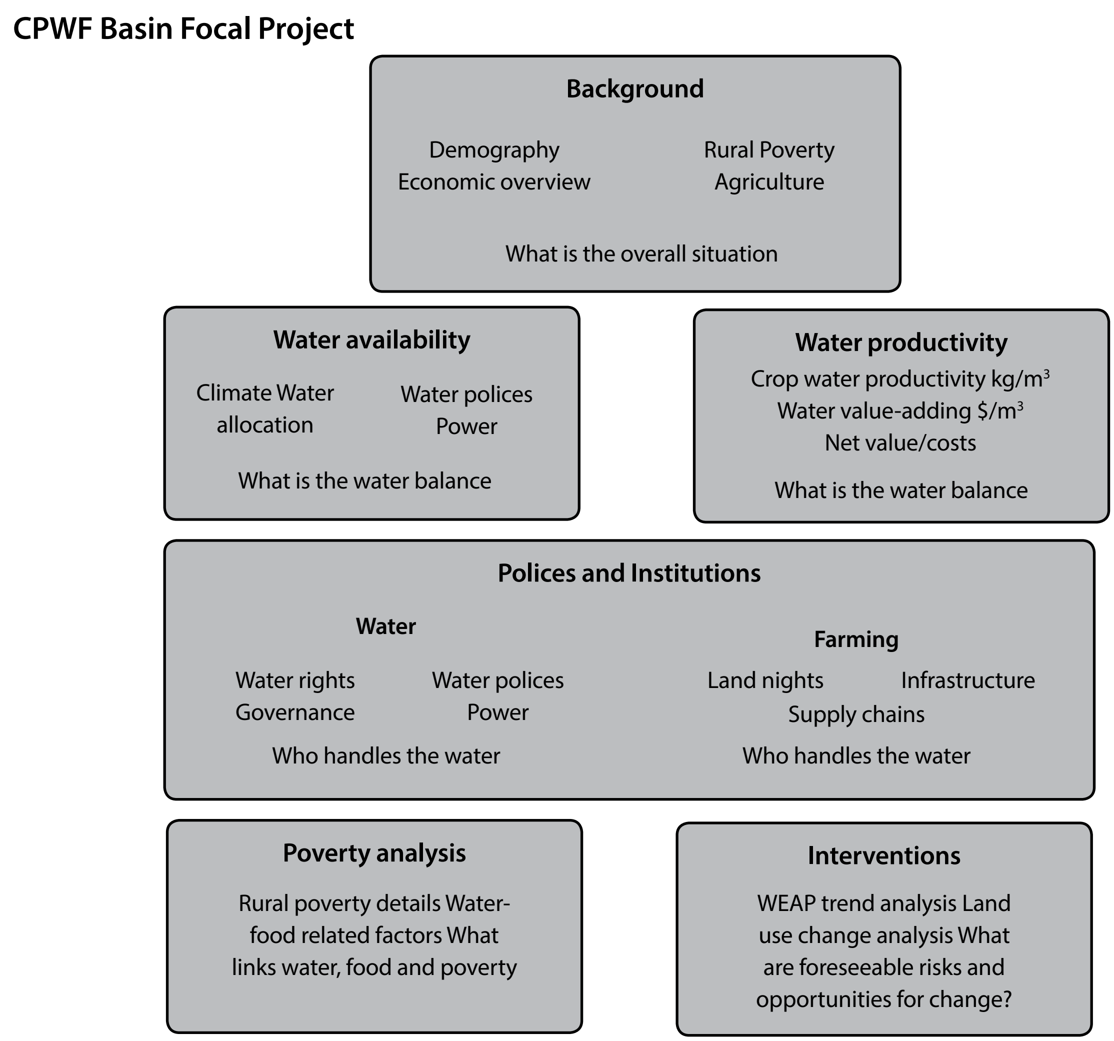


Figure 1. Analytical framework of a logical structure of observations in nine projects in river basins (WEAP = water evaluation and planning)

of urban water, power, sanitation and transport. In some basins, economic systems have responded to increasing water scarcity with no discernible impact on rate of development. In other areas, water related factors have a clear impact on rural development, which can be felt concurrently through food, income or environmental security. This can be difficult to analyze, since impacts can be interchangeable. Moreover, development of one may threaten another, such that it is the total picture that needs to be considered.

Factors that couple water to development

From observations in 10 basins, we conclude that there are four factors that link water to development.

Physical Water scarcity

Water scarcity has been described as either physical or economic (Seckler *et al.* 1998). Here we focus on physical water scarcity, as reported in the Yellow River, Karkheh, Indus and upper Limpopo basins. While the Nile as a whole is not considered water scarce, political tensions occur because Egypt and Sudan rely totally on inflows from the less developed upstream countries. Population density is low in the Limpopo where less than 1% of available water is used for irrigation. Conversely, population density in the Yellow River is extremely high and irrigation consumes 14% of average basin flow.

On average, the Niger, Nile, São Francisco and Volta Basins are moderately water scarce. Data of average water availability hides spatial variations, such that less populated parts of all are water-scarce. The Ganges, in general, is only moderately water-scarce but contains areas of extreme or increasing scarcity.

Areas of low scarcity include the Andean system and the Mekong. Nevertheless, the Andes basins are extremely diverse and contain some of the driest places on earth; average annual rainfall in Lima is less than 100 mm and the city is dependent on outside water supply. Areas of northeast Thailand, southern Laos and Cambodia in the Mekong are frequently affected by drought and seasonal water scarcity due to prolonged dry seasons of up to six months.

Evidence suggests that variation of water availability is not strongly correlated with poverty. An illustration of this apparent paradox is the comparison between the Democratic Republic of Congo (DRC) and Israel: the water-rich DRC is among the poorest in the world, while water-poor Israel ranks among the richest (Molle and Mollinga 2003). Analysis from basins suggests that water scarcity is one factor controlling development. It is undoubtedly a major concern for those agricultural economies such as Pakistan, Egypt, India and China that have developed their agriculture through intensive use of irrigation. The poorest people, however, live in areas where such development has not occurred, and where other factors therefore influence development more strongly. It is important to understand this in the light of geographical variation of development processes.

Dry areas do not support large populations without irrigation, but in some basins irrigation has supported the development of intensified agriculture using rates of abstraction that now seem unsustainable. In some cases further growth may be possible by improving water productivity. The situation becomes problematic when areas (for example, Indus and Yellow River basins) that already face moderate to severe water scarcity are squeezed by demands from non-agricultural sectors. Parts of these basins seem to have reached maximum water productivity so that the options for further growth of low value agriculture are limited. In such cases, further development depends on a move away from dependence on basic agriculture towards higher value crops or non-agricultural activities.

Economic water scarcity

Lack of access to water resources, sometimes referred to as economic water scarcity (Seckler *et al.* 1998), was reported as a widespread problem in basins and occurs even in relatively well-watered areas such as central Ghana. It occurs because either there is a lack of infrastructure development; or there are institutional constraints, which may grant access to some, but deny access to others, usually to the poorest, most disadvantaged people. The Asian basins Karkheh, Mekong, Indus, Ganges and Yellow generally have well-developed infrastructure and high levels of access to water. Gini coefficients for income are generally moderate or low, suggesting that economic benefits are relatively widely distributed. Available groundwater resources are generally exploited, with over exploitation common in some regions.

The Andes and Limpopo have high Gini coefficients implying inequitable income distribution.
Both have experienced political tensions over inequitable access to limited water resources. In the Niger, Nile, and Volta basins, infrastructure is very underdeveloped. Access to sanitation in rural areas is very poor.

In Asia, the variability in degree of development of water resources between countries is quite high, while in Africa the degree of development is low nearly everywhere. Excluding Egypt and South Africa from the data, access to water in African countries is lower than Asian countries (index of 7.3 vs. 10.8), but the standard deviation is only half of that of the Asian selection (2.38 vs. 4.38), which shows that access is uniformly low in Africa. The correlation between access and capacity for the 147 countries analyzed worldwide by Lawrence *et al.* (2002) is relatively high (r2 = 0.68). Access to water and the level of development are strongly linked.

Exposure to water related hazards of drought, flood and disease

Floods and droughts occur sporadically, but they have a disproportionately negative impact on the poor. This is because they push them into survival conditions in critical years, and overall deter critical investment that may allow them to escape from poverty. Although droughts tend to occur sporadically, in recent years, serious droughts have led to food insecurity over large parts of sub Saharan Africa and South Asia. Severe drought frequently affects the Limpopo, Nile and Niger basins, with several major events in the past decade. Though less frequent, drought has recently damaged food security in the Ganges.

Floods are generally of more limited geographic extent but – as demonstrated by the major 2010 floods in the Indus, Niger and Volta - they cause intense disruption and loss of life and property. Floods are a serious problem in the Limpopo Basin, where there are extreme year-to-year variations in flows with major floods in Mozambique in 2000 and 2008. In the Andes and upper Ganges, floods are of small magnitude but associated landslides disrupt transport infrastructure. Floods in the lower Ganges pose a serious hazard that appears to be increasing in magnitude. Devastating historic floods in the lower Yellow River are a reason for strict control of flow. In the Mekong, 90% of flow occured in three months, leading to widespread flooding in the lower basin. Contrary to being considered a hazard, however, the inundation is regarded as vital to the aquatic resource on which 65% of the basin's population depend.

Water-related diseases such as malaria, schistosomiasis, and onchocerciasis (river blindness), impose serious constraints on land use over large parts of sub-Saharan Africa. The central Volta is a hotspot for malaria, which is also an important hazard in other African basins. Together with the widespread but now controlled incidence of onchocerciasis, it is one reason for low agricultural activity of the central Volta.

Water productivity

Following Hoff and Rockström (2009), we divided water productivity into productivity of green and blue water, and restricted our comments to water productivity of crops. Blue water productivity describes the conversion of water abstracted from rivers for irrigation. Green water productivity is the conversion of precipitation in rainfed agricultural systems. Cai *et al.* (2011) provided more details on the water productivity of crops, livestock and fish. This and the basin reports (Water International, September 2010) suggest that green water use is far greater in most basins than blue water use and also that green water productivity is substantially lower than blue water productivity. This supports the conclusion of Molden et al. (2007) that improvement of rainfed agriculture presents a major opportunity to meet the demand for more food without increasing agricultural water use.

Blue water productivity

Productivity of blue water is very high for irrigated areas in the Yellow River basin. Estimates for some areas approach the likely maximum for wheat of approximately 1kg/m^3. Slightly lower estimates are recorded for irrigated areas in the upper Ganges, although they are lower in the lower Ganges and the Indus. Values from the Nile Delta have been boosted in recent years through production of high value crops, in addition to the integration of aquaculture and agriculture.

Irrigation is less widespread in the Mekong, but values of water productivity from the Delta region are also very high, and have increased over time more than keeping pace with the demand for food. In the Karkheh, water productivity of irrigated crops is much lower. With the exception of the Delta and Gezira region of the Nile, irrigation consumes less than 1% of water in the Limpopo, Niger, Nile and Volta basins and contributes little to economic activity of the basins.

Green water productivity

Overall, green water accounts for over 70% of the water flux in the 10 basins included in the BFP studies of the CPWF.
Water productivity in parts of the Yellow and

Ganges Basins are high (>0.5 kg/m^3), although less than that of irrigated areas. Elsewhere, water productivity varies between 0.1-0.5 kg/m^3, suggesting widespread low activity of the agricultural system. Water productivity of rainfed agriculture in the African basins is generally extremely low (water productivity <0.1 kg/m^3).

Low water productivity is a consequence of a wide range of limitations that collectively constrain agricultural production, and cause the widespread limit on the contribution of water and agriculture to economic development. Estimates of water productivity indicate that activity is well below potential, and taken together, low blue and green water productivity represents a systemic failure of agriculture to convert water into food or income. This is by far the most important water-related constraint to improving food, income and environmental security by consumption of water by agriculture.

Crossing from local to global scales

Coherence between different scales: global, basin and local

The linkages between the conditions that are discernible at a global scale and what happens in catchments and farming or fishing communities are complex and need clarification. Data at broad global scales indicate the emerging tension between food and water systems. Population increase and changing dietary habits are expected

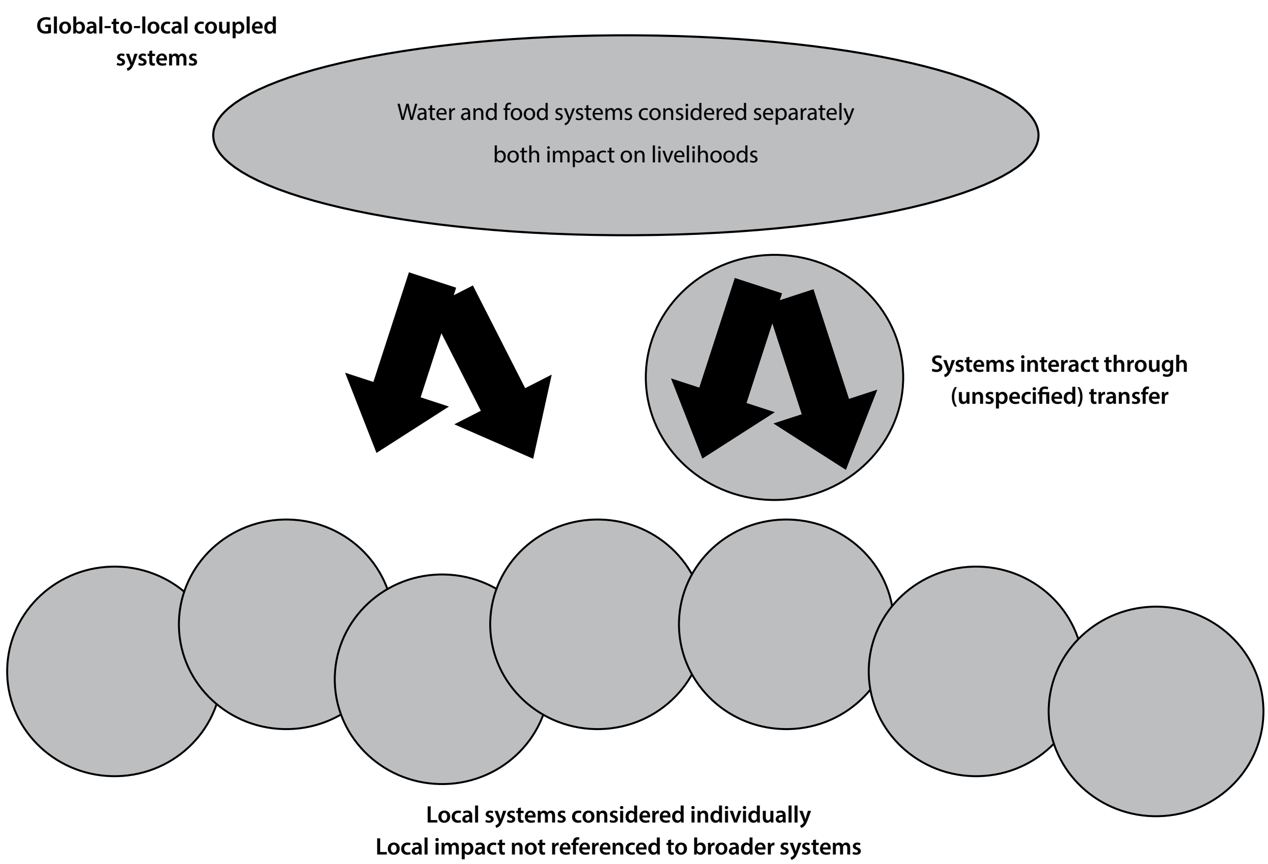


Figure 2. Food and water systems interact strongly at basin scale but linkages are difficult to see.

to double the demand for food and animal feed. Present and projected conditions are expressed very clearly in the Comprehensive Assessment of Water Management in Agriculture (Molden 2007). At a local scale, the situation can appear very different, reflecting the strong influence of local conditions on the way people manage water and food to support their livelihoods. The systems are connected within river basins through transfers of water, food or other products of agriculture (Figure 2). But how, exactly? What are the particular pressures and opportunities that occur within individual basins? How can these complex behaviors be described and analyzed, and what are their impacts on poverty locally? By adopting the basin as the prime object of analysis the BFPs connected what is happening within basins to trends and pressures that are evident globally.

To move beyond analysis within individual basins towards a global view, we organize observations from basins according to the themes of the papers in this issue: water availability (Mulligan *et al.* 2011); water productivity (Cai *et al*. 2011); and poverty (Kemp- Benedict *et al.* 2011). The overall condition of economic development in river basins can be understood using the scheme of the World Development Report (Byerlee *et al.* 2009). Figure 3 shows basins arranged according to two variables: rural poverty and agriculture as a percent of GDP. The arrow tracks a generalized "development trajectory" in which agriculture is seen as a necessary, but not sufficient basis for development. The trajectory passes from strongly agricultural economies in the Niger, Volta, Nile and Limpopo,

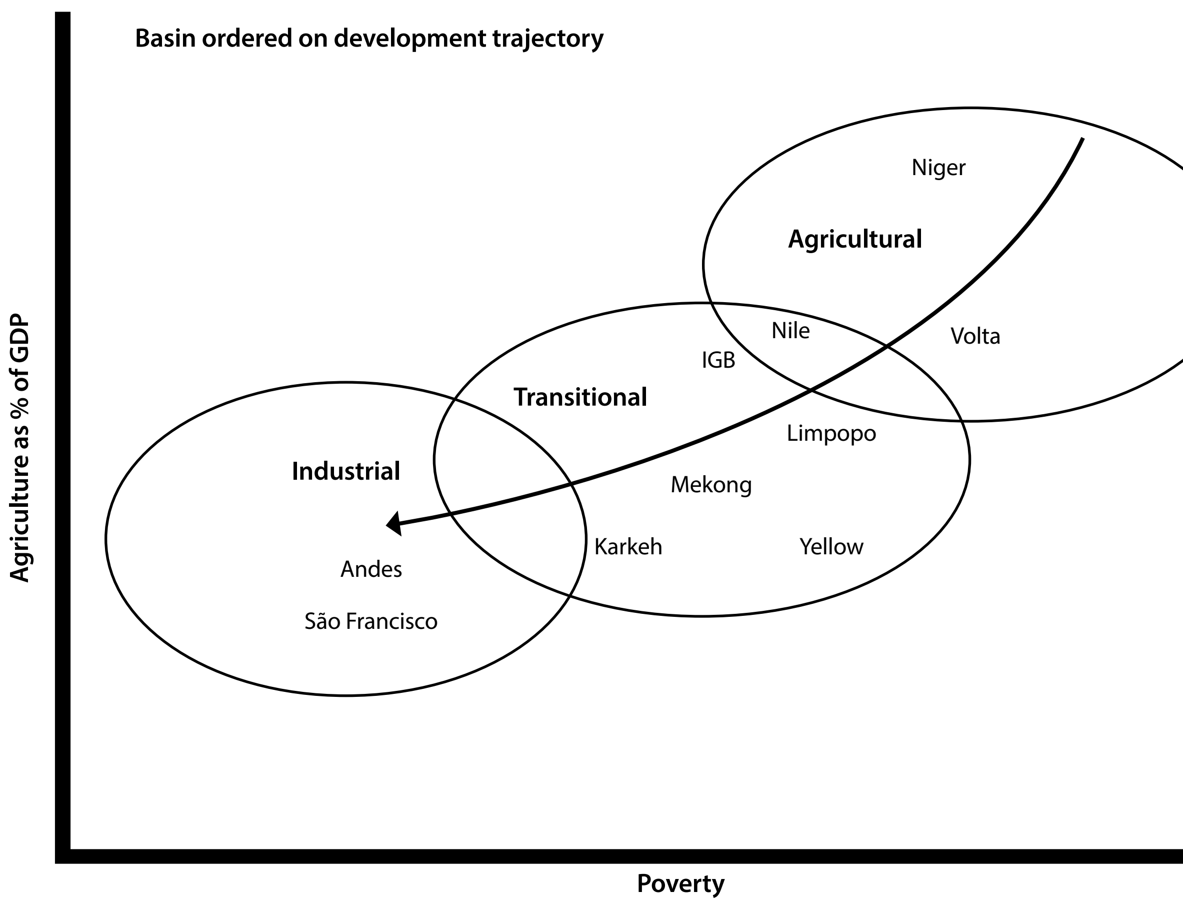


Figure 3. BFP basins ordered according to rural poverty and agricultural contribution to gross domestic product (GDP).

through those of transitional economies (Indus, Ganges, Mekong, Yellow); to basins containing industrial economies such as the Andes. It should be noted that most basins contain large variations: for example, the Mekong is transitional, but contains areas of Laos that are strongly agricultural and others in Thailand and Vietnam that are industrial.

We suggest this as a "first cut" of generalizing conditions throughout the developing world, since it is the development drivers, in conjunction with resource constraints, that determine the broad variation of constraints and opportunities (Figure 4).

Agricultural basins: Niger, Nile, Volta

Agriculture dominates activities in these basins but agricultural productivity is very low and rural poverty widespread. With the exception of mining industries in some countries, non-agricultural activities contribute little to economic activity. Water infrastructure is poorly developed, normally at 1% or less of its potential. "Non-engineered" agriculture is relatively more important than in transitional or industrial economies. In drier basins, livestock systems are very important for the poorest. In wetter areas, fish and wetlands provide vital livelihood support, on which the poorest and landless depend heavily. Demands on water resources are not fully expressed as population densities remain low, though increasing. People are exposed to water-related hazards (Figure 5).

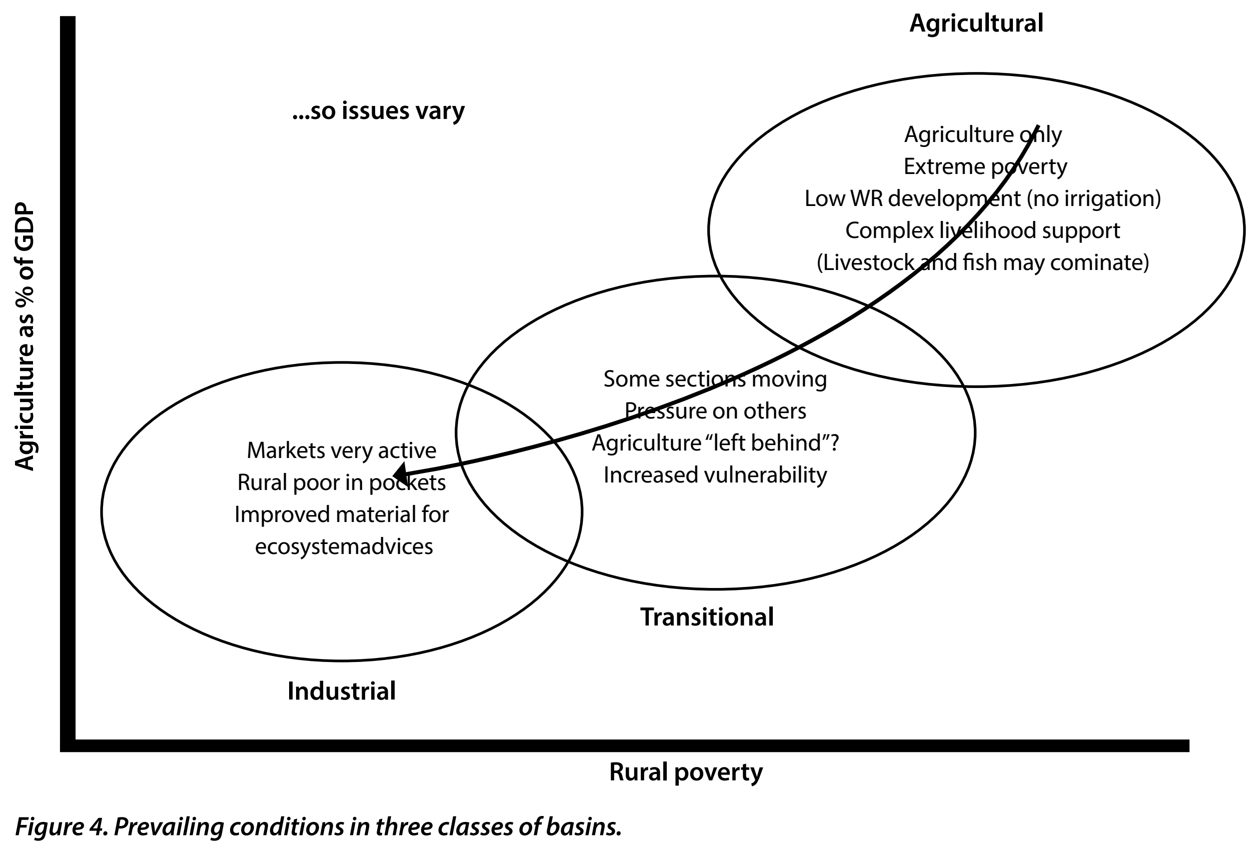


Figure 4. Prevailing conditions in three classes of basins.

Byerlee et al. (2009) show clearly that improving agricultural productivity is a necessary step to move economies along their development pathway. A prime development objective in these basins is to focus on the provision of basic needs of sanitation, healthcare, education and transport. Market development and infrastructure are key issues that are poorly developed. The major opportunity to agriculture is to support food security through rainfed agriculture without compromising livelihoods of those dependent on marginal livestock or aquatic systems. Development of water resources for irrigation may deliver local benefits, but from such a low base, this seems likely to have limited impact on rural poverty.

Transitional basins: Indus-Ganges, Limpopo, Karkheh, Mekong andYellow

In transitional economies, activities that are non-agricultural and that add higher value make increasing contributions to gross domestic product (GDP) and attract people out of agriculture. These are the areas that are expected to experience most rapid growth of economic activity and population, although the population within the Yellow River Basin is declining. It is in these regions that demand for food is expected to intensify and where water resources are generally well developed. Non-farm activities expand, and may be inter-woven with agriculture to support development. Overall, however, the process seems to be one of uneven and localized development in which many gain but some are left behind.

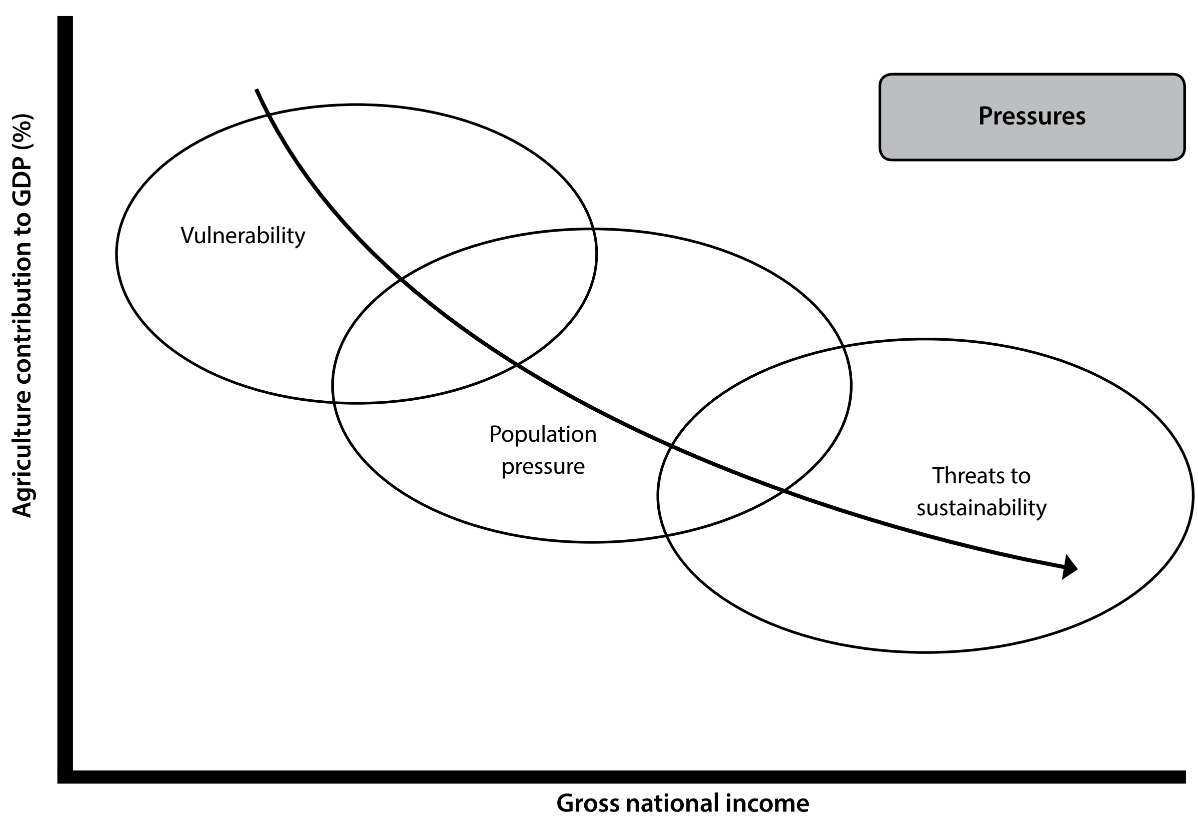


Figure 5. Pressures change with development status.

Agriculture remains important at a national level, and agricultural productivity increases in response to market demands and requirements for food security of an increasingly urban population. Agriculture may also wield considerable political power. Greatly increased agricultural activity may exert pressure on water resources and compete with expanding non-agricultural demands. Issues of water quality emerge but lack the institutional capacity for ecosystem servicing. There is only partial protection against hazards of flood, drought and water-related diseases.

The main opportunity seems to be institutional development to enable transparent, informed and broad-based processes of change, which can distribute benefits and capacity without constraining development. This can occur under a range of political environments.

Industrial basins: Andes, São Francisco

Agriculture is no longer a major economic contributor in industrial economies. Rural poverty remains in localized areas. In such conditions agriculture retains its importance as a means of reducing the risk of social unrest caused by depopulation to urban areas. Markets are highly active. Direct food security may decrease in importance as income security increases through exploitation of higher value agricultural activities. Water resources may be highly stressed, but resources may be managed intensively. Ecosystem services and benefit sharing become increasingly recognized as a means of ensuring environmental security. Greater levels of economic activity afford a high degree of protection from water-related hazards.

Food security is reasonably assured in these conditions. Income security is relatively insensitive to agricultural activity. Therefore, while agricultural activity remains supported, often for political reasons, increasing opportunities are sought for development of ecosystem services. These are required to maintain the environmental security of water supplies to urban and industrial consumers, hydropower and high-value agricultural activities. Aesthetic and cultural factors play increasingly important roles at steering development through regulation and political norms.

Developing insight to support change

Change will occur in food and water systems according to prevailing drivers in each and in how institutions respond to the drivers. Groups of people will be affected by these changes as they strive to feed themselves and maintain economic activity. In a situation of unequal power, some are likely to be left behind, or lose their livelihood support from water and other resources as they are commandeered by others.

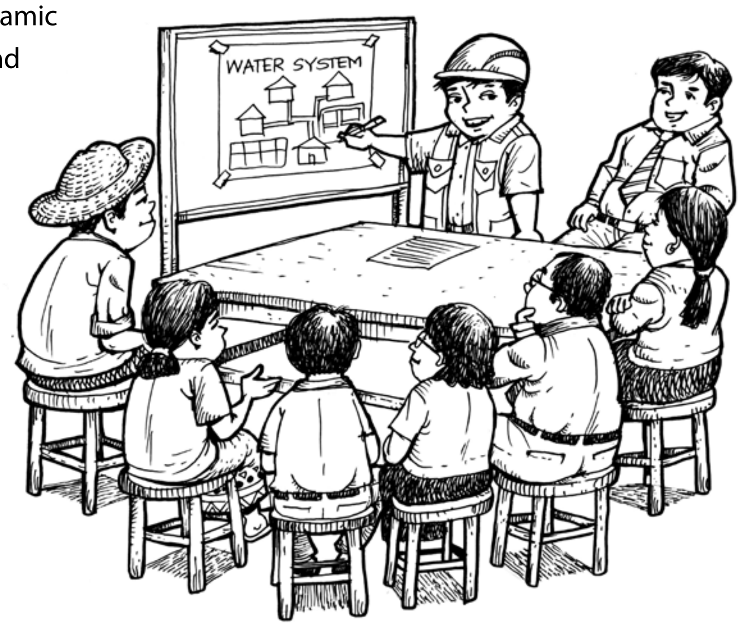
Change can occur in diverse ways but intervention can assist either by increasing the capacity of existing resources to improve productivity or by reducing the likelihood of loss of livelihood. This can only be achieved by negotiation, through the process of deliberative water politics (Dore 2007) in which people agree to adopt or accept actions based on informed and transparent debate and deliberative consideration of the options.

Conclusions

While it is convenient to visualize a global water and food crisis in which increasing demand for food and water results in increasing poverty, food insecurity and political conflict, detailed analyzes from the BFPs show a far more nuanced reality. Analysis of conditions in basins shows a complex dynamic between development processes and the natural resources they consume. This dynamic can push river basins, or parts of them, beyond the level at which ecosystem services of water provision, food production, energy and other services can be delivered in a sustainable manner. This raises problems of potential conflict over limited resources between different communities within river basins. An alternative situation occurs when resources are effectively underdeveloped. In such cases, poverty is associated with low productivity of land and water.

The relation between water and food systems and the development that they support is bi-directional. Water and food systems influence development and development influences the use of water and food resources. Societies use a range of ecosystem services as they develop, but conversely, the way these are used depends strongly on the development status of those societies, their power, their capacity to govern themselves and their capital. Consequently, while development in the Yellow River has allocated virtually all the water resources in the basin, it has also worked to increase the productivity of the system by assembling all components into a highly productive system.

The global environment supports people through the provision of ecosystem services such as food production, water supply, sanitation and hydropower. People appropriate services individually or communally, through institutions that govern sharing, production and investment. However, institutions need to evolve a holistic approach to address issues of unequal development that leads to unequal sharing



of resources and benefits. In many cases this requires a complete rethink of how departments of water resources, agriculture, mining, and health can be restructured to avoid the compartmentalized, independent institutions of the past that have proved so inadequate to confront the issues of water, food and livelihoods.

In many of the river basins studied in the BFPs, a serious problem is the underdevelopment of land and water resources as indicated by low water productivity. Lack of development is related to many factors that can be summarized collectively as a lack of coherence within farming systems, in which lack of access to resources, finance, or markets prevent farmers from developing land to its potential productivity. In the poorest areas, we attribute lack of development to water-related hazards such as drought, floods, or disease, which have a known negative impact on the investments that are essential to escape poverty. Our analysis of conditions in basins shows the need for a detailed synthesis across all the BFP basins of water availability, water productivity, institutions that underpin how people use water and food systems, and the specific consequences of these factors to livelihoods and poverty. There are problems of watwe and land resources scarcity, especially in basins characterized by transitional economics characterized by transitional economies. Our analysis further shows that a more widespread condition is low water productivity, particularly of green water. A general observation, explored in more detail in the basin reports, is that while serious problems exist at national or sub-national scale, at a global scale, the capacity exists to meet, in theory at least, future global demand for water and food. The basin reports indicate the problems of exploiting this capacity in a sustainable and equitable manner. They also point to the overriding need for institutions that will balance the demands of different groups of people within basins in addition to balancing the pressures for development and environmental protection within the environment it uses.

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Tag: Basin Focal Projects (BFP)

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