Integrated Approach and Equity Principles to Promote Sustainable Water Management in Bangladesh

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1. Introduction

Water is of paramount importance to human being. It is a unique commodity for which everyone is stakeholder. Availability of water and reducing risks of water related hazards are important determinants of economic growth and social prosperity. Water management projects are intended to create opportunity for socioeconomic activities. Because of lack of environmental and equity considerations, water management projects in Bangladesh bring benefit to a section of the society while cause hardships to other section. Non-water sector activities also affect water regime, and many water problems stem from activities in non-water sectors. The increasing demand of water and the rising damage due to water related hazards because of population growth, economic development and expansion of socio-economic infrastructure have made the water management a challenging task. Consideration of the effects of non-water sector activities is also essential for sustainable water management. Integrated approach to water management (GWP, 2000) is essential to make progress towards the requirements of equity, public health security, livelihood security, environmental preservation and sustainability. Chowdhury (2007) discusses the concept of integrated water resources management and the actions needed to implement this concept in Bangladesh. Present paper briefly discusses the importance of integrated approach and equity principles in water management and steps needed for sustainable water management.

2. Interdependence of Land, Water, Ecosystems and Socio-Economic Development

Water regime is affected by water use, land use and infrastructures that are part of socioeconomic activities, and some of those activities belong to non-water sectors. Integrated water management approach (GWP, 2000) is essential to address the problems that stem from water sector and non-water sector activities. Attention to the linkages that are active in the interdependence of water resources system and socio-economic system (Figure 1), is essential for sustainable water management.

Functions of water resources system: The water resources system (WRS) performs a wide variety of functions that deliver goods and services for the society. Some of the functions of the WRS in Bangladesh are mentioned by dividing them into four broad categories as follows: (i) regulation functions such as moderation of flood peak, augmentation of dry season flow, transport of sediment, maintenance of river morphology, prevention of saline water intrusion, etc; (ii) environmental functions such as domestic water supply, drainage of surface water, recharging wetlands and groundwater, assimilation of wastes, etc.; (iii) ecological functions such as provide soil

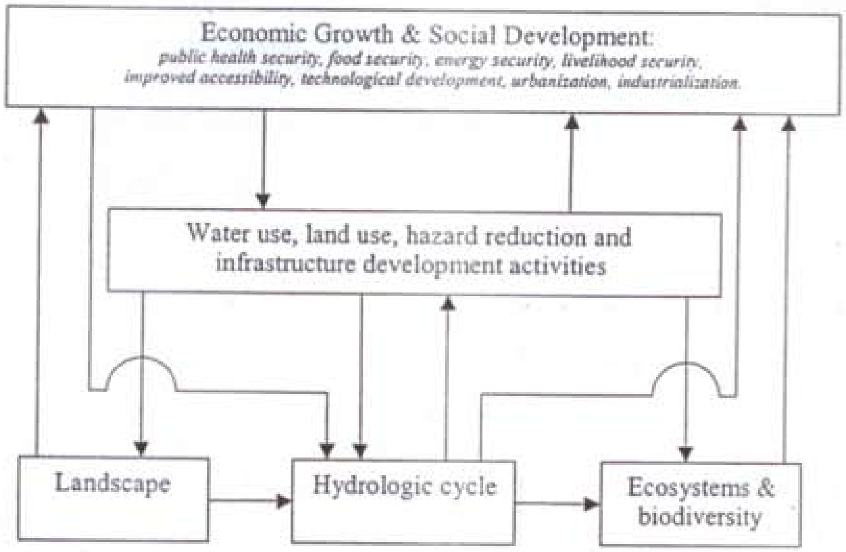

Figure 1: Interdependence of land, water, ecosystems and socio-economic development.

moisture for vegetation, habitat for fish, aquatic plants and wild life, and resort for migratory birds, support bio-diversity, etc.; and (iv) socio-economic functions such as supply of water for agriculture, industry and power generation, providing conditions for navigation, recreation & tourism, etc. Water regime and ecosystems in Bangladesh are subject to severe stress because of the inconsistency of water use, land use and infrastructural activities with the functions of WRS.

Effects of water management activities: Water regime is affected by water withdrawal for irrigation and industries. Water retention projects create opportunity for expansion of cultivable land, industries, culture fisheries, etc. Flood control projects bring changes in floodplain water regime, create land use opportunities and transfer the flood risk elsewhere. Change in water regime affects aquatic ecosystems and livelihood activities. Experiences in Bangladesh show that water management interventions bring economic benefit to one section of the society while cause economic hardships to another section especially the poorer section. Water dependent livelihoods such as fisherman, boatman, aquatic plant harvesters, etc. have been adversely affected by water management projects as discussed later. Attention to the linkages that are active in the interdependence of land, water, ecosystems and socio-economic development (Fig. 1), is essential for sustainable water management.

Effect of land use activity on water regime: Modification of land cover by land use change (e.g., agricultural land to rural homestead and market, rural to urban, forest to agriculture, etc.), encroachment of wetlands, deforestation and hill cutting brings changes in the physical properties of land surface. These land use activities modify landscape that brings *changes in the infiltration and groundwater recharge processes and surface runoff* and sediment transport processes that cause increased flood flow and decreased dry season flow in the river and alteration of the river regime. Road, water control and hazard prevention infrastructures trigger land use change, modify drainage pattern and transfer hazard risk elsewhere. Elimination of lowlands and wetlands that are rich in ecological resources, reduces storage space for floodwater. Changes in hydrological process can cause increased risks of extreme flood, drought, riverbank erosion, excessive sediment in water, very low flow, salt water intrusion and environmental degradation.

3. Equity Issues in Water Management

Equity consideration in natural resource management is an important requirement for the promotion of the goals of sustainable development. Water is an indispensable resource, and how this natural resource is managed has critical implications on economic development and social prosperity. Equity concept in natural resource management has been discussed by Deshpande et al. (2004). Water is a basic need for human being, animals, plants and environment, and equity consideration in water management decision is essential to satisfy the basic needs. In pursuing Integrated Water Resources Management, the GWP (2000) stresses that equity should be among the overriding criteria that take into account of social, economic and environmental conditions. How to absorb equity considerations in policies and mechanisms of Integrated Water Resources Management has been discussed in GWP (2003).

Multipurpose use of water: Water is essential for public health, food production, industry, energy production, communication, recreation, fisheries and ecosystems. Good quality of water and favorable condition for water dependent livelihoods are among the key determinants of economic growth and social prosperity. Water management activities generally involve construction of water control structure in order to create favorable hydraulic condition by bringing changes in water regime. Main purposes are to create opportunity for water use and to reduce risk of water related natural hazards. Because of the change in water regime, there is also possibility of social costs due to adverse effect on public health, environment, ecosystem services and water dependent livelihoods. A major environmental concern is the conflict between the water use by human and the water needed by the river itself to transport sediment, to maintain its morphology, to satisfy ecological requirements, to prevent salt water intrusion etc.

Basic human need and fairness in decision making: Equity implies protection to water rights, and access to safe drinking water is to be ensured as it is a basic human need. Water management project should not be such that it serves the interest of a group of the society but aversely affect others in the community. Focused attention to socio-economic vulnerability of low-income groups such as marginal farmer, fisherman, boatman, etc. is essential for fairness in decision making. It is to be ensured that the low-income groups are not adversely affected. Equity requires that the interests of people living in poverty need to be considered and affirmed (GWP, 2003).

Water dependent livelihoods: Equity requires that provisions are to be made to give protection to the prevailing livelihood opportunity, particularly the water dependent subsistence activities. Livelihoods of a section of rural population such as fisherman, boatman and aquatic plant harvester are dependent on water regime. They belong to poor section of the society. Large decrease in water depth due to water withdrawal and obstruction to flow by water control structure cause adverse effect on these livelihoods.

Social justice regarding distribution of social costs and benefits of water management project: The equity concept implies that water management decision should be free from bias and should ensure social justice in the distribution of social costs and benefits of water management project. In many cases, inequity stems from water use conflict that arises when water consumption by one use causes decrease in water available for other use. The competing water needs have caused rise in conflicts between different water users, different sectors and different regions, e.g., between domestic and agricultural uses, agriculture and industry, agriculture and fisheries, upstream and downstream, highland and lowland, rural and urban areas, fisheries and flood control project, navigation and flood control project etc. The weaker groups are usually the victims of water use conflict. Hydrologic, morphologic, social and environmental impacts of flood control, drainage and irrigation projects in Bangladesh have been studied by Chowdhury et al. (1997). They observe that flood control interventions bring economic benefit to one section of the society while cause economic hardships to another section especially to those poorer sections who are dependent on many free resources of floodplain.

Upstream-downstream conflict: The equity concept implies that planning of water use and land use activities in the upstream area should take into consideration of the impact on water regime in the downstream. The effect on water regime in the lower part of river basin because of water use and land use activities in the upstream part of the basin is a major issue in water management. Excessive consumptive uses of water at upstream deprive the downstream users of water resource. The water regime in coastal zone is adversely affected if the freshwater inflow falls below minimum in-stream flow requirement due to reduction of upstream inflow. For example, diversion of Ganges water at Farakka by India since 1975 has created severe water shortage and saline water intrusion in the Ganges Dependent Area in Bangladesh. This led to loss in agriculture, fishery and other sectors and caused damage to already fragile environment and bio-diversity (WARPO, 2002).

Promotion of equity: In order to promote equity in water management activities, some of the essential considerations in water management decision are as follows. Water management should give special attention to the recognition that access to safe water is a basic human need and is essential to public health and livelihood. All out effort is to be made for preservation of water quality, environmental flow and ecosystems. Water management decision should ensure that no one is deprived of prevailing opportunities for livelihoods, no household is dislocated by infrastructure construction and particular attention is needed to the water dependent subsistence activities.

4. Sustainable Development Concept

The critical role of water in sustainable development is receiving increasing recognition. Water is essential for public health, crop production, fisheries, forestry, ecosystems, industry, energy, communication and recreation. Water scarcity undermines the security of public health, food, environment and livelihood. On the other hand, occasional extreme water related natural hazard causes threat to public health and livelihood and also damage to agricultural land, homestead and infrastructure that destabilizes the socio-economic activities and results in immense sufferings to the society. Therefore, availability of good quality of water and reduction of vulnerability to hazards are among the key determinants of economic growth and social prosperity.

Condition for sustainable development: Sustainability includes a consideration of the future as emphasized in the Brundtland Commission's Report (WCED, 1987), "humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs". This implies that, for sustainable development, natural resources are to be used such a way that these resources are not exhausted so that what is done today does not undermine the development and environmental needs of present and future generations. The availability of water in proper quantity and quality for present generation as well as for future generations is a necessary condition for sustainable development. This is a challenging task because of the complex interrelationships among water resources systems, ecosystems and socio-economic systems that are subject to spatial and temporal variabilities.

Integrated water management for sustainable development: The importance of the linkage between water management and sustainable development has been reflected in the Agenda 21, entitled "Programme of Action for Sustainable Development", of the United Nations Conference on Environment and Development at Rio de Janeiro in 1992 (the so-called Earth Summit). It highlighted the importance of integrated approach to water management for sustainable development. This can be seen in Chapter 18 of Agenda 21, entitled "Protection of the Quality and Supply of Freshwater Resources: Application of Integrated Approaches to the Development, Management and Use of Water Resources". It says that "Four principal objectives should be pursued, as follows:

- to promote a dynamic, interactive, iterative and multi-sectoral approach to water resources management, including the identification and protection of potential sources of freshwater supply, that integrates technological, socio-economic, environmental and human health considerations;
- to plan for the sustainable and rational utilization, protection, conservation and management of water resources based on community needs and priorities within the framework of national economic development policy;
- to design, implement and evaluate projects and programmes that are both economically efficient and socially appropriate within clearly defined strategies, based on an approach of full public participation, including that of women, youth, indigenous people and local communities in water management policy making and decision making;
- to identify and strengthen or develop, as required, in particular in developing countries, the appropriate institutional, legal and financial mechanism to ensure that water policy and its implementation are a catalyst for sustainable social progress and economic growth."

Further commitments to the integrated approach to water management have been made 10 years later in the World Summit on Sustainable Development at Johannesburg in 2002. Emphasis to the Integrated Water Resources Management has been given in this summit. Some of the important recommendations with respect to water that are included in the Framework for Action at Johannesburg Summit are as follows:

- Developing Integrated Water Resources Management and water efficiency plan by 2005 for all major river basins of the world.
- Developing and implementing national/regional strategies, plans, and programmes with regard to Integrated Water Resources Management.
- Improving efficiency of water uses.
- Facilitating public-private partnership.
- Involving stakeholders, especially women, in decision making, management, and implementation process.

5. Integrated Water Resources Management Concept

Definition of IWRM: The Integrated Water Resources Management (IWRM) concept that is promoted by the Global Water Partnership (GWP), is considered to be able to address the needs of the development goals of the society in a sustainable manner. The principles of IWRM have been explained by GWP (2000). For the purposes of providing a common framework for IWRM, the GWP (2000) uses the following definition: 'IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resulting economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems'.

Activities related to integration process: Integration process involves integration between natural and socio-economic systems, basin wide planning of water management, water conservation through demand management, participatory planning and decision making, mainstreaming of water resources, increase water use efficiency and promote equity, etc. These aspects are briefly discussed below.

Consideration of interaction between natural and socio-economic systems: IWRM looks at the entire hydrological cycle in the basin and the interaction of water with other natural and socio-economic systems. This requires consideration of the interdependence of land, water, eco-systems, infrastructures and institutional framework. It is also required that water resources management takes into account multiple users, multiple purposes and multiple objectives. These requirements call for integration. The natural system has critical importance for resource availability and quality. Integration is required between land and water management, surface water and groundwater management, freshwater management and coastal zone management, wet season and dry season water management, quantity and quality in water resources management, and upstream and downstream water related interests. The human system that fundamentally determines the resource use, waste production and pollution of the source, and which must also set the development priorities. This category of integration involves mainstreaming of water resources, cross-sectoral integration in national policy development, macro-economic effects of water developments, integration of stakeholders in the planning and decision process, and integrating water and wastewater management.

Basin wide planning of water management: Integrated water management has to take into account variability of quantity and quality of water in time and space, and river basin is a natural unit for such integration. Land use developments and vegetation cover at a location in the basin influence the water regime, water quality and water availability at downstream locations, and these influences must be considered in the management of water resources. Basin wide water management is not only important as a means of integrating water use and land use, but also critical in managing the relationships between quantity and quality and between upstream and downstream water interests (GWP, 2000).

Water conservation: The finite water resource is under increasing pressure because of increasing water demand due to population growth and increased economic activity. A basic aim of water management is to conserve this finite natural resource. GWP (2000) observes that treating water as an economic good may help balance the supply and demand of water, thereby sustaining the flow of goods and services from this important natural asset. The traditional supply oriented approach is no longer a feasible option. GWP (2000) emphasizes the strategy of limiting the demand for water. While managing water demand, special attention should be to the recognition that access to safe and sufficient water is a basic human need and is essential to public health and livelihood. Proper demand management can ensure equity in the allocation and maximum possible efficiency in the utilization of water resource.

Stakeholders participation in planning and decision making process: IWRM concept emphasizes that water development planning and management should be participatory, involving users, planners and policy makers at all levels The significance of involving of the stakeholders in the management of water resources is elaborated in the report of GWP (2000). An important issue is the need to identify water resources management functions according to their lowest appropriate level of implementation; at each implementation level the relevant stakeholders need to be identified and mobilized.

Mainstreaming of water resources: IWRM approach implies that water-related developments within all economic and social sectors be taken into account in the overall management of water resources (GWP, 2000). Thus water policy must be integrated with national economic policy, as well as with national sectoral policies. Conversely, economic and social policies need to take account of the water management implications. A proper enabling environment is essential to integrate water management with the overall development process of the country. Towards this, the Government should play the role as an enabler. Some of the important responsibilities of the Government are: formulating national water policies to set goals for water use, protection and conservation and principles of water allocation, enacting water resources legislation to translate water policy into law, implementing regulations, standards and guidelines for the protection of basic human needs and environment, expressing the political will to enforce legislation and regulations, separating regulatory and service providing functions to ensure transparency and accountability, allocating financial resources and providing incentives to water needs.

Overriding criteria: The GWP (2000) stresses that in pursuing IWRM there is a need to recognize some overriding criteria that take into account of social, economic and environmental conditions as mentioned below.

- **Water use efficiency:** Because of the increasing scarcity of water and financial resources, the finite and vulnerable nature of water as a resource, and the increasing demands upon it, water must be used with maximum possible efficiency;
- **Equity:** The basic right for all people to have access to water of adequate quantity and quality for the sustenance of human wellbeing must be universally recognized;
- **Environmental and ecological sustainability:** The present use of the resource should be managed in a way that does not undermine the life-support system thereby compromising use by future generations of the same resource.

6. Examples of Inequity in Water Management

There are about 800 implemented small-scale and large-scale water management projects that are dependent on surface water system. Bangladesh Water Development Board and Local Government Engineering Department are implementing agencies for large scale and small scale projects respectively. Most of the projects are intended for creating favorable environment for agricultural growth. Area covered by flood control projects is nearly two-thirds of the country while that by dry season irrigation projects is nearly one-third of the country. Some examples of inequity in water management in Bangladesh are discussed below.

Loss of livelihood of fisherman and protein insecurity for the poor: As an example of inequity in the distribution of social costs and benefits, the case of flood control (FC) and water conservation projects in Bangladesh can be mentioned. These projects are intended mainly for protecting cropland from river flood and supplying irrigation water. These projects provide more benefit to the rich people by creating opportunities for culture fisheries that requires large investment. But these projects cause negative impacts on open water fisheries because of obstruction to the fish migration route. As a result, a section of rural poor who catches fish from open water bodies for their livelihoods, suffer due to loss of open water fishery habitat.

Water depth at downstream reaches of many rivers and in wetlands become very shallow during dry season due to uncontrolled withdrawal of water for irrigation, and consequently ecosystem is adversely affected. As a result of FC projects, many floodplain wetlands have shrunk and lost hydraulic contact with the river. Open water fisheries have been adversely affected by FC projects because of reduced aquatic habitat and blockage of the movement of fish between river and floodplain. As per National Water Management Plan (NWMP), a major water management issue is the great damage done to capture fisheries by past interventions notably by FC, drainage and irrigation works (WARPO, 2001b). The NWMP expresses concern that unless urgent steps are taken, capture fishing will become a thing of the past, at great commercial loss and raising major issues of protein security for the poor.

Loss of livelihood of boatman: Water control structures on rivers and khals cause obstruction to boat transport, and boatmen suffer from loss of livelihood due to these interventions. Many small rivers and khals become almost dry during dry season due to irrigation by low lift pumps, and consequently country boat plying is hindered. Hunting (1992) reported that in half of the 17 flood control, drainage and irrigation projects that it investigated, the water control infrastructures had seriously impeded boat transport. Shawinigan Lavalin (1993) studied 66 projects in the North-East region, and found that 19 have major and 14 have medium level negative impacts on boat transport. In flood control, drainage and irrigation project areas, many boatmen have lost their livelihoods (Halcrow & Others, 1998).

Disruption of domestic water supply by irrigation projects: The situation analysis report on water supply and sanitation (Ministry of LGRDC, 1994) observes that an increasing number of hand tubewells for drinking and domestic purposes became inoperative for 2 to 3 months a year towards the end of the dry season because of excessive lowering of groundwater level due to expansion of shallow and deep tubewells for irrigation. The impact of seasonally lowered water table due to groundwater irrigation on rural domestic supplies is a concern for water management (WARPO, 2001a).

Social suffering due to land acquisition for flood control projects: Another example of social suffering is due to land acquisition by flood control projects that involve acquisition of substantial land for embankment construction. Land acquisition causes immense economic and social sufferings to the poor households who lose their land. Among the worst sufferer, those small agricultural landholders who lost their land and those households who lost their homestead land. Because of the loss of homestead land, people from the households with homestead land only become homeless and are compelled to migrate to other places. The social costs are not compensated by the economic compensation, and there is high dissatisfaction with land acquisition. HIFAB and MARC (1992) have assessed the economic and social impacts of land acquisition by selecting 6 flood control projects of which two in the north-west region and one in each of the north-central, north-east, south-west and south-east regions. Household survey in the 6 projects shows that 38% households lost land and 4% lost homestead.

Water pollution: A widely discussed issue related to equity is the river water pollution that makes water unsuitable for domestic use, irrigation, industry, fisheries, etc. Concentrated water demand and waste production severely affect water regime in the urban and peri-urban areas. Deteriorating water quality of rivers due to disposal of domestic wastes and industrial effluent, has become a great concern. Water users in the downstream and adjacent area of the city are deprived of water rights because of huge consumptive use and pollutant discharge in the city. A surface water supply plant at Sayedabad on the Sitalakkya river commissioned in 2002 for water supply to Dhaka City is under threat since 2003 due to fall of water quality at the intake due to disposal of urban wastes and industrial effluent. Social justice is being seriously hampered due to the absence of proper action against water pollution. The powerful group of the society is mostly responsible for water pollution. Industrial pollution of the river Buriganga on which the Dhaka City is situated, has brought misery to the adjacent low income people as they can not use river water for daily washing and bathing. A large section of highland population in the Chittagong Hill Tracts is dependent on river water for domestic use. Water quality decline in some hilly rivers due to urban sewage disposal, industrial effluent disposal, seasoning of timber in the water, leakage of fuel from engine-boat, etc. has created difficulty to domestic use of river water by highland people.

7. Water Regime in Bangladesh

Floodplain landscape: Major portion of Bangladesh is formed by deltas of three large rivers the Ganges, the Brahmaputra and the Meghna [Figure 2(a)]. The three large rivers meet inside Bangladesh and the combined out-fall discharges to the Bay of Bengal. Approximately 7% of the total area of 1.74 million sq.km. of the three river basins lies in Bangladesh. Numerous tributaries and distributaries of the three large rivers and extensive floodplains is the main physiographic feature of the country [Figure 2(b)]. Unconsolidated floodplain sediments occupy about 80% of Bangladesh while tertiary hill areas in the east occupy about 12% and pleistocene terrace areas in the north-central (NC) and north-west (NW) occupy about 8% (Brammer, 1996).

Source of water: Water regime in Bangladesh is mainly dependent on the runoff generated in the basins of the Ganges, the Brahmaputra and the Meghna. About 80% of runoff that flows through Bangladesh, is from upstream of the country while 20% is contributed by the rainfall over the country. Annual volume of runoff to the sea is equivalent to about 12 meters of depth over Bangladesh's area under the three river basins. Contribution of the Brahmaputra, the Ganges and the Meghna to the annual flow in Bangladesh is approximately in the ratio of 9:5:2. Because of snowmelt in the Himalayas, the Brahmaputra starts rising ahead of monsoon in early April. River flood is an annual phenomena in Bangladesh. Flooding is caused mainly by spill from Brahmaputra and Ganges rivers and their tributaries and distributaries during July to September. Flash floods from the hills occur during the pre-monsoon months of April and May in the Meghna basin of north-east (NE) region and in the south-east (SE) and eastern hills (EH) regions [Figure 2(b)]. The quaternary alluvium of Bangladesh delta constitutes a huge aquifer. Surface water and groundwater are in continuous interaction because of closeness of the upper aquifer to land surface. A major source of water in the river during dry season is the base flow contribution by groundwater.

Functions of floodplain: Floodplain landscape performs many hydrological, socio-economic and ecological functions. An important hydrological function is the water storage in flat topography where drainage of floodwater to the sea is a slow process since land elevation is near to the sea level. Local rainfall-runoff and river floodwater from upstream are stored in the floodplains and gradually drained to the sea. In this way floodplains moderate the flood flow by acting as detention reservoir. Inundated floodplain recharges the shallow aquifer that contributes base flow to the river during dry season. The inter-tidal lands create a flushing action through alternate storage and release of water that helps in maintaining the morphology of alluvial tidal rivers.

(a) Ganges, Brahmaputra and Meghna basins

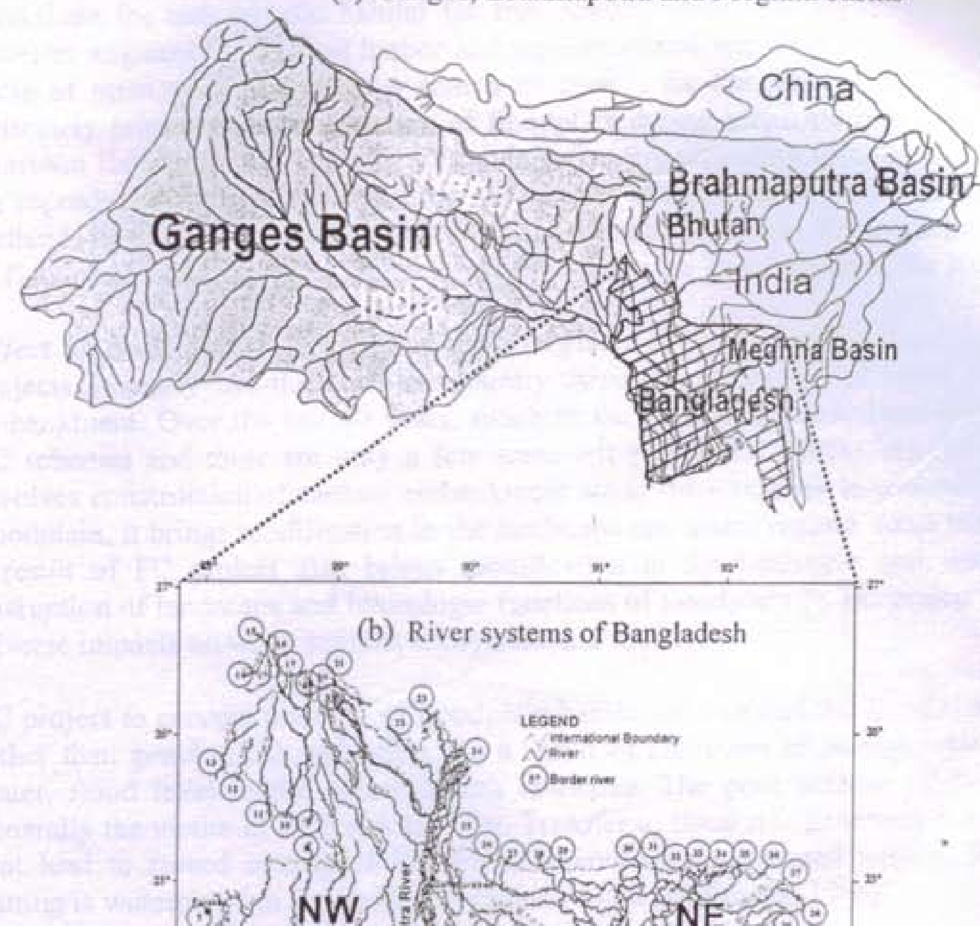

Figure 2: Ganges, Brahmaputra and Meghna basins and river system of Bangladesh

Water storage process in the floodplains, wetlands and inter-tidal lands provide conditions for rich aquatic habitat for fish, turtles, birds and other wild animals, and resort to migratory birds, and harbor and support animal and plant bio-diversity. The life cycle of open water fisheries, a source of protein for the poor section of society, is intimately related to the inundation of floodplain during monsoon flood. Floods during monsoon link up the floodplains, wetlands and rivers providing suitable aquatic habitats for reproduction, migration, breeding and growth of open water fishery. The floodplain wetlands have extensive bio-diversity-based economic activities. The ecological resource of floodplain is an important source of livelihood for the poor section of the society.

Effect of flood control project on water regime: Area covered by flood control (FC) projects is nearly two-thirds of the country through construction of about 8000 km of embankment. Over the last 40 years, much of the floodplains have been brought under FC schemes and there are only a few areas left (WARPO, 2001a). As the FC project involves construction of earthen embankment along the riverbank to prevent flooding of floodplain, it brings modification in the landscape and water regime. Land use change as a result of FC project also brings modification in the landscape and water regime. Disruption of landscape and hydrologic functions of floodplain by FC project has caused adverse impacts on water regime, ecosystem and society.

FC project to prevent flooding of floodplain has actually shifted the flood risk elsewhere rather than genuine risk reduction. As a result of reduction of storage space for flood water, flood level in the adjacent area increases. The poor section of the society is generally the victim of such risk transfer. Transfer of flood risk generates social conflicts that lead to forced cutting of FC embankments by the affected people. Such forced cutting is widespread in the northwest region (Alam and Franks, 1993).

The FC polders constructed in the coastal area since sixties under the coastal embankment project have created new form of risk. The objective of the polders is to prevent inundation of floodplain agricultural land by tidal water during high tide. The polders have brought major changes in the tidal regime by reducing storage area for flood tide. Because of reduced tidal prism, peak tidal velocity has reduced and siltation in the channels has occurred. The Master Plan of Bangladesh Inland Water Transport (DHV, 1989) considers the coastal embankment project as the main cause of deterioration of waterways in the region. The review of coastal embankment project by Halcrow & Others (1993) considers that the FC polders in the south-west region have caused rise in channel bed which in turn has resulted drainage congestion. The water logging has become a major environmental concern in the region. The water logging hazard caused by the rise in riverbed due to FC polders, has generated widespread discontent among the people. Rahman (1995) documented the environmental consequences and human sufferings. The continued water logging hazard has caused serious damage to agriculture, forestry, fisheries, livestock and physical infrastructures. Many people had to leave their ancestral homestead by abandoning traditional livelihood activities. The NWMP and its Development Strategy (WARPO, 2001a,b) consider it of foremost importance to rationalize coastal embankment schemes on the basis of environmental audit. Williams (1919) gave warning 91 years ago about such consequences of embanking tidal rivers in the Ganges Delta. Majumdar (1941) observed 69 years ago that as a consequence of embanking the rivers in the delta, there was a considerable rise in the flood level and subsequently gradual rise of the riverbed. He remarked that the Irrigation Engineers in Bengal were thus faced with the most unenviable situation created by the lowering of land to be drained and rise of river bed.

8. Steps Needed to Establish Integrated Approach and Equity Principles for Sustainable Water Management

Multi-objective planning considering interactions of socioeconomic and water resources systems: Equity consideration in water management needs to look at multiple water users, multiple purposes, water rights and associated vulnerabilities. The decisions in water management should aim at poverty reduction, public health security, vulnerability reduction, environmental protection, ecosystem sustenance, economic growth and social prosperity. This requires multi-objective water resources planning that can address the needs of public health, agriculture, fisheries, ecosystems, navigation, industry and water related hazard reduction. This approach needs to look at the multiple functions of natural components of water resources system and their social and environmental implications in order to understand and decide how the water resources can be managed in environmental friendly and equitable manner to make progress towards the objective of sustainable development. Water regime and water availability are also affected by land use change and infrastructure construction that are part of socioeconomic activities as discussed earlier. Focused attention is needed to the livelihood systems of the poor section of rural population who are mostly dependent on floodplain resources that are sensitive to water management intervention and land use change. The success of this multi-objective planning approach depends on proper understanding of the linkages among land, water, ecosystems and socio-economic development (Fig.1) and the interdependencies and interactions among system components and water users. IWRM approach is essential to take account of these linkages, interdependencies and interactions among water resources system and socioeconomic system.

Integrated land-use planning: Land-use activity that is not consistent with water regime is an important cause of degradation of water regime. Extent of flood damage depends on the land-use distribution. Uncoordinated land-use activity is one of the causes of extensive flood damage. Land cover change due to land use activities affects infiltration and runoff processes. Water regime is continuously influenced by the increasing infrastructural and land use activities due to growth in socio-economic activities. Land-use planning is to be carried out in an integrated way in order to take into account of the linkages among floodplain landscape, water resources system and socio-economic systems. Socio-economic infrastructures such as roads are to be made consistent with landscape and water regime. Land-use regulations can be an effective means of reducing the damage associated with flood. A guideline and manual by UN (1997) discusses the land-use planning process that would be helpful to disaster reduction.

Eco-friendly and multi-functional infrastructure: Land use and physical infrastructures modify floodplain water regime and affect ecosystems. It is emphasized in the National Water Policy (Ministry of Water Resources, 1999) that water development plans will not interrupt fish movement and will make adequate provisions in water control structures for allowing fish migration and breeding. To avoid harmful effects on floodplain eco-systems, hazard management infrastructures and other physical infrastructures (e.g. road) should be made eco-friendly. Water control infrastructures are to be made consistent with the water regime, and are to be made multi-functional by making provision for fish-pass and boat-pass so that the needs of agriculture, open water fisheries, navigation and ecosystems are satisfied. Community participation and ecosystem maintenance criteria should be included in the operation rule for water control structures in order to benefit the livelihoods that are dependent on ecological resources.

Flood management: Planning of flood management projects should take into consideration of the functions of floodplain landscape and water resources system, the social and ecological consequences of flood management interventions, the water dependent livelihoods and community perceptions. Controlled flooding concept is to be introduced in flood control projects by installing regulators along the embankment. Inflow of flood water is to be allowed in the protected area and it is to be spread over the area in a controlled way through the regulating structure. This will facilitate silt deposition which is beneficial for agricultural land.

The people are to be motivated to develop flood proofing measures such as raising platform for homesteads and community facilities. The road level, and plinth level of public buildings and facilities are to be raised above the highest ever recorded flood level. The alignment of new road and location of culvert are to be made consistent with the water regime.

Flood forecasting and warning need to be action oriented and location specific so that disruption of communication lines and other critical infrastructures can be prevented by flood fighting. This requires effective coordination among the flood forecasting centre and the agencies responsible for maintenance of socio-economic infrastructures. To make the forecasting effective, it is necessary that forecasting and warning for hazard preparedness should be made on the basis of vulnerability and risk assessment. Vulnerability maps are to be prepared so that the warning system can utilize the maps in order to make focused warning.

Reduction of vulnerability and enhancement of resiliency to water related natural hazards: Water related natural hazards and poverty are closely related. WMO (2006) discusses social aspects of community's vulnerability to flood. Reducing vulnerability and increasing resilience of the society to flood hazard should be the focus of flood management. This requires integration between socio-economic development policies and hazard management planning.

Vulnerability reduction requires physical and socio-economic measures to decrease the susceptibility of a community to the impact of hazards by increasing the capacity of the community to cope, withstand and recover from the impact of hazards. Vulnerability of the society can be reduced by damage minimization approaches through hazard proofing, land-use regulations and hazard preparedness. Appropriate measures are needed to prevent disruption of communication lines and essential utility services. Shelters are necessary for flood victims and need to be located with proper evacuation routes. Shelters are to be designed as multi-purpose so that they can be used as school and community facility. Chowdhury et al. (1998) illustrate how budget constraint, minimizing risk and maximizing equity can be incorporated in decision making for shelter allocation in the storm surge prone coastal area.

The resilience of the society can be enhanced by proper socio-economic development policies. It is essential to ensure the security of livelihoods in order to enhance resilience. To enhance the resiliency of the society, appropriate socio-economic measures are needed so that the people are able to quickly recover from the impact of damages caused by the hazard. The strengthening of coping capacities usually builds resilience to withstand the effects of natural and human-induced hazards. Vulnerability is also a function of coping capacity. Assessment of vulnerability to natural hazards is an essential task in risk management. A UN manual (UN, 1991) elaborates the steps required for hazard assessment, vulnerability analysis and risk assessment. The incorporation of coping capacity in the risk estimation is discussed in the report of ISDR (2002).

Agricultural water management: Agriculture sector is the largest water user and also the largest employer in rural areas in Bangladesh. As stated in the NWMP (WARPO, 2001b), experience confirms that current performance of existing public irrigation schemes is not satisfactory. A major issue is the low water use efficiency in agricultural water supply. There is a great prospect of increasing agricultural productivity in irrigation projects. More area can be brought under irrigation coverage by increasing water use efficiency. Accessibility of marginal farmers to irrigation water is to be ensured. Surface water withdrawal for irrigation should be managed in such a way that open water fisheries, navigation and ecosystems are not adversely affected. A minimum spacing between irrigation tubewells is to be maintained in order to avoid excessive lowering of groundwater table and disruption of hand tubewell. Volume of groundwater withdrawal during dry season should not exceed the volume of recharge during wet season.

Public health security, livelihood security and ecosystem protection: Access to safe water and sanitation is to be ensured in rural areas as it is essential to public health. Many rural livelihoods are dependent on existence of favorable condition in rivers, khals and wetlands. Protection to prevailing livelihood opportunities should be ensured. Every effort should be made to avoid dislocation of poor households due to land acquisition for infrastructure construction. Necessary steps are to be taken so that subsistence activities of low income groups are not hampered by water use and land use activities. A large portion of rural livelihoods is dependent on floodplain ecological resources. Proper steps are needed for protection and maintenance of ecological resources and biodiversity.

Wetland restoration and environmental flow preservation: Wetlands perform important hydrologic functions and provide habitat for ecological resources. Programmes are to be taken to restore wetlands. A floodplain land use regulation should be formulated with the objective of preserving floodplain functions, protecting wetlands and ecosystems, maintaining drainage routes and waterways. The regulation should impose constraint of environmental flow in order to ensure in-stream flow requirement for maintenance of river morphology, sustenance of eco-system and prevention of saline water intrusion. In-stream flow requirement for non-consumptive use of water (e.g., hydro-power generation, navigation, recreation, etc.) should also be given attention in water management. Decision regarding implementation of land use and hazard management projects should be supported by social and environmental impact assessments.

Urban water management: Concentrated water demand and waste production severely affect water regime in the urban and peri-urban areas. Urban water management has special significance in Bangladesh since total urban population is more than one-fourth of country population. Because of rapid expansion of urban areas and industries and growth of population, urban population is subject to severe water shortage, water quality deterioration and ecosystem degradation. Non-usability of water at downstream locations due to urban pollution is another concern. Enforcement of pollution control measures is needed to ensure that industrial effluents are not discharged untreated.

Sustainable solution to water loss and water pollution requires application of demand management concept in water supply services and application of source control techniques to waste water disposal and stormwater drainage. The strategy for demand management in water supply should be a differential tariff system in which the unit rate increases with the increase in water use, and the slab structure should be such that the lowest rate is affordable by the poor.

Another issue is the rising stormwater flood hazard because of increasing imperviousness and inappropriate drainage system in floodplain topography. Storm runoff can be reduced by inlet control within individual property and by maintaining green area in subcatchments to increase infiltration. Water storage and drainage capacities of urban catchments are to be increased by recovering encroached wetlands and khals. An eco-friendly stormwater drainage system that is appropriate in floodplain topography, is the detention reservoir based gravity drainage system.

Public participation, equity consideration and multi-criteria decision making: The National Water Policy (Ministry of Water Resources, 1999) emphasizes that stakeholder involvement should be an integral part of water resources management, and it should be established in a form that elicits direct input from people at all levels of engagement. Community participation in the identification, planning, implementation, operation and maintenance of water management projects is an essential input for the promotion of equity and transparency and the development of sustainable solution to water management problems. Stakeholders at all level of the social structure should be able to participate in decision making so that all relevant interests are taken into consideration. It is to be ensured that all stakeholders in both inside and outside of the area of the proposed project have access to all information related to the project. People's participation creates opportunity of utilizing local knowledge. Public participation helps to acquire all relevant social information and results in public acceptance of the decisions.

Equity consideration in water management has a special significance in Bangladesh where a large section of the society live below poverty line whose livelihoods depend on many resources of the floodplain. Water management projects should not be based on economic justification alone, and social justice regarding social costs and benefits should be a prime criterion. Decision-making be based on the assessment of the impacts of water management interventions on the National Development Goals (NDGs) There should be equity in the distribution of social costs and benefits of the project. Avoidance of risk transfer, protection of livelihood and preservation of floodplain ecology should be considered in decision making. These concerns can be accounted by a multi-criteria decision making framework that adheres to NDGs and equity principles and is able to account factors like hydrological, morphological, ecological, economic, social, land use implications, water dependent subsistence activities and livelihood opportunity.

Institutional framework and regulations: Proper institutional framework for cross-sectoral information exchange and coordination procedures and formulation of regulations are essential to implement the steps discussed above. Formulation and implementation of regulations, standards and guidelines are necessary to protecting water regime, water quality and sustenance of ecosystem and ensuring community participation. Appropriate land and water use regulations are essential to prevent disruption of hydrological, landscape and ecological functions of alluvial floodplain, hilly watershed and coastal floodplain by physical infrastructure, water use and land use activities. The regulation should impose constraint of environmental flow in order to ensure in-stream flow requirement for maintenance of river morphology, sustenance of eco-system and prevention of saline water intrusion. Proper land use regulation is also essential to reduce vulnerability of the community to water related hazards. Infrastructures should be made eco-friendly and consistent with floodplain water regime. Community participation should be made mandatory at identification and appraisal stages of water use, land use and infrastructure construction projects.

Integrated River Basin Management: The uncertainty in trans-boundary water flow because of water use and land use activities in the upstream part of the river basin is also a cause of concern for the lower riparian country. Integrated river basin management is the means of integrating water use, land use and ecosystem maintenance and addressing the concern related to upstream and downstream interests. The lead time of flood forecast can be increased substantially through exchange of real time river flow data from upstream parts of the basins. River basin is a naturally occurring unit of the landscape, and it is the logical unit for planning of water management. Integrated river basin management is essential for sustainable development of water resources in co-basin countries. Formation of river basin commission is necessary for integrated river basin management.

Bangladesh is a lower riparian country in the basins of the Ganges, the Brahmaputra and the Meghna (Fig. 2), and occupies about 7% of the total area of the three river basins.

About 80% of runoff in Bangladesh is from upstream of the country. As a result change in water regime in the upstream part of the river basin brings change in the water regime in Bangladesh. Integrated river basin management is necessary to develop water resources for the benefit of the whole population of the basin, develop action plan for adaptation programme on water related hazard management, maintain required in-stream flow for environmental preservation in the floodplain region and prevent saline water intrusion in the coastal region. Cooperation among co-basin countries is necessary for basin wide planning of water management.

Basin wide cooperation to address climate change implications: Climate change impacts have been seen as a major knowledge gap in the NWMP (WARPO, 2001b) of Bangladesh. Being located at the lower ends of the Ganges, Brahmaputra and Meghna basins and at the head of the Bay of Bengal (Fig. 2), impacts of climate change and sea level rise have important implications for Bangladesh. Climate change would cause modification in the distribution of temperature, precipitation and evaporation over the three river basins which in turn would bring changes in the frequency and intensity of hazards such as river flood, riverbank erosion and drought during wet season and low flow during dry season. Some implications of sea level rise are loss of land, impediment of the drainage of flood flow of the three rivers, increase in frequency and intensity of cyclonic storm surge floods from the Bay of Bengal. An assessment of possible impact of climate change on water availability in the Ganges, Brahmaputra and Meghna basins by Fung et al. (2006) indicates that the dry season is likely to become drier, and there is a possibility of increase in the water deficit along the Ganges.

Bangladesh occupies about 7% of the total area of the Ganges, Brahmaputra and Meghna basins as discussed earlier. About 80% of runoff in Bangladesh is from upstream of the country. Hence climate change over the basins of the three rivers would bring major change in the water regime in Bangladesh. Integrated river basin management is essential to address the issues related to the possible impacts of climate change over the river basin. Cooperation among co-basin countries is necessary for action plan for adaptation programme to address the climate change issues.

9. Concluding Remarks

Water is the key to socio-economic development and quality of life. The increasing water demand because of population growth and the increasing water use, land use and infrastructural activities would bring major change in the floodplain water regime. Sustainable solution to water related problems requires integrated approach to water management by taking into consideration of the interdependence of land, water, ecosystems and socio-economic development. Attention to socioeconomic, environmental and ecological implications of water management and land use activities is needed for the promotion of equity and sustainable development. Decision making in water management needs to take into account the contribution of water management interventions in alleviating poverty, supporting livelihoods, strengthening economics and sustaining ecological systems. Multi-objective water resources planning is required to address the needs of public health, livelihoods, agriculture, fisheries, ecology, river morphology, salinity intrusion prevention, navigation, industry and hazard reduction.

Sustainable water management requires equitable distribution of social costs and benefits of water management projects among stakeholders. Appropriate regulations, standards and guidelines are needed to ensure social justice in the distribution of social costs and benefits of water management projects. Public participation at all stages of decision making is essential for the promotion of equity and transparency. Creation of enabling environment by the Government is a necessary condition for implementation of this management approach. Bangladesh is a lower riparian country in the basins of the Ganges, the Brahmaputra and the Meghna. Water regime, ecosystems and water availability in Bangladesh are affected by water use, land use and hazard management activities in upstream areas. Integrated river basin management is essential for the well being of the people of the lower riparian country. This requires cooperative effort by the co-basin countries based on the principles of equity and sustainable development.

References

Alam, M.K. and Franks, T.R. (1993), The north-east regional study FAP2, Proc. 3rd. Conf. on the Flood Action Plan, pp29-64, FPCO (presently WARPO), Dhaka.

Brammer, H. (1996), The Geography of the Soils of Bangladesh, University Press Ltd., Dhaka.

Chowdhury, J.U. (2007), Integrated Water Resources Management Concept and Actions Needed for Bangladesh, Seminar on Postgraduate Research in Integrated Water Resources Management, 17 December, BUET, Dhaka.

Chowdhury, J.U., Rahman, M.R. and Salehin, M. (1997), Flood Control in a Floodplain Country *Experience of Bangladesh*, prepared at IWFM, BUET, Legal No:1276/97, ISESCO, Rabat, Morocco.

Chowdhury, J.U., Watkins, D.W., Rahman, M.R. & Karim, M.F. (1998), Models for cyclone shelter planning in Bangladesh, *Water International*, IWRA, USA, 23(3), pp.155-163.

Deshpande, R.S., Venkatachalam, L. and Narayanamoorthy, A. (2004), " Policies for Access, Equity and Equality: *Physical Resources and Human Resources*", in Natural Resources Management and Livelihood Security, ed. K.V. Sundaram, M. Moni & Mrityunjay M Jha, Concept Publishing Company, New Delhi, India.

DHV Consulting Engineers & others (1989), Bangladesh Inland Water Transport Masterplan, Final Report, Vol. 1, pp.70-71, Bangladesh Inland Water Transport Authority (BIWTA), Dhaka.

Fung, C.F., Farquharson, F. & Chowdhury, J.U. (2006), "Exploring the impacts of climate change on water resources – regional impacts at a regional scale: Bangladesh", in Climate Variability and Change – Hydrological Impacts, ed. S. Demuth, A. Gustard, E. Planos, F. Scatena & E. Servat, IAHS Pub. No. 308, pp. 389-393, UK.

GWP (2000), Integrated Water Resources Management, Background Paper No. 4 prepared by Technical Advisory Committee, Global Water Partnership (GWP), Stockholm, Sweden.

GWP (2003), Poverty Reduction and IWRM, Background Paper No. 8 prepared by Technical Advisory Committee, Global Water Partnership (GWP), Stockholm,Sweden.

Halcrow & Others (1993), Final Report of Southwest Area Water Resources Management Project, FAP4, FPCO (presently WARPO), Dhaka.

Halcrow & Partners Ltd., Mott Macdonald Ltd. and Others (1998), Social Impact Assessment, Annex A2 in Vol. 2 of the Inception Report of NWMP, WARPO, Ministry of Water Resources, Dhaka.

HIFAB International and Multidisciplinary Action Research Centre, MARC (1992), Final Report of Land Acquisition and Resettlement Study, FAP-15, FPCO (presently WARPO), Dhaka.

Hunting Technical Services Ltd. (1992), FCD/I Agricultural Study, FAP-12, Main Report, Vol. 1, FPCO (presently WARPO), Dhaka, Bangladesh.

International Strategy for Disaster Reduction (ISDR, 2002), Living with risk: A global review of disaster reduction initiatives, Geneva.

Majumdar, S.C. (1941), Rivers of the Bengal Delta, p.10, 24, 28-41, Irrigation Branch, Dept. of Communication and Works, Government of Bengal, Bengal Government Press, Alipore.

Ministry of LGRDC, UNDP and UNICEF (1994), Bangladesh Situation Analysis Water Supply and Sanitation, Local Govt. Div., Ministry of LGRDC, Govt. of the Peoples Republic of Bangladesh.

Ministry of Water Resources (1999), National Water Policy, Government. of the Peoples Republic of Bangladesh.

Rahman, A. (1995), BEEL DAKATIA The Environmental Consequences of a Development Disaster, The University Press Ltd., Dhaka.

Shawinigan Lavalin Inc. (1993), Water Transport Study, Northeast Regional Water Management Project, FAP-6, FPCO (presently WARPO), Dhaka.

United Nations (UN, 1991), Mitigating Natural Disasters *Phenomena, Effects and Options* A Manual for Policy Makers and Planners, UNDRO/MND/1990 Manual, New York.

United Nations (UN, 1997), Guidelines and Manual on Land-Use Planning and Practices in Watershed Management and Disaster Reduction, ST/ESCAP/1781, ESCAP, Bangkok

WARPO (2001a), National Water Management Plan Development Strategy, Water Resources Planning Organization (WARPO), Ministry of Water Resources, Dhaka.

WARPO (2001b), NWMP, Vol.2: Main Report, Vol.3: Investment Portfolio and Vol.4: Regional Plans, Ministry of Water Resources, Dhaka.

WARPO (2002), Options for the Ganges Dependent Area, Vol 2: Prefeasibility Study of the Ganges Barrage Project, NWMP, Ministry of Water Resources, Dhaka.

WCED (1987), Our Common Future (The Brundtland Report), World Commission on Environment and Development (WCED), Oxford University Press, Oxford, UK.

Williams, C.A. (1919), History of the Rivers in the Gangetic Delta 1750-1918, Bengal Secretariat Press, Calcutta (reprinted by EPIWTA in 1966, Dhaka).

World Meteorological Organization (WMO, 2006), Social Aspects and Stakeholder Involvement in Integrated Flood Management, WMO-No.1008, Geneva, Switzerland.

INTERDISCIPLINARITY IN RESEARCH ON INTEGRATED WATER RESOURCES MANAGEMENT: PITFALLS AND CHALLENGES

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Abstract
How do engineers deal with the social sciences, and how do social scientist incorporate technology and ecology in their frameworks? This paper tries to define what interdisciplinarity is, why it rarely occurs and what scope there is for interdisciplinarity in the field of integrated water resources management. The Irrigation and Water Engineering group at WUR has over the past 20 years attempted to develop a 'strong' interdisciplinary research approach that cuts across the boundaries of the natural and social sciences. Important interdisciplinary concepts in the IWE approach are the sociotechnical nature of water resources systems, the practice and process of water resources policy and management, and the realization that water is a politically contested resource. This attempt at integration of analytical perspectives covers only one out of five meanings that can be attributed to the integrating aspect of integrated water resources management. The other aspects cover integration of different uses of water, institutional integration, geographical integration and the integration of the field of water resources development and management into a broader agenda of rural transformation. The paper identifies three core fields of IWRM research: water, access and agrarian change; institutional transformation; and feedback mechanisms between technology and agro-ecology. The paper concludes that the present consolidation of IWRM as a policy and research focus tends to be more about re-labeling than about reform and re-orientation, and propels the formulation of new IWR planning models that lean on governmental action and embody normative notions of what constitutes 'good management'. Four benchmarks are proposed to assess the innovative nature of an interdisciplinary research programme on IWRM.

Keywords: interdisciplinarity, integrated water resources management, sociotechnical systems, policy process, policy practice, water control.

1. Introduction

How do engineers deal with the social sciences, and how do social scientists incorporate technology and ecology in their frameworks? This paper discusses the contours of 'strong interdisciplinarity' in the context of water resources management. With 'strong interdisciplinarity' we mean conceptual and methodological integration –if that is the right term- of physical/technical science and social science perspectives on water resources management. 'Strong' refers to the *simultaneous* analysis of the technical/ecological and the social, as different but internally related dimensions of a single object.[1] This as opposed to 'add on' approaches, which analyse the technical/physical and the social dimensions separately, leaving disciplinary frameworks untouched, and then try to link them. Separate analysis is both a conceptual, methodological and practical problem. It results in conceptual languages that are difficult to marry, non-matching data-sets, and reports, policy documents and projects divided in separate, discipline-oriented sections.

[1] On the notion of internally related dimensions and other philosophical underpinnings of our approach, see Sayer (1984) 'Weak interdisciplinarity' would be interdisciplinarity within either the technical/physical or the social sciences (for example irrigation and soil & water conservation, or sociology and economics). Though such forms of interdisciplinarity raise their own complexities, we feel the problems are relatively simple as compared to crossing the boundaries of the natural and the social sciences.

The history that informs this paper is the experience of the Irrigation and Water Engineering group at Wageningen University, which over the past 20 years has tried to develop a sociotechnical teaching programme (from 1980) and a sociotechnical research programme (from the late 1980s), starting from an agronomy and civil engineering foundation. We would not want to argue that the transformation from a disciplinary to an interdisciplinary orientation has been fully completed, but some headway has been made, and a substantial research programme is in place that will further develop the approach (see annex 1 for list of Ph.D. research).

The paper tries to define what interdisciplinarity is, why it rarely occurs and what scope there is for interdisciplinarity in the field of integrated water resources management. The paper concludes with a number of pitfalls and challenges that have to be faced when trying to organise an interdisciplinary research programme like the 'Water for Society' initiative under discussion.

2. The quest for interdisciplinarity in the IWE group

The attempt at self-transformation by the IWE group from an agronomy/civil engineering focus on irrigation to a broader, interdisciplinary scope on irrigation and water resources management originated from and was shaped by the following contextual factors.

a) The emergence of an international 'irrigation management debate' in the 1970s. This in itself emerged from increasing awareness of malperformance of particularly large scale canal irrigation, which started to question the technocratic nature of irrigation development. This resulted in the establishment of IIMI, now IWMI, the International Water Management Institute. Academically Cornell University probably had the strongest and most influential group of irrigation researchers (Levine 1992).
b) The critique of the socio-economic effects of the Green Revolution, in which irrigation was heavily implied, on small farmers and landless labourers, as part of a broader social critique of the student and social movements that emerged in the late 1960s and 1970s. This translated into a concern for the role of irrigation/water resources management in rural transformation (a concern phrased in different periods by different terms, like basic needs, small-farmer approaches, poverty alleviation, equity, livelihood security, and most recently sustainable development).
c) Given the engineering background of most of the students and staff involved in the self-transformation process, the orientation always had a rather practical dimension: how can the social and institutional aspects be made useful to professional work? If the IWE group's development is seen as a case study of the emergence of a field now called 'the social study of science and technology' (see for example Wajeman and Mackenzie 1985; Bijker and Law 1992), it is remarkable that that development occurred *within* a technical/physical institutional context. Impressionistic knowledge of 'social study of technology' research groups suggests that often researchers with a technical/physical science background played an important role in them, but these groups tend to be housed in social science faculties and/or become separate groups outside the technical disciplinary groups. In the IWE group there was a conscious decision to develop the social perspective 'in-house', which raised its own problems.

This is not the place for a detailed historiography of the IWE group. We will only identify the different strategies that have been attempted to achieve transformation towards interdisciplinarity, which, in our view, hold some general lessons.[2]

Shaking a box full of disciplines

The initial strategy, from 1980, was what was called above an 'add on' strategy. In the teaching programme this resulted in an inclusion of a large number of social science courses (sociology,

[2] It can be noted that the outcome of similar efforts in other technical/physical disciplinary groups in Wageningen University was different. For example, in Tropical Crop Science the attempt failed, and in Tropical Forestry and Erosion and Soil and Water Conservation it took different forms. The establishment of a chair called 'Technology and Agrarian Development' (presently held by Prof. Paul Richards) also was an offshoot of the drive for interdisciplinary and critical development studies in the 1980s and 1990s.

political economy, economics, extension, law, gender studies). At the research level this translated in an effort to establish a national research group 'Irrigation and Development' and a (failed) attempt to get this funded. In both cases the approach was to put a multitude of disciplines together in a box, shake, and then hope that something useful would come out. Some would call it multi-disciplinarity. It proved to be very difficult. Students experienced it as an increased burden: they had to become and engineer, and sociologist, and *et cetera*. The problem-oriented teaching that was introduced, did not deliver the integration that was aimed at. This curriculum produced some hybrid professionals who later became important in the development of the research programme, but on the whole it was not a satisfactory approach. It also generated endless debates on the relative weight on the technical and the social courses in the programme, which showed that 'integration' had not really happened.

At the level of research the main problem was that there was no research tradition in this particular engineering discipline (2 PhDs from 1900 up to the late 1980s!). Ambitions were high, but capacity low. More generically, there was a serious language problem between the disciplines. Social scientists were perceived to pursue their own conceptual concerns, not intrinsically linked to irrigation/water resources management, and as generally unwilling to treat technology and the physical environment other than as a 'black box' context. However, the interaction with particularly the sociology discipline produced one important result: the adoption of an 'actor-oriented approach' (as advocated in Wageningen by Prof. Norman Long's Development Sociology group). The initial research were macro-studies on the political economy of irrigation and irrigation and underdevelopment. The 'actor orientation' refocused the research to what we would now call irrigation/water resource management *practices*. This dovetailed very nicely with the concern for small farmers, local development, livelihood security and the like, as well as the 'field orientation' that many engineers have anyway.

Re-theorising the disciplines

In 1990 a serious reflection on the trial and error approach of the 1980s took place by a group of staff and graduate students. This resulted in a rather different strategy to achieve interdisciplinarity (see Artefakto 1990).[3] The core element of the new approach was the choice to posit technology (and by extension the agro-ecological environment) as the central research object. This can be seen as an effort of the group to force itself to reconceptualise its own direct field of expertise: irrigation infrastructure and irrigated agriculture. More generally put, the standpoint chosen was that the social dimensions of the material artefacts and environment needed to be theorised. And by implication, from a social science perspective, the material dimensions of social relations needed to be theorised. The different disciplinary conceptual frameworks thus started to be questioned. Questions were raised like: what are the management requirements of different types of division structures, and, what are the physical and technological dimensions of water rights? The new perspective was summarised in the phrase 'sociotechnical approach' - without a hyphen (Mollinga 1998; Vincent 1997). Many of the Ph.D. projects explore this newly defined sociotechnical terrain (see annex 1).

The 1990s have been characterised by a search for conceptual frameworks that are able to incorporate both the physical/technical and social dimensions of irrigation/water resources management. Of major influence has been the SCOT framework (social construction of technology framework; see Winner 1985; Bijker and Law 1992). This allows an interpretation of the social relevance of the design characteristics of technical artefacts, and an understanding of the process of their emergence and consolidation as a process in which different interest groups simultaneously contest the constitution of new social and material orders. A second framework that has been very inspiring is labour process

[3] In the 1990s most energy went into the development of the research programme, while in the 1980s, particularly the first half of it, the teaching programme was the main focus. In the 1990s the irrigation teaching programme remained largely unaltered. It is only very recently that resonsideration is taking place of the approach to teaching and the content of the curriculum, in an effort to move from an still largely 'add on' framework to a more inclusive sociotechnical setup. One of the things happening in the present reorganisation of study programmes), and that social science teaching needs to be incorporated in 'beta-gamma' courses. This in itself is possibly a step forward. This issue is left aside here; we focus on research.

theory (Burawoy 1985), as this conceptualises the social and technical relations of production as internally related. For agriculture frameworks on 'styles of farming' (van der Ploeg 1991) and the technological and administrative task environment, i.e. the regulation of production processes (Benvenuti 1975; 1991, Frouws 1995) have provided related starting points. A third rich field for sociotechnical theory formation has been the notion of property rights or hydraulic property. The notion that property rights are embodied in physical infrastructure and the organisation of the landscape has proved a very rewarding starting point for research. In terms of general social theory the theoretical constructs that have been most influential are Giddens' notion of 'structuration', and related to that Bourdieu's notion of 'practices', that is a particular view on the nature of human agency and social structure (Giddens 1984; Bourdieu 1977). Also helpful have been the legal pluralism framework (Pradhan et al 2000) and human ecology approaches (Bennett 1990).

Emerging issues

The IWE sociotechnical approach was developed as a counterpoint to disciplinary science. However, in the 20 years since 1980, mainstream natural science has also undergone considerable transformation. The rise of systems theory has been particularly important. This has implied the emergence of different modeling approaches to the complexity and multi-dimensionality of water resources management issues. Examples are efforts to link hydrological models to decision support systems, or to integrate economics into the modeling of ecological systems' dynamics. These approaches may be different avenues to interdisciplinarity. Our problems with these models are not related with the issue of interdisciplinarity as such, but to other issues discussed below. What would be relevant in our view is more discussion of the epistemological and conceptual underpinnings of the different approaches to modeling complex systems.

One of the more practical issues in interdisciplinary research is the methodological trade-offs that are encountered in field research (for an example from the soil and water conservation field see Mazzucato and Niemeijer 2000). We are still to systematise the methodological demands on interdisciplinary research.

Interdisciplinarity and funding

In the academic nor in the development policy world there are strong incentives for interdisciplinarity of the 'strong' kind. On the contrary, incentives for alignment within and along disciplinary boundaries are much stronger. The organisation of funding and the organisation of universities and other institutions are still largely in disciplinary terms, despite continuous declarations of good intent regarding interdisciplinarity. The situation is very similar to that of policies to increase the participation of women. For example, personnel policy in Wageningen University has been gender sensitive on paper for a long time, but has not resulted in any increase in female academic staffing levels.

Practically this gap between the theory and practice of academic organisation, has implied that for funding its academic research the IWE group has largely relied on 'unconventional' funding sources (like money earned through overheads on consultancies and development projects, piggy backing on policy oriented research, and some grants from development foundations). However, the step to more conventionally funded doctoral and post-doctoral research is being taken slowly. The overall impact of this situation has been that the development process of sociotechnical research has taken longer than it perhaps could have.

Some lessons

Interdisciplinarity is not just a communication problem between disciplines. 'Strong' interdisciplinarity, that is interdisciplinarity across the boundaries of the natural and social sciences requires re-theorisation of disciplinary frameworks, that is a critique and reformulation of disciplinary concerns on both sides. If this is not undertaken 'integration' remains elusive. An implication is that 'hybrid' scientists and professionals need to be trained, who embody the new frameworks and methodologies.

Academic organisation and the organisation of funding for academic research probably runs behind developments in the field. Defining chairs and research groups around issues or research objects rather than on the basis of disciplines as conventionally understood[4] has been undertaken in some places, but is not as strong as it perhaps should be.

3. Core concepts of the IWE approach

This section presents the core concepts of the IWE interdisciplinary research approach to water resources management.

1) Sociotechnical systems

As argued in section 2, understanding water management requires a framework that integrates technical and social science perspectives, addressing both dimensions simultaneously (and in their mutual interactions) and not consecutively or separately as is usually done. The basic underlying idea of such an interdisciplinary approach to water management is that water management technologies do not only mediate people's relationships with bio-physical processes, but also shape the people-people relationships that are part of water management. Where most existing approaches to water management take either the social relations or the technologies as a given, the IWE approach explicitly focuses on the interactions between technology and social relations by conceptualizing technology as a sociotechnical system (Mollinga 1998). This can be operationalised as follows. Looking at technology development as a process of *social construction* allows for an analysis of how objectives and interests of different participants in technology development translate into design characteristics. That is, how technical characteristics express particular social relationships. The notion of *social requirements for use* allows an analysis of the management demands of technologies: which skills and forms of organisation are implied in the design of a particular technology and are needed to make it work properly. Thirdly, the notion of *social effects* raises the question what the emergent properties of particular technologies are in a given social context (f.i. the socio-economic effects of individualised water control through tubewells).

2) Practice and process

Policy formulation and implementation are complex processes of formal and less formal, legal and illegal, open and hidden interaction and negotiation of different interest groups. Policy formulation and implementation therefore need to be treated and analysed as political processes in which many interests are at stake rather than as prescriptive recipes. This implies, among others, a critical perspective on the relation between planning and reality (Long and van der Ploeg 1989; Thomas and Grindle 1991).

Underlying this view of policy are particular notions of human agency and social structure. These revolve around the view that people are knowledgeable and capable actors, active players in creating new social and material environments, even when they have to operate within a context that is only partially of their own making, and with motivations that are only partly conscious (Giddens 1984; Bourdieu, 1977). These "regularised types of acts" or structured and structuring human practices are form of strategic conduct involving "strategies of control within defined contextual boundaries" (Giddens, 1984:288-293). Practices take place in arenas or domains of interaction (Villarreal, 1994), with boundaries defined by technology, social relations, and by time and space. In their strategic action people mobilise a diverse set of resources. Practices exhibit 'systemness'. They consist of routines, and are structured by rules (Giddens, 1984). At the same time practices are characterised by discontinuities or interfaces. At these interfaces "the goals, perceptions, interests, and relationships of the various parties

[4] Of course, what is considered a discipline is not constant over time. New ones evolve and old ones disappear. The contention here is however that the increased proliferation of disciplines that has occurred in the second half of the 20th century as a response to forces of specialisation is still with us, while reconfiguration would be desirable in response to increased demand for the analysis of complex and multi-dimensional systems.

may be reshaped as a result of their interaction, (Long, 1989:2). This interaction may be constructive and consensual, but it may also be conflictuous and divisive.

3) Contested control
Water is considered as a *politically contested resource*, implying that water allocation decisions and practices often entail open or hidden conflicts of interests. The underlying view is that water allocation and distribution plans and practices do not (just) come about as the result of a methodical application of rational or scientific data processed by engineers and planners. Rather, such decisions are part and parcel of wider political economic processes in which different actors strategically manipulate information and other resources to pursue particular goals and objectives.

The approach proposes a broader concept of politics than is normally used in professional irrigation and water management circles, comprising not only state (and inter-state) politics, but also the politics of water resources policy, and the notion of everyday politics of water resource use. The approach is concerned with the analysis of processes of water allocation and distribution at different levels. In these processes, social relations of power are constituted, negotiated, mediated, reproduced, transformed or otherwise shaped.

The notion of 'water control as politically contested resource use' can be operationalised by identifying three different dimensions of control (Mollinga, 1998). These are a) technical control, focussing of the regulation of physical processes through technical devices or shaping of the natural environment, b) organisational control, focussing on the regulation of human behaviour, and c) socio-political and economic control, which involves the conditions of possibility for particular forms of technical and organisational control. The theoretical point is that these different dimensions of control are mutually constitutive, implying that transformation of systems involves interrelated changes in all three dimensions.

4. Thematic fields in integrated water resources management

This section first discusses what we mean by integration when talking about integrated water resources management. After that the fields of research that seem to us to be of particular relevance for a critical engagement with the policy notion of IWRM are outlined.

The meaning of integration
When talking about integrated water resources management, it is important to be clear about the meaning of 'integration', as this is a qualifier indicating what is special about this type of water resources management. The integration concept can carry at least the following five meanings.

i) The integration of different uses of water
Perhaps the most obvious meaning of integrated water resources management is the integration of the different uses that are made of water (irrigation, drinking water, industrial use, the ecological function of water, etcetera). It is necessary to look at these different uses not in isolation because they influence each other. Use in one domain affects the quantity and/or quality of water available for utilisation in other domains. Particularly with scarcity levels increasing, this becomes an important issue. A popular policy vocabulary in this respect is that of the 'functions and values' of water, and the different types of water (like blue, green and fossil water).

ii) The integration of analytical perspectives
The logical corollary of the awareness that the different uses of water are related, is the need for analytical frameworks to understand these relationships. Its is a main argument of this paper that because the organisation of knowledge production tends to be along disciplinary and sectorial lines, a positive effort at integration of the different disciplinary and sectorial approaches is required.

iii) The integration of the different institutions responsible for water resources development and management

Another consequence of the linkages between the different uses of water is the need for institutional integration. This need exists at different levels of governance and administration. It raises the more general issue of how to organise stakeholder involvement in water resources policy making, planning, development and management.

iv) Geographical integration

Another form of integration is the question of the relationships between upstream and downstream users in a watershed or basin. Apart from becoming part of a single institutional domain with common policies (the concept of basins as the unit of management), new linkages between upstream and downstream users have to be created to improve livelihood security. These could consist for example of reciprocal resource transfer mechanisms: compensation for upstream water conservation and development activities by downstream users.

v) The integration of water resources development and management into a broader agenda of rural transformation

The fifth meaning of integrated water resources management is that of water resources management as embedded in and part of the process of rural development. This means integration in the sense of water resources development addressing or being a vehicle for the achievement of objectives like for example ecological sustainability, growth, poverty alleviation, gender equity, employment generation, quality of life, in short, human development.

In a recent Dutch policy document on IWRM all these meanings can be found in the discussion of what IWRM is (NEDA 1998:chapter 1). The document also states that there is an emerging consensus on the need for and features of IWRM (*ibid.*: box 3). We would like to argue that this emerging consensus at the global, general and ideological level contains, and perhaps disguises, a large variety of meanings given to the concept. These different meanings are related to the different interests and agendas of a variety of stakeholders with regard to water resources management. Therefore, the concept itself is politically contested. Reflection on this contestation is required to understand the intellectual and policy trajectory that IWRM has taken and will take in the coming years. One way to look at IWRM is to see it as a new, scientifically designed policy concept + method, that is newly brought into the water sector to solve its major problems, constituting a qualitative break with the past. Another view is that it is better conceived in a more continuous fashion as both the product and the site of realignment of interests and meanings in the domain of water resources management.

Fields of research

We would want to suggest the following broad fields of research as particularly relevant for further development of the IWRM concept, and for transformation of water resources management practices in general. We list fields of enquiry, in each case starting with a central question.

a) Water and development: access and agrarian change

Question: *Which set of interlinked relationships shape the access of different user-categories to water use and management?*

This research starts from the notion of interlinked or interlocked markets and broadens this to interlinked exchange relations, and interlinkage in access. Interlinked markets are well researched for groundwater/well irrigation, but much less for other forms of irrigation and water use. The research not only addresses access to the physical resource, but also for example access to decision-making on resource use. An example is the multiplicity of gender relations shaping women's access to and participation in decision making in water users associations. Property rights would be an important theme here, as in the definition and realisation of rights to land, water and technology, a lot of the access is shaped.

Question: *What is the role of irrigation and water conservation in the process of agricultural and agrarian change?*

Irrigation and water conservation can be key factors in the intensification and commercialisation of agricultural production. At the same time they are potentially powerful instruments for the state to regulate agricultural, economic and socio-political development. The government agenda for water resources development not only includes achievement of food security, but also other objectives like political legitimisation, (re)settlement of particular sections of the population, containing social unrest, and others. The issue of agricultural production increase (sustainable or not) is connected with broader state and market related processes and objectives. The research can be pitched at different levels, ranging from user/farmers strategies for increasing production, productivity and livelihood security, to the impact of globalisation on water use and management regimes.

b) Institutional transformation for integrated water resources management: platforms, public action and paradigms

Question: *What are the process characteristics of the contestation of water resources management by different interest groups?*

The politics of water resources management includes different levels: from the everyday politics of water use, to the politics of irrigation/water resources policy, to inter-state hydropolitics, to the emerging global politics of water. The study of policy and politics as 'it really is' (rather than as it should be) involves looking at policy and politics as social processes in which policy concepts and agendas and their implementation are contested by different interest groups. It implies a critical attitude to rational planning models and performance analysis frameworks that do not incorporate a process dimension. This field involves the study of water use and management practices at different levels, the social shaping and contestation of reform policies, and the emergence and functioning of multi-stakeholder platforms in water resources management.

Question: *Which forms of organisation of water users and other interest groups have emerged in response to government policy, increasing water scarcity, poor performance and other external influences on and problems in the water resources systems, and how have these forms of organisation contributed to transformation of the sector?*

This research not just focuses on resource use and management practices, but on the specific question which forms of interest group organisation emerge in the process. The research calls on theories of civil society and public action. The modes of influencing the policy process by interest groups are highly variable and include political lobbying, media campaigns, public interest litigation, water tribunals, pilot experiments, demonstrations, organising public consultations and formulation of alternative Acts or Rules.

Question: *Which concepts, meanings and paradigms of 'development' are part of and shape the international policy discourse on water resources?*

This research embarks on a critique of biases in existing policy discourses on water resources. These include gendered notions of households for example, technocratic notions of agricultural modernisation, normative concepts of 'good governance', and the conceptualisation of 'water resources' itself. The context of the research is the resurging interest in water resources worldwide. Part of this topic is a question on the social origins of the water engineering profession in different parts of the world, what its characteristics are, and which transformations it has undergone. This mobilises theory on the dynamics of professional groups, feminist theory on male domination/masculinity in engineering, and the relation between science/technology and colonialism.

c) Technology and agro-ecology: feedback, design and management

Question: *Which feedback mechanisms exist in water resources systems that either enhance or undermine ecological sustainability?*

Mobilises theories on ecological dynamics and the behaviour of water in watersheds. The assumption is that the feedback mechanisms are multiple: ranging from bio-physical ones to economic, cultural and socio-political ones. Can the characteristics of ecologically robust water resource use systems be identified? One area of research is the possible synergies of integrating rainfed agriculture/soil and water conservation and irrigated agriculture .

Question: *a) What are the social requirements for use of different water infrastructures as technical systems?*

b) What are the characteristics of water infrastructure design processes as examples of social construction of knowledge and artefacts?

This research mobilises theories on the social construction of science and technology, and aims to identify the social dimensions of water infrastructure hardware.

5. Conclusion

New networks and solidarities are emerging around the notion of IWRM, as a result of the political sanction it has been given in the second World Water Forum held in the Hague in March 2000. The 'Water for Society' workshop for which this paper is written is one activity through which the exercise of (re)labeling and (re)alignment takes place. In the process, allocation of funds for research and intervention is shaped or decided. We would like to make the following two observations on this global process of the consolidation of IWRM as a policy and research focus.

1. Research on the politics of irrigation reform processes suggests that water bureaucracies are very creative in maintaining their construction and supply-driven orientation even in seemingly fundamental institutional reform processes (Panella 1999; Rap, Wester and Nereida 1999). If this finding can be generalised, one needs to fear that IWRM will in many cases become a re-labeling exercise rather than a reform process. Also in academia re-labeling capacity is highly developed.
2. The dominant impetus in the emerging debate on IWRM seems to be the formulation of new integrated water resources planning models. These start from strong assumptions that IWRM is necessary and possible, are generally strongly state/government focused (or as an alternative, market mechanism oriented), and tend to be highly normative in content by embodying - often implicit - notions of what constitutes 'good management'.

This may be considered a too gloomy attitude at the start of a possibly positive development. However, in a more positive interpretation these observations are not only pitfalls but also challenges. In relation to the second observation: though intervention-oriented models may be indispensable in policy implementation situations, they can and should, in our view, not double as analytical frameworks for understanding real integration practices (or the absence of these). It is the job of academic research (among other things) to question rational planning models, and suggest adaptations and alternatives. And on the first observation: which institutional, financial and other mechanisms exist or can be created to stimulate innovative forms of interdisciplinary research and intervention practice in water resources management?

In the mean time these authors intend to continue their research on 'real water resources management and policy practices'. We suggest that a benchmark for assessing the innovative nature of research on IWRM might include the following questions.

a) Does the research design use explicitly sociotechnical (or socio-ecological, or socio-physical, *et cetera*) conceptual frameworks?
b) Does the research design focus on developing normative frameworks and models for better water resources planning or does it investigate actually existing practices?
c) Does the research design incorporate notions of contestation, power and politics?
d) Does the research design explicitly address issues of livelihood security, equity and/or other parameters for human development of the weaker sections in society?

References

Artifakto '90 (1990) *Het sociale van het materiele. Een voorstel voor vakgroeps- en leeronderzoek naard e sociale inhoud van irrigatietechniek (The social contents of artefacts. A proposal for research on the social contents of irrigation technology).* M.Sc thesis, Department of Irrigation and Soil and Water Conservation, Wageningen Agricultural University, Wageningen, The Netherlands.

BENNETT, JOHN W. (1990) "Ecosystems, environmentalism, resource conservation, and anthropological research". In: Emilio F. Moran (ed.) *The ecosystem approach in anthropology. From concept to practice*. The University of Michigan Press, Ann Arbor, pp. 435-457.

BENVENUTI, BRUNO (1975) "De Technologische-Administrative Taakomgeving (TATE)". *Marquetalia*, tijdschrift voor landbouw en politiek: arbeid & technologie in de veenkoloniën, pp. 111-136.

BENVENUTI, BRUNO (1991) *Geschriften over landbouw, structuur en technologie*. Ingeleid, bewerkt en vertaald door Jan Douwe van der Ploeg. Wageningen Studies in Sociology No. 29, Wageningen Agricultural University.

Bijker, Wiebe, and John Law (1992) *Shaping technology / building society: studies in sociotechnical change*. Cambridge, MA: MIT press.

BOURDIEU, PIERRE (1977) *Outline of a theory of practice*. Cambridge University Press, Cambridge, etc., (original 1972).

BURAWOY, MICHAEL (1985) *The politics of production. Factory regimes under capitalism and socialism*. Verso, London.

FROUWS, JAAP (1995) *The social regulation of agriculture. Reflections from a politico-sociological perspective*. Paper presented at the "Agrarian Questions: The Politics of Farming anno 1995" conference, Wageningen, May 1995.

GIDDENS, TONY (1984) *The constitution of society. Outline of the theory of structuration*. Polity Press, Cambridge

LEVINE, GILBERT (1992) "The irrigation programme at Cornell University" In: Diemer, Geert and Jacques Slabbers (eds) *Irrigators and engineers. Essays in honour of Lucas Horst*. Thesis Publishers, Amsterdam.

LONG, NORMAN (ED.) (1989) *Encounters at the interface: a perspective on structural discontinuity in rural development*. Wageningen Studies in Sociology 27. Wageningen Agricultural University.

LONG, NORMAN AND JAN DOUWE VAN DER PLOEG (1989) "Demythologizing planned intervention: an actor perspective". *Sociologia Ruralis*, Vol. 29, No. 3/4, pp. 226-249

MACKENZIE, DONALD AND JUDY WAJCMAN (EDS.) (1985) *The social shaping of technology. How the refrigerator got its hum*. Open University Press, Milton Keynes and Philadelphia.

Mazzucato, Valentina, and David Niemeijer (2000) *Rethinking soilawater conservation in a changing society. A case study in eastern Burkina Faso*. Tropical resource management papers, No. 32, Wageningen University and Research Centre, Erosion and Soil and Water Conservation Group, Wageningen, The Netherlands.

Mollinga, Peter P. (1998) *On the waterfront. Water distribution, technology and agrarian change in a South Indian canal irrigation system*. Ph.D. thesis

NEDA (1998) *Water for the future. Integrated water resources management. 2. Policy priorities for Netherlands development assistance*. Netherlands Development Assistence, Ministry of Foreign Affairs, The Hague.

Panella, Thomas (1999) *Irrigation development and management reform in the Philippines: stakeholder interests and implementation*. Paper presented at the IWE-WB-GOAP Politics of Irrigation Reform conference held at Hyderabad, Andhra Pradesh, India, 11-14 December 1999.

Ploeg, Jan Douwe van der (1991) *Landbouw als mensenwerk. Arbeid ;en technologie in agrarische ontwikkeling*. Coutinho, Muiderberg.

Pradhan, Rajendra, Franz von Benda-beckmann and Keebet von Benda-Beckmann (eds.) (2000) *Water, land and law. Chnaging rights to land and water in Nepal*. Wageningen agricultural University.

Rap, Wester and Nereida (1999) *The articulation of irrigation reforms and the reconstitution of the hydraulic bureaucracy in Mexico.* Paper presented at the IWE-WB-GOAP Politics of Irrigation Reform conference held at Hyderabad, Andhra Pradesh, India, 11-14 December 1999.

Sayer, Andrew (1984) *Method in social science. A realist approach.* Hutchinson.

VILLARREAL, MAGDALENA (1994) *Wielding and yielding: power, subordination and gender identity in the context of a Mexican development project.* Ph.D. thesis. Wageningen Agricultural University.

VINCENT, LINDEN F. (1997) *Irrigation as a technology, irrigation as a resource: a sociotechnical approach to irrigation.* Inaugural lecture. Wageningen Agricultural University.

WINNER, LANGDON (1985) "Do artefacts have politics?" In: Donald MacKenzie and Judy Wajcman (eds.) *The social shaping of technology. How the refrigerator got its hum.* Open University Press, Milton Keynes and Philadelphia, pp. 26-38.