Interdisciplinary approach to water management

From the uplands to the coast – the Ganges-Brahmaputra-Meghna basin

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Summary

Many people have stressed the need for a fundamentally new approach to the management of rivers and coastal areas. Water resource engineering and management need a broadened framework, which includes ecology, social and economic development and integrated institutional arrangements. This changing perspective provides a very different functional format for developing policies for rivers and coastal areas. These policies should be based on interdisciplinary knowledge of the river from the upland catchment to the coast. Economic analysis and ecosystem valuation can play a facilitating role in trans-boundary cooperation, so important to survive in the Ganges-Brahmaputra-Meghna (GBM) river basin now and in the future.

Initial estimates of the likely impacts of climate change at a river basin level are diverse and the STREAM model suggests that the water availability in the Ganges-Brahmaputra-Meghna catchment may decrease. This will effect the growing number of inhabitants and the valuable ecosystems, if no adaptive measures are undertaken.

Trans-boundary discussions leading to a common and integrated water management policy for the entire river basin is an important adaptive option. Such international cooperation will help conserve water and increase the resilience of the Ganges-Brahmaputra-Meghna basin and its resident population.

***The Himalaya** – the uplands, home of the glaciers where the rivers start their journey to the coast. (photo of Annapurna-South, Nepal: © Evert Wesker)*

1. Need for a holistic approach to water management

South Asia is characterised by a very high degree of engineering intervention in the terrestrial part of the hydrological cycle. Led by India and Pakistan, the region is the home of the largest irrigation system in the world. In the second half of the last century, many water engineering projects were undertaken using traditional engineering approaches that originated in Europe. These were introduced to Southern Asia by the colonial rulers who were primarily interested in higher return from agriculture. There was little understanding of and concern for the effects on the aquatic ecosystems and their services. Large dams and barrages were built to harness hydrological flows, mostly for the promotion of irrigation. Many projects guided by traditional engineering have drawn serious criticism when looked at from the perspective of sustainability, social equity and the economy. No consideration was given to the value of the freshwater ecosystem services in supporting the livelihood of millions of poor either in policy or in practice.

The Ganges-Brahmaputra-Meghna (GBM) basin is an example where trans-boundary issues play an important role in water management. The GBM basin forms a part Hindu-Kush-Himalaya region (Figure 1) and covers more than 1.7 million km^2, 85% of the rainfall occurs during the June – October monsoon. The population density of the basin varies from over 700 in Bangladesh to 120 inhabitants/km^2 in Nepal. The population of the GBM basin will pass 1 billion by the year 2020.
The increasing need for water represents a great challenge for the governments and the water professionals of the river basin countries, especially if one considers the anticipated impacts of climate change.

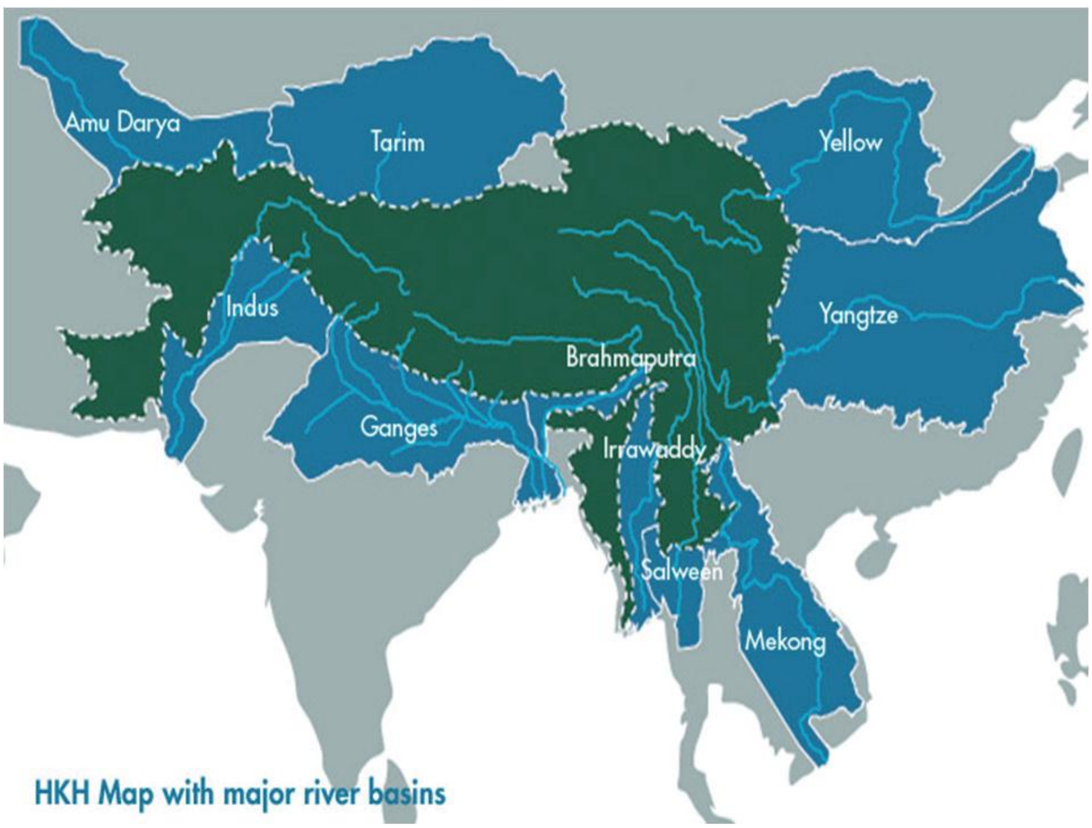

Figure 1: ***The Ganges – Brahmaputra catchment area:*** *1.75 million km^2, five riparian countries, about 1 billion inhabitants in 2020 forms an important part of the Hindu-Kush-Himalaya region. (source: ICIMOD, Kathmandu)*

Over the past decades, and in the aftermath of the Rio Earth Summit in 1992, it became clearer that a professional approach to water management was required. Surface and groundwater needed to be considered as a resource, forming part of the global hydrological cycle rather than a reserve to be contolled by structural interventions.

Accordingly, diplomatic negotiations and agreements on the management of trans-boundary rivers, should be based on the emerging interdisciplinary water sciences and ecological water engineering.

Fortunately in the past few years water science and engineering have recognised the importance of the aquatic ecosystems and their needs. These needs are not merely quantitative, but include for instance the knowledge on periodic patterns of flow in order to maintain the ecosystem services. Examples include the water needs of the fishing economies, which require flows of a sufficient quality and quantity that can support the movement of fish communities and their life cycles. Sufficient quantities of good water is needed for humanity and ecosystems to maintain the productivity of their valuable resources.

From the uplands to the coast

Emerton and Bos (2004) provided the impetus for the transformation of the traditional view of rivers, simply as a source of water to one of a diverse ecosystem functioning, all the way from the upland catchments to the estuary and the deltaic and coastal systems. From this perspective, ecosystem processes are closely linked to the naturally available water resources. The integrated approach of an entire river basin, as a collection of productive ecosystems, is important for the sustainable development of the water resources. The holistic understanding of rivers strengthens the need for ecological engineering and facilitating its applications. Such a development in thinking will have a positive influence on the approach to negotiations for basin level collaboration, joint management and hydro-diplomacy, directed towards equitable and sustainable use of water in the river basin. International river basin negotiations are particularly relevant against the background of present water use and water quality, and for identifying resilient, adaptive responses to the impacts of climate change.

Low lying coastal area of the GBM basin: *Where the waters and sediments of the Ganges, Brahmaputra and Meghna reach the coast: fertile, densely populated deltaic plains, intertidal areas and a large mangrove belt dissected by rivers and tidal channels. (photo: NASA)*

A number of positive experiences in river basin cooperation and negotiations are at hand. See CCC I-2-4 and the integrated river basin and marine management plans and its implementation by the EU countries (websites: European Commission - EU Water Framework Directive and International Commission for the Protection of the Rhine - ICPR).

The coastal part of the Ganges-Brahmaputra-Meghna basin is heavily dependent on the freshwater flows from the upstream areas and socio-economic processes therein. Flooding of the low-lying deltaic plain depends largely on the upstream river regime. The agriculture, fishery and natural environment of the Indian and Bangladesh coastal zone is for instance affected by the extent of the salt water intrusion during dry season. The survival of the valuable and highly productive Indian and Bangladesh Sundarbans, a unique unbroken mangrove belt, is affected by subtle changes in the boundary between fresh and salt water. Today the encroachment of salt water depends very much on the river discharges. In addition, it is envisaged that accelerated sea level rise may also a play an increasingly important role.

2. The importance of economics

The narrow perceived economics of the use of trans-boundary waters have created local upstream-downstream conflicts. Wider economic considerations are often neglected, however they can make a positive contribution in the policy context when addressing trans-boundary water issues, such as is the case of the Ganges-Brahmaputra-Meghna (GBM) river basin in south Asia (Bandyopadhyay and Ghosh, 2009).

Traditionally, engineering interventions into water systems are purely designed to satisfy narrow economic demands. In order to arrive at an optimum policy for river basin management, a wider economic assessment of water engineering projects is essential. This new paradigm for water management, while emphasising the need for demand led management, stresses the need for a more comprehensive means of allocating resources. This mechanism will create a valuable trade-off among the various water, social, cultural, economic and ecological sectors, and compromise socio-economic and ecological services.

Ever since traditional engineering was applied in the GBM basin, national economic priorities guided the interventions. The Farakka barrage on the Ganga, for example, was constructed without any bilateral or multilateral discussions, other than data sharing on floods in the Himalayan Rivers.

The basin remains a unique developmental puzzle with the co-existence in the basin of relatively good per capita water availability and the largest number of people of the world living in poverty.

The wider considerations including economy and ecology, should pave the way for the countries sharing the basin to seek and create a more comprehensive agenda for cooperation in water system management at various spatial levels. Considerations of ecological characteristics in the adoption of a modern engineering approach in the basin and the promotion of a diversity of inputs in the design, can make the transition to a new era of holistic and inclusive hydro-diplomacy more feasible.

In addition to the emerging ecological point of view, a fundamental rethink on the economics of water is taking place. Important economic values are being identified within ecosystem processes. Ghosh and Bandyopadhyay (2009) deal with valuation of water in the economy and the ecosystem sectors.

Valuation of natural processes can raise awareness of the market and the policymakers on the importance of the ecosystem and natural resources. The relevance of biodiversity conservation or carbon sequestration by wetlands is better understood if expressed in monetary values. Valuation can also help legal proceedings determining damage, such as pollution from upstream areas negatively influencing downstream inhabitants and ecosystems. To deal with compensation policies properly, the economic value of the damage needs to be assessed in order to obtain the cost of the negative effects (Bann, 2002; OECD, 2002).

Valuation of natural processes and resources helps the revision of investment decisions, such as infrastructure development, that might otherwise ignore the possible harm to the natural environment. The assessment of ecological costs and benefits of water projects is more and more recognised to be integrated in large scale hydrological projects. Notably, the absence of estimates of the ecological costs of large hydrological projects provides an inbuilt subsidy (Flessa 2004).

Pricing of water

It is critically important to choose the most comprehensive and inclusive mechanism for the valuation of water related ecosystem services. Here, an inclusive valuation framework that would encompass the various issues of ecology, economy, and society is needed. In such an inclusive valuation framework, the valuation not only of the socio-ecological systems (SES) as defined by Ostrom (2005), but also a broader ecological system that is contingent upon the intricate dynamics of the SES is discussed. In the inclusive valuation framework, the ecosystem and its services are included in the account statistics of a nation's economy. While such a development in procedures will be necessary and welcome, most of the policy makers of the countries involved in the Ganges-Brahmaputra-Meghna basin are not yet equipped for such a transition.

Water market

Once a baseline valuation of the various services provided by water systems is obtained, a basin wide market for the various services (provisioning, regulating and cultural) can emerge. While a customised forward contract can exist between nations on water sharing, in a more mature framework, one can think of a future market where standardised contracts can be traded. This may have considerable significance for conflict resolution and mitigation of the use of scarce resources. An efficient futures market for water can help in determining the price of water. Of course, this will require multi-level participation from all the nations in the region. With proper information dissemination, this price will reflect upon the scarcity of the resource.

3. Need for Regional cooperation

The South Asian Association for Regional Cooperation (SAARC) was established for the promotion of regional cooperation. The rivers connect several countries in the region, and thus, their cooperative management is very important for the best use of water resources and the economic development of the basin. However, hydro-diplomacy on the international rivers has not been on the agenda of SAARC in any serious way. In fact, the most recent water-related cooperation date back to 1996 when both the India-Bangladesh Treaty on the sharing of the restricted flow of the Ganges and the Treaty between India and Nepal on projects on the Mahakali came into effect. One of the oldest bilateral negotiations between India and Nepal on the river Kosi has been in place for several decades without a breakthrough.

On the positive side, the delay will allow all the projects to be reconsidered from an ecological perspective with a more comprehensive economic framework, than was possible for those conceptualised in the earlier traditional engineering paradigm. In addition, such an agenda should include China in hydro-diplomatic discussions for several reasons. Firstly, China plans to undertake many water related projects on Tsangpo (Brahmaputra) upstream of the river's point of entry into India. Secondly, a part of the Ganges sub-basin also falls in China. Here global climate change may have a significant impact on the permafrost areas, affecting the pattern of river discharges.

In recent years, the SAARC has achieved some progress in cooperation on developmental issues such as trade and industry. Economics may be a preferable entry point for water related negotiations and diplomacy on the Ganges-Brahmaputra-Meghna basin. Economic and ecologic valuation of the water resources in the basin has been proposed as an instrument for mediating trans-boundary water conflicts. If properly applied, in the trans-boundary context, it offers a more objective and achievable basis for resolving disputes. The need for trans-boundary cooperation within the basin will increase with the pursuit of common, no-regret adaptive solutions to fight the impacts of global climate change.

The SW Bangladesh – NE India coastal zone: the Sundarbans *(blue green), the largest uninterrupted mangrove belt of the world, an UNESCO World Heritage site and Biosphere Reserve, is dependent on the equilibrium of between fresh and salt water in its estuaries and groundwater. Large parts of the mangroves could be lost under influence of climate change. (photo: NASA, Jesse Allen, 28-01-08)*

The story of water in the Ganges-Brahmaputra-Meghna basin

The Ganges-Brahmaputra-Meghna (GBM) river basin in south Asia poses several complex challenges to the existing notions of development and hydro-diplomacy. Spread over the south Asian nations of Bangladesh, Bhutan, India, Nepal, and vast areas in the Tibet region of China, the GBM basin (1,745,400 sq km) is the second largest hydrological system in the world after the Amazon. The two major rivers of the hydrological system are the Ganges and the Brahmaputra. These two rivers and their tributaries flow beyond national boundaries and are prone to disputes that are a common feature of international trans-boundary watercourses around the world.

The story of humanity and water in the GBM basin is the story of numerous anthropogenic interventions. In the process, human societies in the basin have substantially transformed the natural flows and environment of the basin, from the Himalayan uplands to the deltas, where the highly productive mangrove forest, the Sundarbans, is located. This is the largest mangrove forest in the world.

For a sustainable future, the following steps are suggested:

- Cooperation between and among countries sharing the GBM basin, based on a perspective of the Himalayan rivers as functioning ecosystems, from the uplands to the delta, informed by scientific knowledge on all the ecosystem services they provide;
- The most critical concern arises from the absence of publicly available data on detailed hydrological flows, and other associated important variables in the basin. In the interest of the residents of the basin and for scientific knowledge on its waters, the need to share information among the various nations has been stressed by many professionals. Without this, no framework for hydro-diplomacy, can provide for sustainable use of the water resource;
- Understanding and assessing the impacts of global warming and climate change on water availability and ecosystem services of the Himalayan rivers is urgently needed (Bandyopadhyay, 2009). Such studies will be facilitated by an international collaborative approach. Serious consideration in developing such an future perspective is a priority of the region;
- The annual inundation of flood plains during the monsoon needs to be viewed as a known natural process, which needs better understanding and not routinely described or ignored as a 'natural disaster';
- The scope and objectives of structural interventions in these rivers needs to be expanded beyond the present preoccupation with large structures for water supply and hydropower generation.;
- More comprehensive methods for the assessment and approval of water projects should be employed from the very beginning e.g. in the pre-feasibility studies;
- Economics can play an important facilitating role through institution building (creation of water markets), as well as providing an objective tool for conflict resolution (by the inclusion of valuation tools).

India because of its position in south Asia politically, economically, and technically and with its high level of diplomatic competence, can take the initiative forward and help develop a new perspective for closer cooperation in the Ganges-Brahmaputra-Meghna basin. Never before has the challenge of poverty alleviation depended on the art of hydro-diplomacy and the science of ecological engineering and climate so critically, as it does in the basin today. The role of economics in providing a comprehensive evaluation framework needs to be re-emphasised, as it is also needed for sustainable management in the basin today.

4. Estimates of impacts of climate change in the Ganges-Brahmaputra-Meghna basin

The climate change impacts may exacerbate the water resource availability in the GBM basin. Changes in rainfall and increasing temperature will affect the extent of the glaciers, rain and snowfall, evaporation, and river discharges all influencing the water balance and the water availability in the entire river basin including the coastal zone.

The likely impacts of climate change on the coast will be an accelerated sea level rise, an increase in frequency and intensity of typhoons. These impacts will increase the frequency of flooding by the sea and the encroachment of salt water (see CCC II-1-1). Initial estimates of the likely impacts of climate change at a river basin level are diverse and the STREAM model suggests that the water availability in the Ganges-Brahmaputra-Meghna catchment may decrease.

Spatial distributed water balance models simulating water balance in large river basin are important for integrated management of an entire basin. STREAM is such a Geographical Information System based model allowing analysis of water availability patterns and changes in these patterns, both temporally and spatially. These changes can be caused by socio-economic interventions as well as by external influences such as climate change. The factors used in the STREAM–GBM application range from land-use changes such as deforestation, increased irrigation to dam construction and dredging of river channels. These influence flooding, salt water intrusion and the health of the mangrove forest.

The Intergovernmental Panel on Climate Change regional climate scenarios for precipitation and temperature and sea level rise are also used as input parameters, together with land-use and soil type maps and Digital Elevation Maps. All these input data are freely available (see also CCC III-3-2-6).

The output parameters are maps with changes in monthly aridity, water discharges and snow cover, and water demand versus water availability for the entire GBM basin. Salt-water intrusion and mangrove habitat suitability were the output modules for the delta. The STREAM model, with a grid size of 50 km^2, is calibrated and validated using several decades of monthly hydrological observations.

Four sets of hydrographs of the Ganges station Faraka (on the Indian side of the Indian Bangladesh border) and the Brahmaputra station Bahadurabad in Bangladesh (near the Indian border) show the current situation and the estimated reduction in the peak flows of the three IPCC based climate scenarios. The 2050 Medium Climate change scenario is based on a “carbon dioxide doubling temperature” of 3.0 degree Celsius.

The hydrographs suggest a substantial reduction of the peak flows of both rivers (see Figure 2). The reduction of Brahmaputra peak flow may be somewhat smaller.

The spatial distribution of the aridity indices shows serious shortage in the Western part (Rajasthan) of the Ganges sub-basin. This estimated reduction in river discharges is, in large part due to increased evaporation.

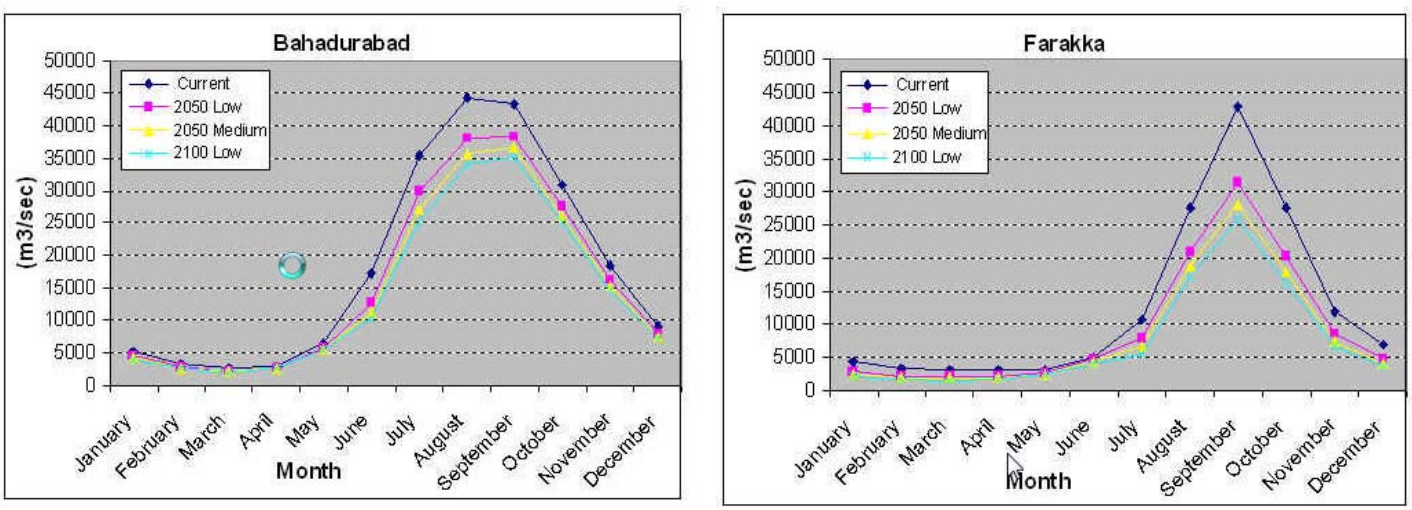

*Figure 2: **Monthly discharges (m3/sec) in the lower Brahmaputra and Ganges** - current situation and three IPCC climate scenarios: 2050 Low & Medium and 2100 Low scenario; these hydrographs are output of STREAM-GBM GIS model (source: STREAM-GBM GIS model – see also CCC III-3-2-6)*

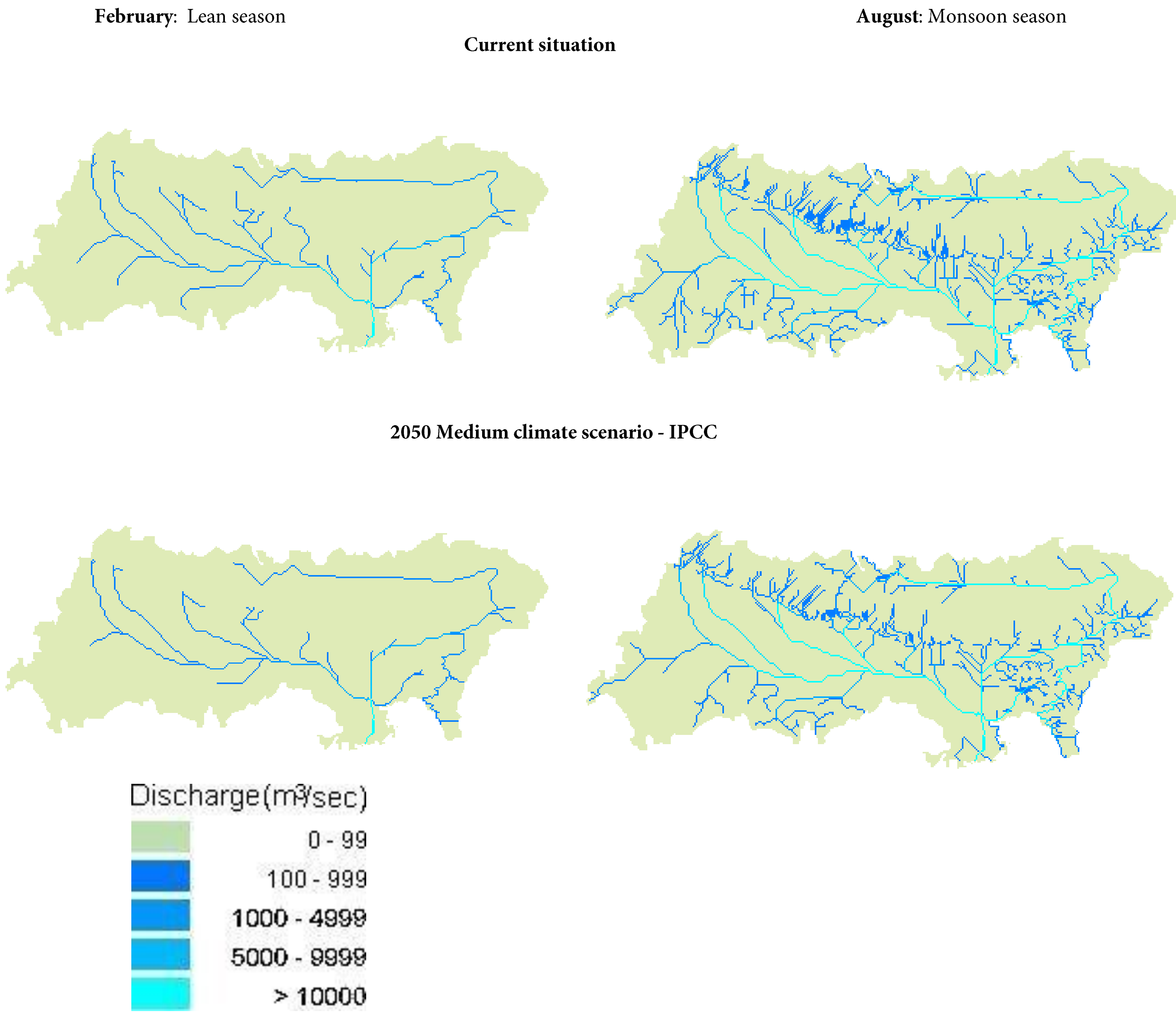

*Figure 3: **STREAM–GBM output**: River spatial drainage pattern and discharges in m3 /sec for the months February and August, current situation and in 2050. (source: STREAM – GBM GIS model – see also CCCIII-3-2-6)*

The STREAM-GBM spatial discharge outputs suggest a reduction of Ganges peak river discharges notably in the SW and W and in the 'foothills' of Himalayas, and a smaller reduction of the Brahmaputra peak flow in the NE part of the basin. Similar changes in spatial distribution can be observed during the low-flow season.

This GIS based river basin model can provide preliminary estimates of the effect of remedial measures as well as the impacts of climate change on the water cycle. The STREAM GBM model outputs are regarded as first estimates only and illustrate the possible order of magnitude of the impacts of climate change for a basin.

STREAM encompassing an entire river basin, is used in trans-boundary river basin management and discussions.

The GBM- STREAM demo is available in this CCC-Internet publication (see CCC III-3-2-6).

5. Conclusions

River and coastal management is in need of a new approach. For a holistic view, water resource engineering and management need to be considered in a broadened framework, which includes factors, such as ecology, institutional arrangements, and social and economic development. This changing perspective in water resource engineering will provide a very different functional format for developing river and coastal policies. These policies should be based on interdisciplinary knowledge.

Feasibility studies for large scale river intervention projects should take into account the ecological costs of stream-flow diversion, depletion, and their impact on ecosystem services.

Economics can play a new and important facilitating role in trans-boundary cooperation, through introducing water saving concepts such as water markets and providing objective tools for conflict resolution.

First estimates of climate change impacts at the entire Ganges-Brahmaputra-Meghna river basin suggest that the area of decreased water availability might increase notably in the W – SW of Ganges sub-basin. The Brahmaputra basin seems somewhat less affected. A reduction in future peak flow will increase the salt water intrusion in the coastal zone of the basin, further exacerbated by the anticipated acceleration of sea level rise, affecting the quality of drinking water, agriculture and natural environment, such as the mangrove ecosystems in the Sundarbans.

The possible, serious impacts of anticipated climate change provide another strong reason for basin-wide, trans-boundary planning and implementation of adaptive measures. Such a basin –wide approach can be considered as a solution that will help conserve water, increase the resilience of the Ganges-Brahmaputra-Meghna basin and thus work towards the reduction of the widespread poverty in the basin.

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