Governing Climate Change Adaptation in Ganges Basin: Assessing Needs and Capacities

Hari Dulal*

The World Bank, 1818 H Street NW, Washington, DC 20433, USA

*Email: hbdulal@gmail.com

Abstract

The Ganges basin shared by India, Nepal, Bangladesh, and China is the most heavily populated river basin in the world. It sustains approximately 500 million people. Even though people living in the basin have coped with and adapted to change in climate for centuries, they are finding it increasingly difficult, as both the frequency and magnitude of climate-induced extreme weather events have increased over the years. Both market and non-market impacts of climate change are increasing, and increasing, quite significantly. In 2007, floods resulting from monsoon rains killed over 2,000 people and displaced more than 20 million people in Bangladesh, India, and Nepal. As traditional coping mechanisms are proving to be increasingly insufficient, improvement in climate change adaptation planning and practices in the basin is becoming increasingly urgent. This paper makes an attempt to assess the effectiveness of climate information system, infrastructure, and institutions, which are considered three important pillars of successful climate change adaptation. The needs and capacities of agencies and institutions to observe, collect, disseminate climate information products and early warning, and existing physical and institutional structures' robustness and flexibility in responding to climatic change and climate-induced extreme events are evaluated.

***Keywords**: Ganges Basin, Climate Change Adaptation, Institution, Information, Infrastructure*

1. Introduction

Extending over China, India, Nepal, and Bangladesh, the Ganges basin covers an area of 1,087,000 square kilometers and is the most populous river basin in the world. The majority of area of the Ganges basin is in India and covers eleven states: Uttarakhand, Uttar Pradesh, Madhya Pradesh, Rajasthan, Haryana, Himachal Pradesh, Chhattisgarh, Jharkhand, Bihar, West Bengal and Delhi and numerous major cities (see table 1).

Table 1. Country areas in the Ganges river basin

Area (km^2)	Countries included	Area of country in basin (km^2)	As % of total area of the basin	As % of total area of the country
1, 087, 300	India	860, 000	79	26
	China	33, 500	3	0.3
	Nepal	147, 500	14	100
	Bangladesh	46, 300	4	32

Source: Adapted from FAO (2011)

More than half of the state's population in Bihar, Uttar Pradesh, Rajasthan, and Madhya Pradesh still rely on the agriculture sector for employment (see table 2). Employment in the agricultural sector, which is the mainstay of the Ganges basin economy, and around which, socio-economic privileges and deprivation revolve is crucial for basin dwellers.

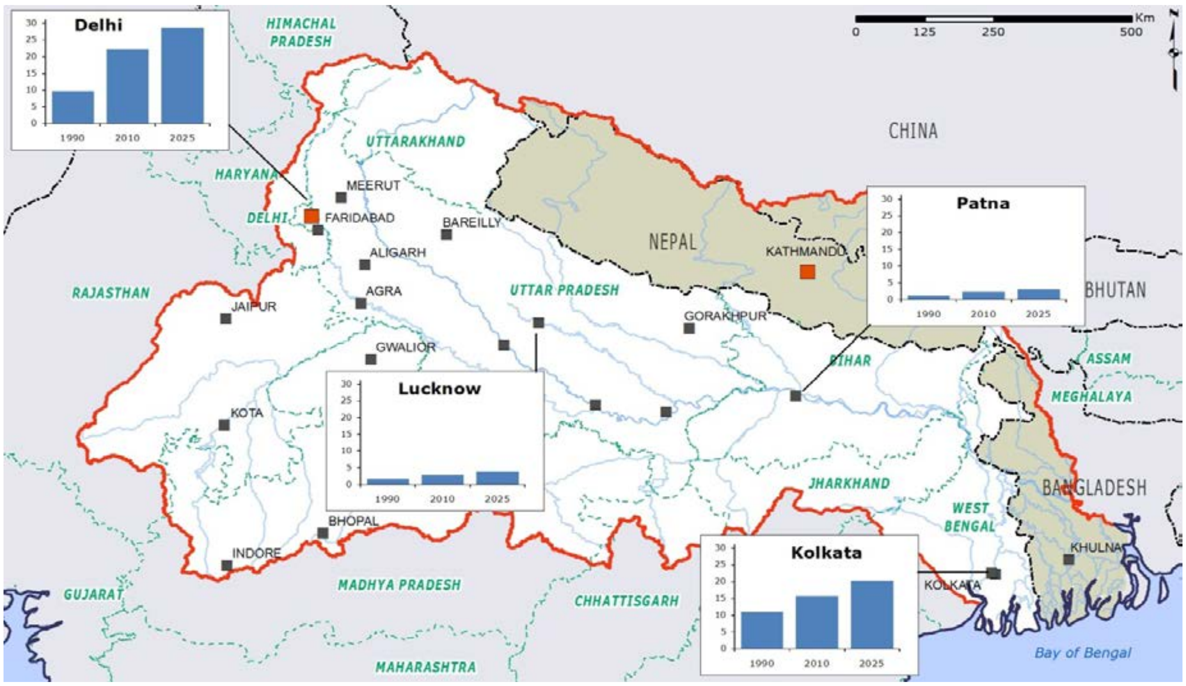
Table 2: Employment Share by Sector – 1993-94 and 2004-05 (%) in selected Ganges Basin States in India

State	1993-94			2004-06		
	Agriculture	Manufacturing	Services	Agriculture	Manufacturing	Services
Bihar	76.7	4.9	15.6	68.9	7.2	18
Uttar Pradesh	68.4	8.7	20.1	60.6	12.3	20.9
Rajasthan	69.2	6.2	15.3	61.3	9.1	18.2
Madhya Pradesh	77.7	5.5	13.4	69.1	7.5	18.2
West Bengal	48.8	19.9	27.1	45.7	17.5	31.6
Haryana	56.9	9.1	27.7	50	13.5	27.7
Punjab	56.4	10.3	28.1	47.4	13.5	29.8

Source: Adapted from Ramaswamy (2007)

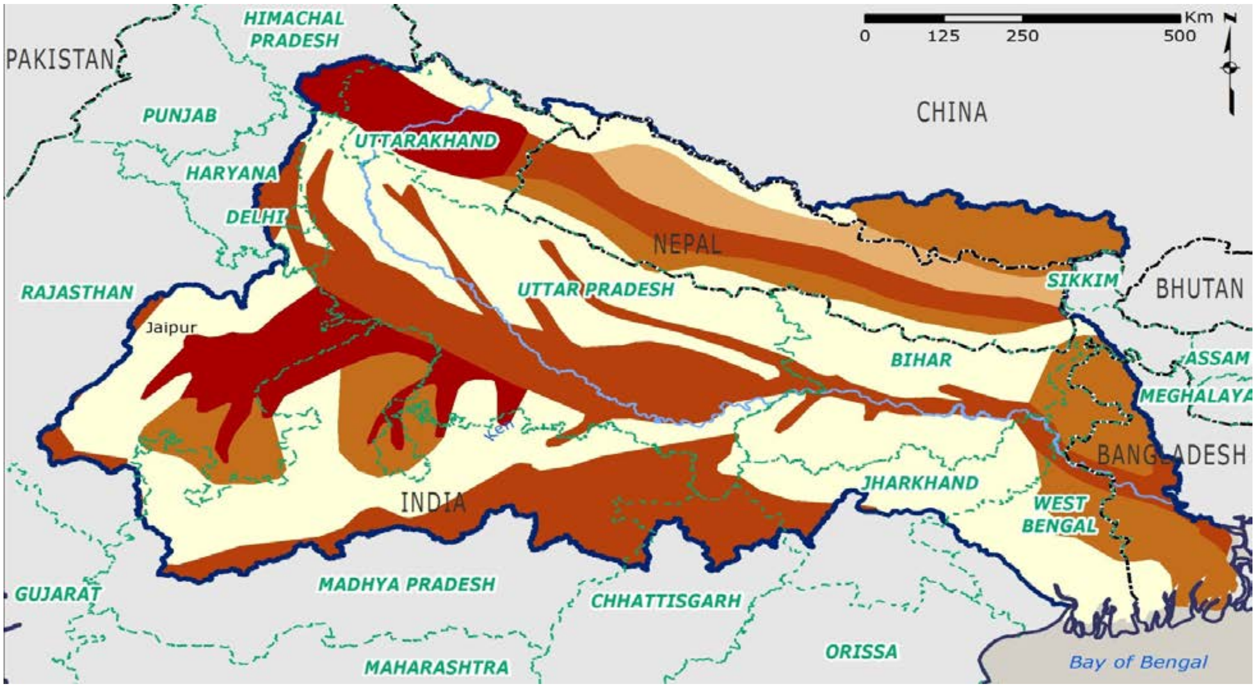
Indo-Gangetic basin is often characterized as a granary or the breadbasket of India. Cropland covers 72% of the area in the basin (Humphreys et al., 2008). Its contribution towards food security and employment is enormous. Indo-Gangetic basin accounts for 93 percent of wheat production and 58 percent of rice production (Sharma et al., 2008). That distinction, however, may soon be a thing of past because of ongoing rapid growth in population and environmental degradation (see figure 1 & 2). By 2050, 61% of the rural population and 56% of the urban population of India will live in Indo-Gangetic Basin (Amarsinghe et al., 2008).

Figure 1. Population in major urban agglomerations *(*millions*)*-1990,2010, 2050



Together, ongoing rapid population growth and environmental degradation pose a serious threat to food security, income, and employment (see figure 2). In eastern part of the basin, riverbank erosion hazard due to morphometric change of the Ganges River is emerging as a serious environmental issue. For example, in the upstream of Farakka Barrage up to Rajmahal in West Bengal, riverbank erosion is already posing a serious threat to food security, livelihoods, and income of famers, especially the smallholder ones (Thakur et al., 2012).

Figure 2. Land Degradation in Ganges Basin



Subsistence farmers in the basin are becoming increasingly concerned about declining agricultural productivity, which could exacerbate, if ongoing environmental degradation is not contained. A random survey conducted in six blocks of the Allahabad district of the state of Uttar Pradesh (UP), which included more than 200 individuals, reveals farmers' growing concern about decline in productivity of major crops. Approximately 55-60% people observed reduction in production of wheat and rice. Even though the adoption of hybrid varieties has prevented a drastic decline in production for the time being, farmers are seriously concerned about the possible loss of traditional varieties of wheat and rice (Tripathi, 2010). Climate change has added another layer of complexity. Given the rising climate risks and climate induced extreme weather event losses, it has become critically important to better understand if and how information, infrastructure, and institutions are influencing climate change adaptation in the Ganges basin.

1.1 Climate Change Concerns and Impacts

Climate change and climate-induced extreme weather events are major concern because of the population’s poverty status and extensive dependence on climate sensitive livelihood options and limited adaptive capacity. People living in the basin are not very well off. For example, 54.5 percent of the population of the state of Bihar in the eastern part of the Indo-Gangetic plain lived below the poverty line in 2004-2005. Rural poverty was 55.7 percent and urban poverty 43.7 percent (GoB, 2012). Given their limited access to endowments and entitlements, these poor are highly exposed, sensitive, and have low adaptive capacity to climate change and climate induced extreme weather events. Mohan and Sinha (2011) assessed exposure, sensitivity, and adaptive capacity of 83 districts in Uttar Pradesh and Uttarakhand. Findings suggest that 20% of the districts in the study area highly exposed to the changes in the climate and climate induced extreme weather events. Not only rural but also urban districts are vulnerable to climate change. Many of the vulnerable districts such as Dehradun, Haridwar, Ghaziabad, Lucknow and Kanpur are the predominant urban districts. Findings also reveal that almost the entire state of Uttar Pradesh is in the medium to high sensitivity category. The western Uttar Pradesh has maximum number of districts in the highly sensitive category. Adaptive capacity is particularly low in the state of Uttar Pradesh, because of higher dependence on the agriculture sector, which is climate-sensitive.

Table 3. Number of flood threatened districts in Indo-Gangetic Basin

State	District area prone to floods		
	0–25%	**25–50%**	**>50%**
Bihar	6	7	12
Haryana	4	8	2
Punjab	0	2	10
Uttar Pradesh	20	25	9
West Bengal	2	5	7

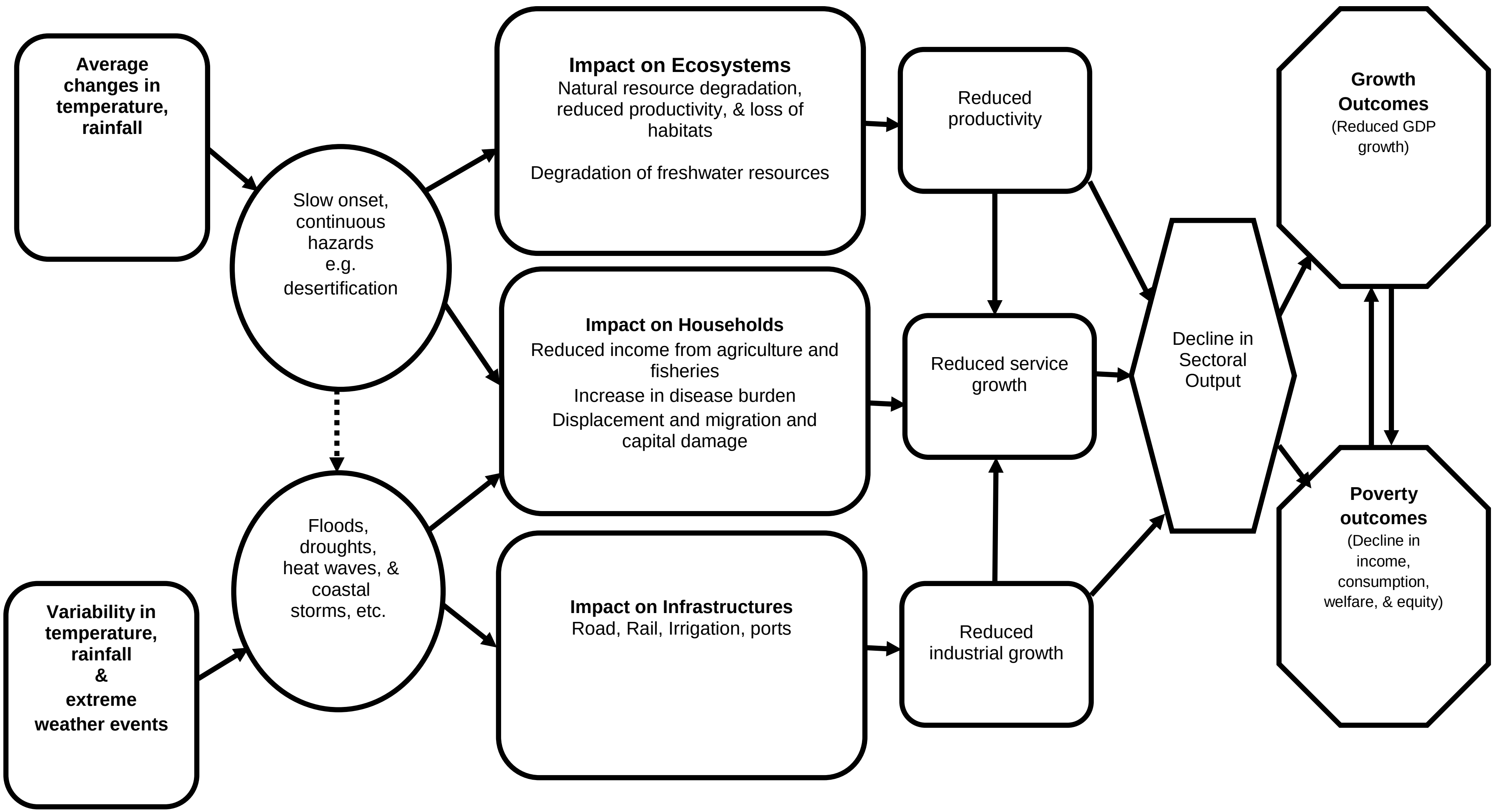
Source: Adapted from the Ministry of Urban Development, 1997.

The situation is quite similar in other provinces as well. There are very few districts in Ganges basin states that are not prone to extreme weather events. A high number of districts in the states of Punjab, Bihar, and West Bengal have a large area that is prone to floods (see table 3). The worst part of the recurrent flooding in the basin is that it adversely affects livelihoods of the 504 million, who happen to be among the poorest in the world (Dixit et al., 2007a). The worrisome aspect of the climate induced extreme weather events such as floods is that they are on an upward swing in the basin. For example, the number of floods reported during the past decades in the state of Uttar Pradesh is alarming. From two in 1970-1980, the number of floods increased to seven in 1980-1990. Eight and six floods occurred during1990-2000 and 2000-2007 periods (Patnaik and Narayanan, 2010). The frequency of floods in future will most likely increase because of increase in precipitation. According to the fourth Intergovernmental Panel on Climate Change (IPCC*)* report, average precipitation levels in the Ganges Basin will increase by approximately 20%. Heavy precipitation events will increase flood risk in the basin. In future, with climate change, the kind of 2007 flood that caused havoc could very well become the norm across the Ganges Basin. On the Nepal side of the basin, models predict increased variability in both monsoon and winter rainfall patterns. While an increase in rainfall is projected for the eastern mid-hills, western mid-hills will witness a general decline in rainfall. The central Terai or flat land will witness a ten to twenty percent increase in rainfall.

Analysis of mean monthly river discharge suggests that climate change will adversely affect regional hydrology of the Ganges and its major tributaries as melting of snow cover on the mountaintops would shift the peak discharge month from August to July. Climate-induced melting of glaciers could lead to increased flooding as well as more pronounced variations in water availability throughout the year. In Nepal's Terai region, farmers have reported that flooding events, particularly during the late monsoon, are becoming more frequent and destructive to agriculture (NCVST, 2009). On the Indian side of the basin, over all, the hydrological cycle is predicted to be more intense, with higher annual average rainfall as well increased drought. Models predict a maximum (10 to 30 percent) increase in precipitation in eastern Gangetic plain, whereas in central and western parts, rainy days are expected to decrease. Flows are likely to be extremely high during the summer monsoon periods. During winter, the flow in Ganges is projected to reduce to about 30% over the next 50 years, as snowmelt water provides more than 85 percent of the winter flows. Even though the basin area in Bangladesh is comparatively smaller, when compared to Nepal and India, the impact of changing river flows is likely to be significant. Frequent floods and low flow condition are likely to adversely impact the saline and fresh water balance along the coast (ISET-Nepal, 2008).

Given that climate impacts reverberate through out the economy, they could affect both affects both growth and poverty of riparian states (see figure 3). Indicative evidence suggests that climate change affects economic output (GDP) (Tol 2002; Deschenes and Greenstone, 2007; Barrios et al., 2007). Using data on temperature and precipitation for a panel of 136 countries over the period 1950-2003, Dell at al. (2008) show that a 1^{0}C rise in temperature in a given year reduces economic growth in that year by about 1.1 percentage points in poor countries. In the long run, a permanent 1^{0}C increase in temperature would reduce aggregate GDP in poor country by 11%.). Adverse effects on poverty and growth in Ganges basin countries would result largely from impact on: ecosystem services, livelihoods, trade, government budgetary revenues, employment, etc. The Ganges basin countries need to reduce vulnerability to climate change, because progress poverty reduction and economic growth gains achieved over the past several decades are at stake.

Figure 3: The Climate-Poverty-Growth Nexus



1.2 Losers and winners of climate change in Ganges Basin

Poor will lose the most from climate change, even though the extent of loss may vary depending upon their actual access to endowments and entitlements. Empirical studies confirm that changes in climate and variability will slow the pace of poverty reduction (Skoufias et al., 2011). Their vulnerability stems from the fact that they live closer to the biophysical, more exposed to the weather, and have lower adaptive capacity (Tol et al., 2004) and depend on climate-sensitive sectors such as agriculture for livelihoods. For about 30.5% of the population in the Indo-Gangetic basin that currently are below poverty line (Sharma et al., 2008), the real chances of escaping from vicious cycle of poverty is diminishing with increase in climate change and climatic-induced shocks and stresses. Even though the Western Indo-Gangetic Plains spanning from Punjab, Haryana, western U.P. and western Nepal Terai has most closely achieved its agriculture production potential, the Eastern Indo-Gangetic Plains, which comprises eastern Uttar Pradesh, Bihar, and West Bengal in India and eastern Terai in Nepal, is far from achieving its productivity potentials (Amarsinghe et al., 2008).

Smallholder farmers, with limited access to endowment and entitlements in the eastern part of the Gangetic plain, will lose the most. Farmers in many parts of the basin are already forced to adapt to changing climate. For example, in Baunsari village, which is located under Pauri block of district Pauri Garhwal, in the state of Uttarakhand in India, famers have been cultivating five different varieties of paddy namely Bauniya, Bankuli, Rasia, Khwida, Lal Satti and Pasaru in irrigated and non- irrigated land in the past, but due to increase in water shortages, they have started planting less water requiring varieties. Out of eight springs in the area, most have either dried up or are depleting. Bankuli is now gradually replacing Bauniya, which was extensively cultivated variety in irrigated land, as it requires less water. Instead of planting white wheat, which requires more water, farmers have started sowing red wheat, as it requires less water in non-irrigated land. Farmers are also increasingly planting cash crops, like tomato, onion, potato, in order to augment decline in productivity of traditional crops like wheat, paddy, and millet, etc. There also has been change in the types of livestock that people like to own in the area. Buffaloes are now being replaced with cows, as buffaloes need more fodder and require stalled feeding (Patwal, 2010). In Rudrapur development block of Uttarakhand state in India, people used to cultivate seasonal rice before 2003, but now, they have started cultivating off-season rice varieties such as Pant 4 & Saket, because of irregular and decrease in amount of rainfall (Kumar, 2010). While the eastern part of the Ganges basin suffers from flood, western part struggles for water required to maintain agricultural production and other uses. With decline in water availability, the agriculture production potential achieved by the Western Indo-Gangetic Plains may soon be a thing of past. Reduction in production of major staples could have serious repercussions on food security, livelihoods, and income as this will be happening at a time when the basin is witnessing rapid growth in population.

Subsistence farmers in the Ganges basin are genuinely concerned about climate change because climate induced reduction in crop yield, which is already a concern in the basin is projected to increase in coming decades. Using the decision support system for agrotechnology transfer (DSSAT) model, Mishra et al. (2013) analyzed the spatial variability of climate change impacts on rice and wheat yields at three different locations representing the upper, middle and lower Indo-Gangetic Plain (IGP). Findings for current climate demonstrate a significant gap between actual and potential yield for upper, middle and lower (IGP) stations. The projections show that during 2011–2040, the largest reduction in rice and wheat yields will occur in the upper IGP. Rice and wheat yields are expected to reduce somewhere between 17.2 and 43.2 percent in the basin.

Given the basin population's heavy reliance on agriculture for food, income and subsistence, it is hard to imagine real winners. In Allahabad, which is the mid-stream areas of the basin and where agriculture is mainly rain-fed, lack of water resources for irrigation and subsequently dwindling returns from the agriculture sector is a growing concern at the community level. More frequent and intense droughts have triggered migration of farmers, as they need to supplement their income. The situation is quite similar in the downstream areas of the basin as well. In Paschim Medinipur of the West

Bengal state, decline in water availability, which could exacerbate with climate change is already a serious cause of concern. The prevalence of largely subsistence-based rainfed agriculture and decrease in winter rainfall, delays in the onset of the monsoons and more erratic rainfall distribution are major factors behind increasing vulnerability to climate change (Bhadwal et al., 2013). Given the heavy reliance on climate-sensitive sectors, the basin level vulnerability to climate change will continue to grow unless people have improved access to credible climate information, flexible infrastructure, and inclusive institutions.

2. Reducing vulnerability through climate information

Communities living in the Ganges Basin have been adapting to the impacts of weather and climate through a range of practices such as crop diversification, water management, irrigation, and disaster risk management, etc. However, given the uncertainties surrounding change in climate, it cannot be assumed that historical or current adaptive capacity will continue to be adaptive capacity in the face of future climate change. It is not only change in climate and recurrence of climate-induced extreme events that will affect people's adaptive capacity, their capacity will also be influenced by ongoing rapid land degradation, water pollution, and land fragmentation in the basin. There are multiple factors at play, which will interfere with people's adaptive capacity. Increasing socioeconomic and environmental shocks and stresses combined with climate change will make it more difficult, if not, impossible to adapt in decades to come. The best way to maintain or enhance adaptive capacity of the basin dwellers' is to provide them with the strategies and tools that will help them: (a) identify climatic threats, (b) identify and guard vulnerable assets, and (c) pursue adaptation options that can help reduce climate risk. Successful adaptation to climate change largely depends on three elements: (a) timely recognition of the need to adapt, (b) an incentive to adapt, and (c) ability to adapt. For vulnerable households to timely recognize the need to adapt, they need to have both access to reliable and detailed information, and the ability to process such information. The more detailed, accurate, and relevant to the individual the climate change information is, the more effective the adaptation strategies undertaken will be (Fankhauser et al., 1999).

Information helps households make rational decisions, and hence, is vital to ensure that adaptation is carried out in an adequate and timely manner (Stern, 2007). It plays a critical role in informing climate change adaptation as it provides both an improved understanding of the actual climate risks and response alternatives (Serrao-Neumann et al., 2013). Even early warning systems are usually way more than just alert systems. They include detection, analysis, prediction/forecasting, and shape climate-risk response and decision-making (Basher, 2006; Glantz, 2009). Effective and targeted use of climate information—not only historical data and immediate weather forecasts, but also seasonal climate predictions and projections of long-term climate change—can help better manage climate risks at all scales (World Bank, 2006). A category 4 cyclone in 1991 led to 138,000 deaths in Bangladesh, but when a category 4 cyclone struck the nation again in 2007, only 5-10,000 people lost their lives. Bangladesh achieved substantial reduction in mortality through an establishment of effective early warning systems, which comprises of high tech information systems and low-tech outreach such as volunteers on bikes. Volunteers spread warning messages (Heltberg et al., 2009).

2.1 Dissemination of Climate information

Timely availability of climate information in user-friendly format is critical to the effective application. In the case of Ganges basin, the user-friendliness of climate information is even more critical because most of the subsistence farmers, who are the main users of climate information, are largely illiterate and live in rural areas where ethnic languages are the only mode of communication. Matured climate information infrastructure that can effectively generate and disseminate credible climate information at all levels is yet to evolve. The transition from a fire-fighting ‘wait and watch’ mode to a ‘predict and prevent mode’ through the use of best available weather and climate information is yet to happen in the basin. Even though technology is rapidly evolving to offer dramatically powerful solutions in flood forecasting, monitoring and management, Ganges basin states are yet to benefit fully from the advancement in technology. Sinha et al. (2012) find that out of 150 households surveyed in the state of Bihar, in eastern part of the Indo-Gangetic plain, only one in fourteen households knew about the Water Resources Department (WRD), an agency responsible for passing information on floods. Only one in six households in the flood prone village knew any staff from the WRD. There is clearly a missing link between WRD and the communities that it aspires to protect against floods, which is projected to increase with climate change. Results indicate that the local authorities such as the WRD that aspire to protect people against floods are not even communicating current variability in climate and extreme weather events properly. They may be aware of expected climate change impacts, but their lack of outreach, raises question about their actual capacity to generate and use meaningful information to develop geographically specific action plans to reduce impacts of climate induced extreme weather events such as flood.

It is not that information flow is not taking place in the basin. In some places, information is being passed on to relevant communities. However, the problem even in areas, where information is being passed on is that they are not really user-friendly. For example, in the state of Uttar Pradesh, in India, the Central Water Commission (CWC) and Meteorological Department provide information about water levels of major rivers to the Relief Commissioner and District Control Rooms every day at 9 am and 3 pm, from 15 June onwards. The District Control Rooms then communicate the warning/information to tehsils (administrative subdivisions)/police stations through wireless, which is then subsequently passed on to flood posts through special messengers (GEG, 2008). This kind of information dissemination might be of some use to educated, comparatively well off households with strong social capital, but for those subsistence farming households with illiterate or semi-literate family members and weak social capital, it is of very little use, if any. The current “one package fits all” approach to climate information dissemination will have to be changed to a more locale and household-specific ones. In the absence of accessible information, poor communities in the basin, whose livelihood is largely agriculture dependent, may continue to rely on unsustainable and often damaging coping strategies, assuming that things would hopefully get better next year.

Table 4. Types and use of information for climate change adaptation in Ganges Basin

Type of Information/Data	Description	Information Use
Climatic and hydrological information	Early warnings	Develop future climate change scenarios
	Projections of future climate conditions	Generate river flow models
Satellite imagery	Linear Imaging Self Scanning false color composite imageries can be used to generate land-use maps indicating various land-use types (e.g., forests, agricultural land, and water bodies)	Analysis and classification of satellite imagery can help identify basin's agricultural sector's dependency on rainfall and groundwater.
Biophysical information	Physiological and edaphological (soil-related) data	Climatic data sets can be integrated with edaphic (soil) and crop physiology data to generate the crop impact models under A1B scenario of climate change.
Socioeconomic information	Employment, dependency, migration patterns, social capital, institutional and information access, crop yields, agriculture input and output prices, etc	Climatic and hydrological information, satellite imagery, and biophysical information can be overlaid with the socioeconomic conditions on ground to identify adaptation options that are feasible for the particular area within the basin given the magnitude of climate impacts and socioeconomic conditions.
	Existing farm management practices, coping mechanisms, and capacity to take up new technology or management practices based on experience of communities	

Source: Adapted from Ali Khan et al. (2012)

Table 4 illustrates the kind of information and their use in enhancing climate change adaptation within the basin. More than collection of the information, what is even more important is, making the collected information user-friendly. Information is of no use if the people that need it cannot use it or benefit from it, fully. Well-packaged climate information does benefit households, whose future adaptive capacity is in question. For example, in Namibia, 76% of Omusati farmers that received weather forecast and early warning found local forms of such information useful for making farming decisions (IECN, 2008). Making climate information useful will require a close collaboration between weather services and local communities. A close collaboration between weather services and vulnerable communities would help weather services better understand local communities' information need and use. In many cases, households that consider themselves to be vulnerable to climate change and climate induced extreme weather events may not know the exact ways in which they can use climate information to reduce their risk to climate change. Osberghaus et al. (2010) surveyed 157 participants from the general public of the German city of Mannheim. Findings suggest that the sole provision of information about expected climate change impacts even if tailored to one's individual context, does not significantly increase personal perceived risk and consequently the motivation to adapt. Increasing the knowledge about concrete coping options to allow people to weigh up their personal options is equally important. In the context of Ganges basin, where there is a heavy reliance on agriculture, improvement in localized weather and climate information, needs to be complemented with strong extension systems so that poor vulnerable households can minimize their losses through the use of improved agricultural techniques and technologies. It is equally important to promote information on the socio-economic aspects of climate change. Vulnerable households and communities need to be also aware of the socioeconomic risks associated with not making best use of the provided information.

3. Role of institutions in adaptive process to climate change

Local institutions play a critical role in supporting adaptation. Their role is important because adaptation to climate change is largely a local phenomenon, which is heavily reliant on household and communities' access to endowments and entitlements (Agrawal and Perrin, 2008; Dulal et al., 2010). Both, formal and informal institutions have a role to play in adaptation to climate change and climate induced extreme weather events. While formal institutions have a more structured role and offer rigid enforcement, informal institutions use locally rooted compliance based on cultural norms, such as customs, traditions, moral values, and shared rules, and are enforced outside of the formal governance structures (Helmke and Levitsky 2004; Osbahr et al., 2010; Ranganathan et al., 2011). Informal institutions supplement local government capacity, and in many instances, take on tasks that government institutions are unable to perform for variety of reasons such as limits on resources (Castle 2002; Sander-Regier et al., 2009). Together, they shape adaptation outcomes by: structuring the way climate impacts are experienced, connecting individual and collective responses to these impacts, and channeling external resources (Agarwal and Perrin, 2008; Lebel et al., 2011; McDevitt, 2012). Their maximum synchronization and complementarity is crucial for adaptation in Ganges basin area because the nature of the existing power relations within Ganges basin communities could very well limit adaptation of certain groups that are at the bottom of social and economic hierarchy. The ubiquitous socio-cultural caste-system is still pervasive throughout the basin. In the absence of recognition of power imbalances between stakeholders, adaptive governance will actually end up reinforcing existing inequalities and the perpetuation of narrow interests (Adger et al., 2005; Plummer and Armitage, 2007).

3.1 Institutional effectiveness in climate vulnerability reduction

At present, river basin management organizations are hierarchical and put in place mainly for constructing large interstate multipurpose projects and water sharing and conflict resolution. Given the arrow mandate, these institutions are not capable of fulfilling more demanding and complex functions related to: water conservation and water productivity improvement, allocation of water among the competing sectors, integrating environmental and social concerns related to the resources, ensuring equitable access and compensating for losing access, and relocating vulnerable population (Sharma et al., 2008). They are also ill-equipped to facilitate interdisciplinary research, dialogue, planning, implementation, and monitoring beyond one or two sectors at a time (World Bank, 1999). Multilevel governance and fragmented interventions that often do not take wider strategic context of the basin into consideration has hindered development and implementation of effective climate change adaptation strategies. As a result, millions of poor in the basin continue to get adversely affected by extreme weather events year after year. Fragmented and concurrent authority is problematic, when it comes to facilitating climate change adaptation, because it hinders inter-governmental learning and the responses to climate change and climate-induced extreme weather events. It reduces the systemic capacity to learn from analyses of potential effects or climate change adaptation strategies employed by other agencies. Institutional constraints removal is crucial as they increase vulnerability to climate change by limiting entitlements and access to resources (Adger and Kelly, 1999). Institutions are the ‘rules’ that govern belief systems, behavior, and organizational structure (Ostrom, 2005) and play a key role in mediating the transformation of coping capacity into adaptive capacity (Berman et al., 2012). By governing access to resources, institutions facilitate climate change adaptation at the local level (see table 5).

Table 5: Role of institution in Climate Change Adaptation

Type	Intervention	Climate	Development	
		Adaptation	Economic Growth	Poverty Alleviation
Institutions	Local institutions (public and non-governmental organizations (NGOs)	-Reduction climatic shocks and stresses through structuring of impacts and vulnerability -Containment of breakdown in resilience through delivery of external resources that facilitate adaptation -Increase in local adaptive capacity	-Reduction in economic disruptions -Increase in local economic performance -Increase in productive infrastructure, labor, skills, knowledge, natural resources, and capital.	-Increased productivity and income -Increase in savings and assets -Enhanced livelihood strategies

The much-needed transformation of coping capacity into adaptive capacity is not happening in Ganges basin, because of a lack of coherence across and between institutions limits. Different rules and management structures for the management of water resources has complicated decision-making and strategic planning in the basin. Besides that, local institutions lack the required capacity to effectively deal with current variability in climate and extreme weather events. Even though local self-government institutions are supposed take up the responsibility for disaster management at the local level according to the 73rd and 74th constitutional amendments of India, their actual capacity to deal with natural disasters is extremely weak, if any at all. For instance, local self-government institutions in the states such as Bihar are not capable of discharging the responsibility for disaster management at the village council level (Kumar et al., 2012).

Fragmentation of authority and lack of oversight might have prevented disaster risk management programs from being well managed, but what is also lacking is the institutional capacity to effectively deal with changing pattern of extreme weather events. For example, material and human resources for disaster management are lacking even at the district level in Bihar (Kumar et al., 2012). The lack of institutional capacity became quite evident during the devastating Koshi flood of 2008. A survey of two hundred and eighty households in villages affected by the Koshi flood of 2008 in northern Bihar reveals institutional failure to respond to extreme weather events in the IGB. Even after 20 days of the flood, half of the families in the worst hit areas were still living and eating in relief camps. Only 12% of the surveyed households reported having a bank savings. The National Rural Employment Generation Scheme (NREGS*),* which is supposed to provide work to rural poor during the lean period, was found to be of not much help. Only about 8 percent of the households reported receiving benefits under the programme, and on average, beneficiaries had engaged in only 25 days of work before the occurrence of the flood (Somanathan and Somanathan, 2009). Recurring extreme weather events and institutional failure to effectively reduce disaster risk and respond to extreme weather events is triggering internal migration like never seen before. Up to 70% of households in blocks suffering floods and water logging (Gayghat, Katra, Aurai, Sakara, Gochaha, Kanti, Marwan) in Muzzaffarpur, Bihar have migrants. Purnia East, Dagarwa, Baisee, Amaur, Baisaa, Kasba and Jalalgarh that are flood prone and K-Nagar, Shre Nagar, Dhamdaha, Bhawanipur, Rupauli and Banmakhi that are water logged have reported massive exodus over the years (Deshingkar et al., 2006).

3.3 Strategies to deal with Climate Change in Ganges Basin

There is no well-planned strategy to deal with extreme weather events in the basin, including in the basin states in India. The policy process in the Ganges basin is often restricted to strategic planning in specific sectors. For example, instead of putting in place a robust strategy to deal with climate induced crop failure and dealing with the growing problem head-on, states submit a humongous claim for the central government to pay (see table 6).

Table 6: Extent of Drought Relief Claims Made by Various States, 2009

State	Claim (millions $)	Claims as % of VCO during 2003-04 to 2005-06	Highest Decline in VCO Witnessed during Last Decade
Bihar	4201.029	126.49	-29.6
Haryana	30.773	16.98	
Punjab	74.657	27.47	-1.3
Rajasthan	125.825	46.7	-31.6
Uttar Pradesh	143.67	11.09	0.2

Source: Adapted from Chand and Raju (2009).

At times, the claims made are even higher than the actual value of crop produced in the state in the entire year. For example, the special financial assistance of 4201.029 million dollars sought from the centre by the state of Bihar to deal with the drought situation in the state is higher than the actual value of crop produced in the state in the entire year. Evidence from the past suggests that the highest decline in crop output faced by Bihar in any year did not exceed 30% of value of the total crop produced. It is not only the local institutions, but also the central government's response to climate induced extreme weather events, have been found to be very weak. Even when the requests for help are made, it takes weeks for help to actually reach adversely affected households. In the case of drought in Gujarat, in 2002, it took nearly nine weeks to send central teams for assessing the drought situation and an additional one more week to consider the state request for relief assistance (Prabhakar and Shaw, 2008). The delay in response adversely affects societal resilience as it exacerbates social inequalities and places acute pressure on groups such as women, indigenous, backward castes and tribes that are already highly vulnerable to climate change, because of their position in the society and limited access to capital assets and institutions.

In a transboundary river basin like Ganges, the need for cross-country cooperation is extremely necessary to reduce basin-level vulnerability to climate change and climate induced extreme events. Climate change is of particular concern in transboundary river basin climate change is of particular concern because there is the potential for disputes and instability if the rate of change within a basin exceeds the institutional capacity to address the change (Wolf, 2009). However, individual countries with low capacities often are not the cause of lower transboundary adaptive capacity. Lower adaptive capacity is systemic to the characteristics of the collection of countries in the basin (Milman et al., 2013). One of the factors behind lower basin-level adaptive capacity in the Ganges basin is because of a lower degree of institutionalization in transboundary water agreements. Higher degrees of institutionalization in transboundary water agreements is extremely important because it helps reduce both negative impacts of transboundary flooding (Bakker, 2009) and conflict during water scarcity (Tir and Stinnett, 2012). The total amount of water in the Ganges basin is actually enough to meet the social, economic and environmental requirements of the riparian countries, if properly managed (Ahmad et al., 2001). The basin-level water management cooperation could create a web of interdependence between riparian states through major role in energy, agriculture and flood control (Rahaman, 2009). Collective and adaptive management practices would also enhance resilience (Bangura et al., 2013). Despite of tangible benefits, controversial issues between the riparian states, including domestic politics and interstate relations are hindering the basin-level water management cooperation and institutionalization of transboundary water agreements. At present, riparian states' are unilaterally going forward with irrigation and water projects and withholding hydrological data. Instead bilateral and project-by-project negotiations, riparian states in the basin need to adopt a holistic approach to cooperation. This would not only result in an equitable distribution of shared water resources but also reduce basin-level vulnerability to climate change and climate induced extreme weather events.

4. Infrastructure Development in Ganges Basin

Adaptive capacity of a nation, region, or a community to a large extent depends on the degree to which its physical structures are designed to accommodate and respond flexibly to climatic change and climate-induced extreme events. Infrastructure needs to be flexible and socially inclusive in order for it to effectively reduce vulnerability to climate change and climate induced extreme weather events. If flexible and socially inclusive, infrastructure will not only reduce vulnerability to climate change and climate – induced extreme weather events, but also: (a) be a driver of economic growth and competitiveness, (b) increase employment opportunities, (c) contribute to poverty alleviation, (d) improve quality of life, and (e) improve the environment.

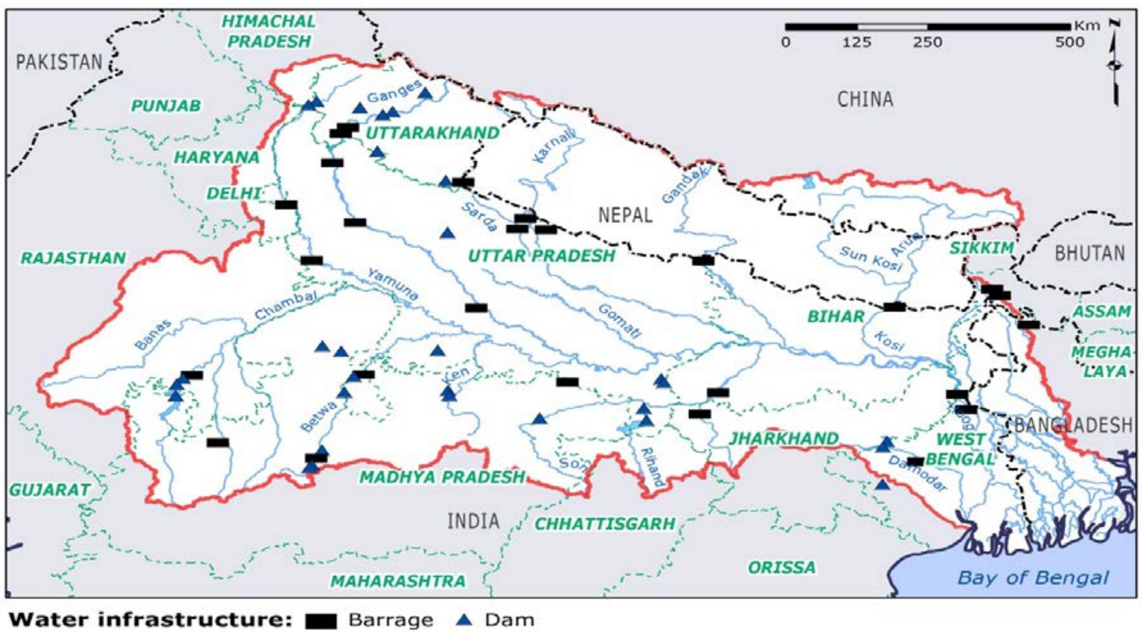
4.1 Strategies and tools used for flood management

The Ganges basin has been shaped by deeper histories of flood control. A significant insight into the contours of the political economy of development in the Ganges basin is afforded by an examination of dams. Even though the colonial engineers in India in the late 19th and early 20th century came to hold the view that river engineering worsened flood peaks, they were prevented from following through with embankment removals by local powerful farmers (D'Souza, 2006). Regardless of the effort made by the colonial government to coordinate and manage flood control measures, private embankments continued to be constructed, flouting all norms, rules and regulations. Landlords got more and more competitive in constructing embankments to safeguard their lands and crops from inundations, as time went by. However, things did not change for better after the end of the colonial era. Dams were one of the centerpieces of the Nehruvian strategy of planned industrialization, along with the other 'temples' of modernization, such as steel refineries and factories (Hill, 2006). Substantial attention was paid to irrigation and flood control and a major chunk of resources was directed towards the sector in the early decades after Independence. The share of expenditure on irrigation and flood control in total budgetary spending on rural economy in 1950–51 was 68.5 percent (Jha and Acharya, 2012). Many embankments in the state of Bihar, for example, were built after the first national policy on water management was formulated in 1955.

The debate over the flood problem in the Ganges basin continues to be centered mostly on technological choices and engineering solutions and ignore complex environmental history, in particular the great hydraulic transformations brought about by colonial rule

(Singh, 2008). By 2006, the embankments covered an area of 3,420 km (Kumar et al., 2012). More than 3500 km of embankment has been built in the last 40 years on plains of north Bihar alone (Dixit, 2003). The situation is quite similar in other states in Indo-Gangetic basin. For instance, in Uttar Pradesh, the state has constructed more than 300 embankments over about 20 rivers, which length-wise measure a little over 3,000 km. These embankments have been constructed over the years starting from 1954 right after the enunciation of national policy on floods. The budget for flood control is ever increasing and so is the flood affected areas and flood losses (Pande, 2012).

Figure 4: Existing Major Dams and Barrages in the IGP



The sad reality about consistent increase in the number of embankments in the basin is that they have not offered respite from flooding. Despite rapid infrastructure development to manage floods (see figure 4), floods continue to occur and displace millions of households in the Ganges basin. On contrary, consistent infrastructure development over the years has resulted in the aggradation of channel beds, and, consequently the spill over of floodwater and waterlogging. Embankments block drainage along with floodwaters within rivers. Sections of the Ganges basin both within India and Nepal that were once subject to brief intermittent flooding now remain underwater for many months at a time (Moench and Dixit, 2004).

4.2 Moving beyond techno-centric solutions

Ongoing infrastructure planning and development in Ganges basin is problematic as it is strictly techno-centric. Still, recurring annual floods in the basin is considered to be a technological problem requiring technological solutions such as diversion of river flow and enhancement of river embankments, when in reality flood vulnerability reduction benefits provided by techno-centric solutions is less than satisfactory. Initially, Bihar had only 160 kilometers of embankment length in 1952, with 2.5 million hectares (Mha) of flood prone area. In 2002, the total length of the embankment increased to 3,430 km and the flood prone area, and instead of decreasing, the area affected by floods increased to 6.88 Mha (Thakkar, 2006). In elsewhere, too, flood vulnerability reduction benefits provided by extensive network of embankments that has been constructed in the Ganges basin over the years is not very impressive (see table 7).

Table 7. Benefits from large-scale infrastructure investments

State/ UT's	Length (km)		Towns/Village (Nos.)		Area benefited in ha (10^6)
	Embankment	Drainage Channels	Protection Works	Protected	
Bihar	3,454	365	47	-	2.949
Haryana	1,144	4,385	448	98	2
Himachal Pradesh	58	11	-	-	0.0097
Madhya Pradesh	26	-	37	-	0.004
Rajasthan	145	197	25	-	0.0816
Uttar Pradesh	2,681	3,593	48	4,511	1.599
West Bengal	10,350	7,129	-	-	2.2005
Delhi	83	453	-	-	0.078

Source: Adapted from Moench and Dixit (2004)

An analysis of the costs and benefits of the structural flood control measures in the Ganges basin conducted by Dixit et al. (2009) suggest that the costs of current structural approaches have exceeded their benefits. In Rautahat District of Nepal, embankments have had substantial negative impacts on the adjacent villages. The negative impacts include: (a) water logging (b) increase in inundation and severe flooding (c) restriction in mobility.

The continued obsession techno-centric infrastructure development has created more problems than it has actually solved, especially for people that are vulnerable to extreme weather events and have limited access to endowments and entitlements. In many places in the basin, embankments have been found to block tributaries from draining into main rivers and caused sediment deposition in riverbeds. Sediment deposition has increased the risks of embankment breach and flooding even during normal-flow stages (Moench and Dixit, 2004). The time has come to think beyond techno-centric solutions. In many areas, infrastructure needed to enhance adaptive capacity of vulnerable population does not require large-scale investments such as building of dams and embankments. Indicative evidence from within the basin clearly suggests that low-cost inclusive infrastructure designs are very effective in controlling extreme weather events (see table 8).

Table 8. Assessment of costs and benefits of alternative interventions along the Bagmati River transect in Nepal.

Interventions	Plusses & minuses	Details
Bagmati, Chandi, and Manusmara Irrigation systems	+ + +	1600 ha
Mechanized pumps including treadle pumps	+ + +	
Forest buffers	+ + +	350 metre wide, 13 Km long strip of forest adjacent to the river. Partly owned and managed by government, partly by community. Timber, fodder and fuel are all products of this forest.
Land protected	+ + +	3,250 ha
Agricultural land lost	- -	
Houses protected	+ +	1,650 houses
Timber produced	+ +	Revenue from selling hard wood goes to the government. Community managed portion is new growth so will only provide timber income after10 to 15 years.
Fuel and fodder produced	+ +	
Raised community shelter	+ +	20 households of Laxmipur plan to take refuge for 15 days during three months of June-August.

Source: Adapted from Dixit et al. (2009)

Given the fact that the governance of planned adaptation takes place on different scales of social organization and more and more actors are taking part in designing and implementation of measures to mitigate and adapt to climate change, the state is no longer in a position to exert exclusive controls or command over adaptation measures' design and execution (Hooghe and Marks, 2003). This is a good development as it provides greater opportunity for local people in the basin to integrate cultural and indigenous aspects in adaptation planning and infrastructure development. A greater replication of some of these best practices, which are being practiced for decades would not only enhance adaptive capacity of vulnerable population, but also free exorbitant sum of money that is currently being spent on large infrastructure development.

5. Conclusion

People in the Ganges basin have been adapting to change in climate over centuries. Natural adaptation capabilities built in the existing systems may, however, be outpaced in coming years and decades as all three pillars: climate information system, infrastructure, and institutions necessary for successful climate change adaptation are weak in the basin. Climate information infrastructure is too weak to meaningfully contribute towards vulnerability reduction. Climate change data and analysis remain underutilized in institutional or sectoral silos. Even in places, where information manages to get out to relevant stakeholders, they are not user-friendly. Provision of precipitation and flood data completely undermine differential capacity of vulnerable population to use climate information. The "one package fits all" approach to information provision completely ignores political, social, and economic realities on the ground. The basin is a complex rural society, with majority of population still living in rural areas. These areas are marred by poor service delivery, a caste ridden socio-economic and political fabric, polarization of institutions by the elites, limited economic opportunities other than agriculture, and poor infrastructure. In order for climate information to be of any use to vulnerable population in the basin, who often happen to be poor with little or no endowments and entitlements, its provision needs to be tailored to meet their needs and capacities. The content and format of climate information should take into consideration the differential information need and use within vulnerable households and communities. It is virtually impossible to reduce basin-level vulnerability to climate change and climate-induced extreme weather events if the current fragmented data and information provision practice were to continue. Data and information sharing about transboundary flow of resources, particularly water resources, is still a very sensitive issue. Riparian states continue to overlook the need for data and information sharing, which is crucial if basin-level vulnerability to climate change is to be reduced to a meaningful level in coming decades.

At present, institutions in the Ganges basin lack both the required capacity and mandate to carry out complex climate change adaptation enhancing functions. The major challenges faced by the government institutions in the basin include weak coordination as a result of conflicting and overlapping mandates, dysfunctional arrangements for inter-agency integration, and inadequate financing for adaptation. Climate change adaptation is yet to be integrated into the planning frameworks of decentralized governance structures and the local planning process is yet to successfully link community-based adaptation with the regional planning processes. Lack of framework and mechanism that facilitates a top-down and bottom-up mix of adaptation responses has dwarfed the chances of propagation of best practices. Current institutional framework for extreme weather events in the basin provides weak, if any, incentives for proactive risk management. This has to change, and change rather fast, or else, signs of weakening of resilience to climate change will soon start becoming visible.

Infrastructure plays a major role in community-level adaptation to climate change and climate induced extreme weather events. However, for infrastructure to enhance adaptation and reduce long-term vulnerability to climate change, it will have to acknowledge sociological aspects of people that chose to live in high-risk areas. Ongoing approach to infrastructure development in Ganges basin is purely techno-centric and does not take social dimensions of vulnerability into consideration. The first step towards meaningful climate risk reduction necessitates a change in the way rivers in the basin are actually looked upon. Since colonial era to date, rivers are being looked upon as obstructions to development. This faulty outlook has led to increase in construction of hard infrastructures, which in reality has increased vulnerability to extreme weather events. Therefore, responding to the challenges posed by climate change and climate induced extreme weather events require an urgent shift in the way infrastructures are planned, designed, and managed in the basin. Evidence clearly suggests local resource-based approach to infrastructure development to be effective in reducing communities' vulnerability to extreme weather events. Integrating natural infrastructure (e.g, wetlands) into flood protection management has been found to benefit poor. Potential benefits include protection from storm surges and flooding, as well as provisioning of ecosystem services.

Acknowledgments

We sincerely thank the Editor of the International Journal of Sustainable Development & World Ecology, and the anonymous referees for their valuable comments and suggestions. The views expressed in this paper are solely those of the authors and should not be taken to be the views of the organization to which the authors are professionally affiliated.

References:

Adger, W. N. and Kelly, P. M. (1999). Social Vulnerability to Climate Change and the Architecture of Entitlements. *Mitigation Adaptation Strategies Global Change,* 4, 253–256.

Adger, W. N., Brown, K. and Tompkins. E. L. (2005). The political economy of cross-scale networks in resource co-management. Ecology and Society 10(2): 9.

Agrawal, A. and Perrin, N. (2008). Climate adaptation, local institutions, and rural livelihoods. IFRI Working Paper, W081-6. International Forestry Resources and Institutions Program, University of Michigan.

Ahmad, Q. K., Biswas, A. K.. Rangachari. R. & Sainju. M. M. (2001). A framework. In Ganges-Bralmmputra-Meghna Region: A Framework for Sustainablv Development. In Ahmad, Q. K.. Biswas. A. K.. Rangachari. R. & Sainju. M. M. (eds). Dhaka University Press Limited. Dhaka, Bangladesh, pp. 1-29.

Ali khan, M., Kumar, A. and Vijaya Lakshmi, K (2012). Applying information for adapting India agriculture sector in Bundelkhand, India. Available online at <http://www.devalt.org/pdf/applying_information_for_adapting_india_agriculture_sector.pdf>

Amarsinghe, U., Xenarios, S.,Bharati, L., Xueliang, C.,Qureshi, A.S.,Shah, T.,Mukherji, A., Sharma, B.,Ambili, G.K., Matin, M., Singh, R., Brooks, A.,Giasuddin, M.,Avila, S.H. (2008). Indo-Gangetic Basin Annual Report 2008. International Water Management Institute, New Delhi, India.

Bakker, M. H. (2009). Transboundary River Floods and Institutional Capacity. *Journal of the American Water Resources Association*, *45*(3), 553-566.

Bangura KS, Lynch K, Binns JA. 2013. Coping with the impacts of weather changes in rural Sierra Leone. International Journal of Sustainable Development and World Ecology. 20(1): 20-31.

Barrios, S., Bertinelli, L., and Strobl, E. (2007). Trends in rainfall and economic growth in Africa: A neglected cause of the African growth tragedy. The Review of Economics and Statistics, 92, 2, 350-366.

Basher, R. (2006). Global early warning systems for natural hazards: Systematic and people-centered. Phil Trans R Soc. 364, 2167–2182.

Berman, R., Quinn, C., Paavola, J. (2012). The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. Environmental Development, 2, 86-100.

Bhadwal, S., Groot, A., Balakrishnan, S., Nair, S., Ghosh, S., Lingaraj, G.J., van Scheltinga, C. T., Bhave, A. and Siderius, C. (2013). Adaptation to changing water resource availability in Northern India with respect to Himalayan Glacier retreat and changing monsoons using participatory approaches. *Science of The Total Environment* (http://dx.doi.org/10.1016/j.scitotenv.2013.05.024)

Castle, E.N. (2002). Social capital: An interdisciplinary concept. *Rural Sociology* 67(3): 331-349.

Chand, R. and Raju, S.S. (2009). Dealing with Effects of Monsoon Failures. *Economic and Political Weekly*, 44, 41/42, 29-34.

D'Souza, R. (2006). Drowned and dammed: Colonial capitalism and flood control in eastern India (1803-1946). New Delhi: Oxford University Press.

Dell, M. Jones, B.F. and Olken, B.A. (2008), Climate Change and Economic Growth: Evidence from the Last Half Century, National Bureau of Economic Research, Cambridge.

Deschenes, O. and Greenstone, M. (2007). The economic impacts of climate change: evidence from agricultural output and random fluctuations in weather, American Economic Review 97(2): 354-385.

Deshingkar, P., Kumar, S., Chobey, H.K. and Kumar, D. (2006). The Role of Migration and Remittances in Promoting Livelihoods in Bihar. Overseas Development Institute, London.

Dixit, A. (2009). Kosi Embankment Breach in Nepal: Need for a Paradigm Shift in Responding to Floods. Economic and Political Weekly, 44, 6, 70-78.

Dixit, A., Upadhya, M., Pokhrel, A., Dixit, K. M., Rai, D.R. and Devkota, M. (2007a). Flood Disaster Impact and Responses in Nepal Tarai's Marginalised Basins, in: Working with the Winds of Change. Towards Strategies for Responding to the Risks Associated with Climate Change and other Hazards. M. Moench, Dixit, A, (eds), ProVention Consortium, Institute for Social and Environmental Transition-International and Institute for Social and Environmental Transition-Nepal, second edition, Kathmandu, 2007, chapter 6, pp. 119 -157.

Dulal, H. B., Brodnig, G., Onoriose, G. and Thakur, H. (2010). Capitalising on Assets: Vulnerability and Adaptation to Climate Change in Nepal. World Bank, Washington, DC.

Fankhauser, S., Smith, J. B., & Tol, R. S. (1999). Weathering climate change: some simple rules to guide adaptation decisions. Ecological economics, 30(1), 67-78.

Food and Agriculture Organization (FAO) (2011). Ganges-Brahmaputra-Meghna river basin. Irrigation in Southern and Eastern Asia in figures – AQUASTAT Survey – 2011. Rome: FAO.

Glantz, M.H., ed. (2009) Heads Up! Early Warning Systems for Climate-, Water-, and Weather-Related Hazards. United Nations University Press, 228 pp.

Gorakhpur Environmental Group (GEG) (2008). Climate change adaptation in India. Gorakhpur: Gorakhpur Environmental Group.

Government of Bihar (GoB) (2012). Economic Survey 2010-11, Ministry of Finance, Government of Bihar, Patna.

Helmke, G. and Levitsky, S. (2004). Informal institutions and comparative politics: a research agenda. Perspectives on Politics, 2, 725–740.

Heltberg, R. and Siegel, P.B. and Jorgensen, S.L. (2009). Addressing human vulnerability to climate change: Toward a `no-regrets' approach, Global Environmental Change, 19, 89-99.

Hill, D. (2006). The Politics of Water in South Asia, *Transforming Cultures*, 1, 2, 1-24.

IECN (2008). Collecting baseline data for climate change adaptation in Omusati Region, Namibia , Windhoek, Namibia: Integrated Environmental Consultants Namibia.

ISET-Nepal (2008). Climate Adaptation in Asia: Knowledge Gaps and Research Issues in South Asia. Kathmandu: ISET-Nepal.

Jha, P. and Acharya, N. (2012). Expenditure on the Rural Economy in India's Budget since the 1950s: An Assessment', Review of Agrarian Studies 1.2, http://ras.org.in/index.php?citation=expenditure_on_the_rural_economy_in_indias_budgets_since_the_ 1950s (accessed 28 July 2013)

Kumar, S. (2010). Industrial area and climate change: A case study from Rudrapur development block. In Pragya D. Varma (Eds.) Reflections of Climate Change Leaders from the Himalayas: Case Studies Detailed. LEAD India, New Delhi.

Kumar, V., Kumar, R., Verma, Jha, R., Chandrashekhar and Poddar, P. K. (2012). Floods in North Bihar: A Recurrent Source of Conflicts. In Prasad Eklavya, K. J. Joy, Suhas Paranjape, Shruti Vispute, (Ed.), Agony of Floods: Flood Induced Water Conflicts in India, Pune: Forum for Policy Dialogue on Water Conflicts in India.

Lebel L., Manuta J.B., Garden P. (2011). Institutional traps and vulnerability to changes in climate and flood regimes in Thailand. Regional Environmental Change 11: 45–58. Somanathan

McDevitt, A. (2012). Topic Guide on Climate Change Adaptation. Governance and Social Development Resource Centre (GSDRC), International Development Department, College of Social Sciences, University of Birmingham, UK.

Milman, A., Bunclark, L., Conway, D., & Adger, W. N. (2013). Assessment of institutional capacity to adapt to climate change in transboundary river basins. *Climatic Change*, 1-16.

Ministry of Urban Development (1997). Vulnerability Atlas of India (Earthquake, windstorm and flood hazard maps and damage risk to housing), Building Materials & Technology Promotion Council, Government of India.

Mishra, A., Singh, R., Raghuwanshi, N.S., Chatterjee, C., and Froebrich, J. (2013). Spatial variability of climate change impacts on yield of rice and wheat in the Indian Ganga Basin. Science of The Total Environment (http://dx.doi.org/10.1016/j.scitotenv.2013.05.080)

Moench, M. and A. Dixit, Eds. (2004). Adaptive Capacity and Livelihood Resilience: Adaptive Strategies for Responding to Floods and Droughts in South Asia. Institute for Social and Environmental Transition-International, Boulder; Institute for Social and Environmental Transition-Nepal, Kathmandu.

Nepal Climate Vulnerability Study Team (NCVST) (2009). Vulnerability Through the Eyes of the Vulnerable: Climate Change Induced Uncertainties and Nepal's Development Predicaments. Institute for Social and Environmental Transition-Nepal (ISET-N), Kathmandu, Nepal.

Osbahr, H., Twyman, C., Adger, W. N. and Thomas, D. S. G. (2010). Evaluating successful livelihood adaptation to climate variability and change in southern Africa. *Ecology and Society,* 15, 2, 27.

Osberghaus, D., Finkel, E., & Pohl, M. (2010). Individual adaptation to climate change: the role of information and perceived risk. ZEW, Zentrum für Europäische Wirtschaftsforschung.

Ostrom, E. (2005). Understanding Institutional Diversity. Princeton, NJ: Princeton University Press.

Pande, A. (2012). Flash Floods in Eastern UP Hill Rivers Flood the Low Lying Region of Eastern Uttar Pradesh Causing Annual Distress Migration. In Prasad Eklavya, K. J. Joy, Suhas Paranjape, Shruti Vispute, (Ed.), Agony of Floods: Flood Induced Water Conflicts in India, Pune: Forum for Policy Dialogue on Water Conflicts in India.

Patnaik, U. and Narayanan, K. (2010). Vulnerability and Coping to Disasters: A Study of Household Behaviour in Flood Prone Region of India. MPRA Paper No. 21992. Available online at < http://mpra.ub.uni-muenchen.de/21992/>

Patwal, B. (2010). A Himalayan village under climate change microscope: A case study. In Pragya D. Varma (Eds.) Reflections of Climate Change Leaders from the Himalayas: Case Studies Detailed. LEAD India, New Delhi.

Plummer, R. and Armitage, D. (2007). A resilience-based framework for evaluating adaptive comanagement: linking ecology, economics and society in a complex world. Ecol. Econ. 61:62–74.

Prabhakar, S. V. R. K. and Shaw, R. (2008). Climate change adaptation implications for drought risk mitigation: a perspective for India. *Climatic Change*, 88:113–130.

Rahaman, M. (2009). Integrated Ganges basin management: Conflict and hope for regional development. *Water policy*, *11*(2), 168-190.

Ramaswamy, K. V. (2007). Regional Dimension ofGrowth and Employment. Economic & Political Weekly, 49, 47-56.

Ranganathan, C. R., Palanisami, K., Kakumanu, K. R., & Baulraj, A. (2011). Mainstreaming the Adaptations and Reducing the Vulnerability of the Poor due to Climate Change. Asian Development Bank Institute Working paper no 333. Tokyo: Asian Development Bank Institute.

Sander-Regier, R., McLeman,R., Brklacich, M., and Woodrow, M. (2009). Planning for climate change in Canadian rural and resource-based communities. Environments Journal, 37, 1, 35-56.

Serrao-Neumann, S., Di Giulio, G. M., Ferreira, L. C., & Low Choy, D. (2013). Climate change adaptation: Is there a role for intervention research?. Futures, 53, 86-97.

Sharma, B. R., Amarasinghe, U. A. & Sikka, A. (2008). Indo-Gangetic River Basins: Summary Situation Analysis. New Delhi: International Water Management Institute.

Sinha, R., Burton, M., and Tiwari, G. (2012). Strengthening the institutional framework for flood and water resources management in Bihar: Developing a strategy for reform (Phase I). International Growth Center Working Paper. London: London School of Economics.

Skoufias, E., Rabassa, M., Olivieri, S., and Brahmbhatt, M (2011). The Poverty Impacts of Climate Change. Poverty reduction and economic management network (PREM) Economic premise no. 51, Washington D.C: The World Bank.

Somanathan, E., and Somanathan, R. (2009). Climate Change: Challenges Facing India's Poor. Economic & Political Weekly, XLIV, 31, 51-58.

Stern, N. (2007). The Economics of Climate Change: The Stern Review. Cambridge University Press.

Thakur, P.K., Laha, C. and Aggarwal, S. P. (2012). River bank erosion hazard study of river Ganga, upstream of Farakka barrage using remote sensing and GIS. Natural Hazards, 61:967–987.

Tir, J., & Stinnett, D. M. (2012). Weathering climate change: Can institutions mitigate international water conflict?. *Journal of Peace Research*, *49*(1), 211-225.

Tol, R. (2002). Estimates of the damage costs of climate change-part II: dynamic estimates, Environmental and Resource Economics, 21:1, 135-160.

Tol, R.S.J., Downing, T. E., Kuik, O. J., Smith, J. B. (2004). Distributional aspects of climate change impacts. Global Environmental Change, 14: 259–272.

Tripathi, A. (2010). People's Perception on Climate Change: A Case Study of Indo-Gangetic Region. In Pragya D. Varma (Eds.) Reflections of Climate Change Leaders from the Himalayas: Case Studies Detailed. LEAD India, New Delhi.

Wolf, A. (2009) A long-term view of water and security: international waters, national issues, and regional tensions. J Contemporary Water Research and Education 142, 1: 67–74.

World Bank (1999). Intersectoral water allocation, planning and management. Washington, D.C.: World Bank.

World Bank (2006). Managing Climate Risk: Integrating Adaptation into World Bank Group Operations. Washington DC: World Bank.