Living Rev. Landscape Res., **8**, (2014), 3
http://www.livingreviews.org/lrlr-2014-3
doi:10.12942/lrlr-2014-3

River Bank Erosion Induced Human Displacement and Its Consequences

Tuhin K. Das
Planning and Development Unit, Jadavpur University
Kolkata 700 032, India
email: tuhin22@hotmail.com

Sushil K. Haldar
Department of Economics, Jadavpur University
Kolkata 700 032, India
email: sushil.haldar@gmail.com

Ivy Das Gupta
Department of Economics, Bhowanipur Education Society College
Kolkata 700 020, India
email: ivygupta@gmail.com

Sayanti Sen
Department of Geography, Bangabasi College
Kolkata 700 009, India
email: sayantisen_ju@yahoo.co.in

Accepted: 23 September 2014
Published: 27 October 2014

Abstract

River bank erosion is one of the critical public concerns in the world at least in some countries. River bank erosion has a long-term consequence on human life. The victims are compelled to displace as they become destitute. On the other hand, the altered flow of rivers (natural or man-made) due to bank erosion also effects river ecology. In this review paper some cases of river bank erosion and their impacts are discussed. The Indian scenario is reviewed in detail to understand the gravity of the problem. It is observed that after forced human migration due to bank erosion, displaced people face economic insecurity due to loss of agricultural land and become unemployed. The victims also suffer from social insecurity due to deprivation of civic rights, health insecurity due to lack of basic infrastructure, etc. All these insecurities caused by forced displacement lead to deprivation, destitute, fragility and increased vulnerability of the families.

Keywords: forced migration, displacement, river bank erosion, insecurity, policy

Imprint / Terms of Use

Living Reviews in Landscape Research is a peer reviewed open access journal published by the Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany. ISSN 1863-7329.

Because a *Living Reviews* article can evolve over time, we recommend to cite the article as follows:

Tuhin K. Das, Sushil K. Haldar, Ivy Das Gupta and Sayanti Sen,
"River Bank Erosion Induced Human Displacement and Its Consequences",
Living Rev. Landscape Res., **8**, (2014), 3. URL (accessed <date>):
http://www.livingreviews.org/lrlr-2014-3

The date given as <date> then uniquely identifies the version of the article you are referring to.

Article Revisions

Living Reviews supports two ways of keeping its articles up-to-date:

Fast-track revision. A fast-track revision provides the author with the opportunity to add short notices of current research results, trends and developments, or important publications to the article. A fast-track revision is refereed by the responsible subject editor. If an article has undergone a fast-track revision, a summary of changes will be listed here.

Major update. A major update will include substantial changes and additions and is subject to full external refereeing. It is published with a new publication number.

For detailed documentation of an article's evolution, please refer to the history document of the article's online version at http://www.livingreviews.org/lrlr-2014-3.

Contents

List of Tables

1 Introduction

People migrate for different reasons, and in different directions. They may migrate from one continent to another continent or from one country to another country within the same continent (external migration), or from one state to another state within the same country or from one district to another district in the same state or from rural area to urban area within the same district (internal migration). Again, migration, whatever might be the direction, can be voluntary or involuntary (forced migration) according to the reasons. Driving force of migration is either the pull factor or the push factor or both. Generally, pull factors are the reasons for voluntary migration (Bell *et al.*, 2010). Pull factors are commonly depicted as better job opportunity, improved life style, better civic amenities, environment friendly climate and many others.

1.1 Push factors for forced migration

Reasons for involuntary or forced migration are mainly push factors. Push factors are natural disasters, war, communal riot, evacuation for so-called development activities, etc. A forced migrant is often called an internally displaced person when he or she is forced to leave his or her home region because of unfavourable conditions (political, social, environmental, etc.) but does not cross any boundary.

Forced migration (including internal displacement) is always a concern as it implies the existence of humanitarian crisis, having many complex manifestations (Zetter, 2012). The causes of forced migration are nothing new, although they vary in time, geographical location and different socioeconomic and political conditions. The major causes are natural or man-made disasters, social or political conflicts and development policies. The 64th Round of National Sample Survey conducted during July 2007 to June 2008 gave some information on the nature of human migration in India (NSS, 2012). According to the survey results more than four percent of the total migrants are forced migrants (Figure 1), and nearly twenty-four percent of the total forced migrations are due to natural disasters.

1.2 Purpose of the study

River bank erosion is one of the natural disasters that causes displacement of inhabitants who previously lived near river banks. Many of those erosion-distressed people loose not only their homes, means of livelihood and assets but also their previous identity, and they, therefore, often try hard for recognition of an identity (Das, 2010). Flood and river bank erosion are almost regular phenomena throughout the world. Between these two types of disaster, the loss due to flood is temporary, but the loss of land due to river bank erosion is permanent and has a long term impact on the economy. Once residential and productive land is lost due to river bank erosion, it can hardly be replaced. Generally, institutional compensation mechanisms are not available for erosion distressed people. This undesirable experience calls for appropriate policy, so that the conflict between river dynamics and human settlement could be minimized.

The purpose of this study is to understand the gravity of the river bank erosion problem through a literature survey. There are numerous scholarly articles and research papers on river bank erosion. Major contributions of these articles address river morphology and impact of human intervention. Nevertheless, few studies have been devoted to impacts of erosion on the lives and livelihoods of affected people. This review article is a systematic study covering the river bank erosion problem in general with examples in different parts of the world, erosion caused by human intervention, and impact of erosion on human life. Major emphasis has been given to socio-economic impact of erosion with special reference to India. Some examples on impact of erosion in other countries have also been included in the discussion where they are available. This study reveals to some

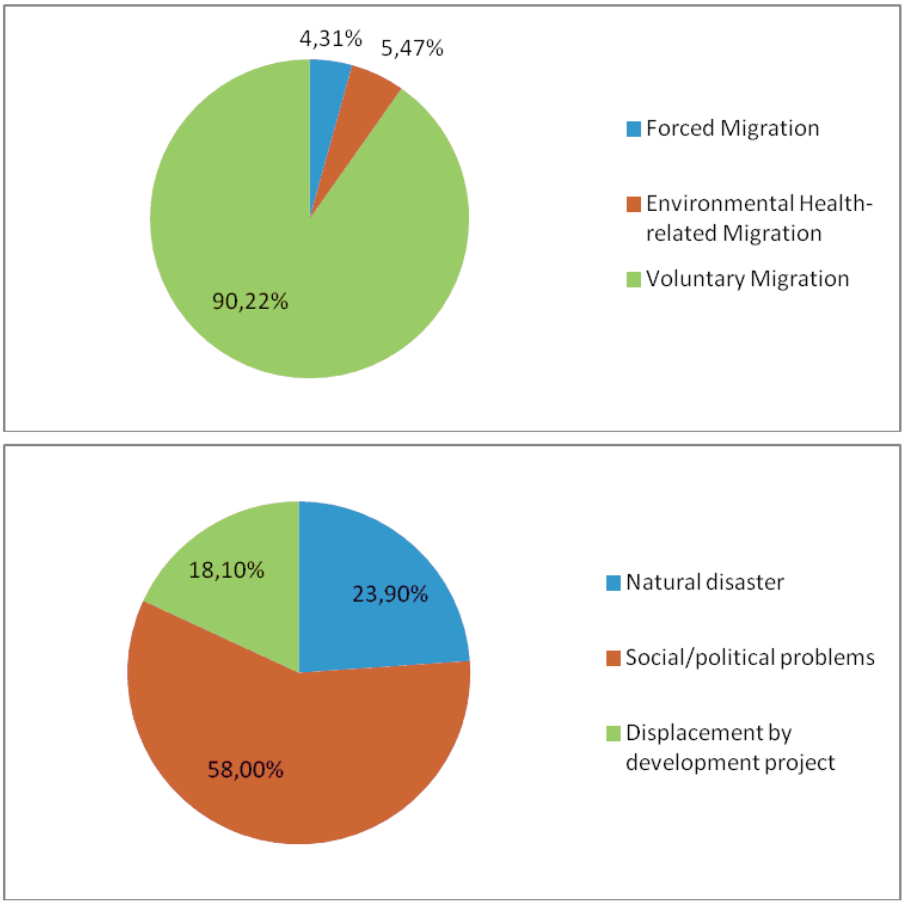


Figure 1: Distribution of migrants by reasons. (Source: NSS, 2012)

extent the state of the art of the literature on this very important topic, and the aspects of the problem where they could be developed for appropriate policy formulation in mitigating conflicts between river dynamics and economic development.

2 River Dynamics and Erosion

Rivers are systems in dynamic equilibrium. It balances water flow and sediment transport. When river channels are altered under naturally dynamic hydrologic conditions, the river readjusts itself with respect to dimension, profile and pattern to reach its former balance or equilibrium (Couture, 2008). Free-flowing rivers tend to reach a state of equilibrium by a process of erosion and deposition. Erosion at one location is roughly balanced by deposition at another (CRJC, 1996). Diverse bank erosion processes occur throughout the river network starting from upper reach to lower reach. In the upper reach, near its source, the river has a huge amount of material to cut through to reach base level, so it primarily erodes downwards, creating a steep-sided v-shaped valley. In the middle reach the river continues to cut downwards but it is also starting to cut sideways or laterally. Once the river has reached the lower course (i.e., lower reach) and is nearing the sea, the river has almost reached its base level, so most of its erosive energy is concentrated on cutting laterally, creating features such as meanders.

Figure 2 illustrates the occurrences of bank erosion along an idealised river network. The bank erosion process in several sections of the river network is influenced by the size of the channel, discharge, and flow strength (Florsheim *et al.*, 2008). So, bank erosion is an ongoing natural process. Even at rivers that are assumed to be stable, their well defined channels shift over a long period of time through the processes of erosion and sedimentation.

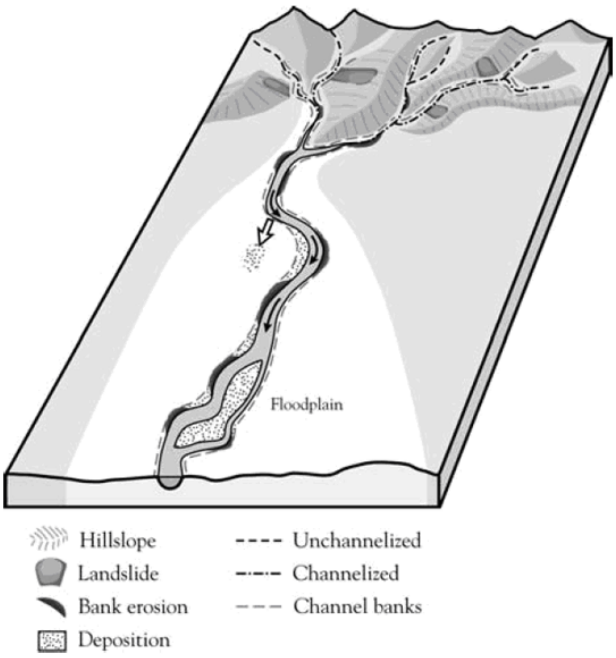


Figure 2: Bank erosion in different sections of an idealised river network. Image reproduced with permission from Florsheim *et al.* (2008), copyright by OUP.

2.1 Mid-channel bars

During the process of erosion and sedimentation, new fragile lands emerge in between the flow channels of some rivers. These lands are called mid-channel bars or braid bars. Most braid bars do not remain stable and have a longitudinal migration. They emerge, submerge and re-emerge continuously. This phenomena has been explained as follows: "accumulated silt leads to the rise of a sand-bed in the interfluves (the region of higher land between channels); being obstructed by this bed the river then divides into two channels with the sand-bed in between. This makes the flow oblique. The flow gets obstructed with the river-bank eventually causing river-bank erosion. The eroded silt and sediment is carried by the river which again accumulates to form a new sand-bed, and the cycle continues" (Mukherjee, 2011, p. 16). However, vegetation succession on mid-channel bars can increase the stability of these semi-stable lands (Coulthard, 2005).

3 Human Intervention and Erosion

River bank erosion is not a serious problem so far as no human settlement is present. But this natural hazard becomes a disaster when riparian buffers are not maintained, and human settlements are situated too close to eroding banks. Moreover, anthropogenic activities along the river stretch disturb the equilibrium of the river dynamics and accelerate the rate of bank erosion. Anthropogenic activities like deforestation, gravel mining, construction of dams and bridges, artificial cut offs, bank revetment and land use alterations change the morphology and natural dynamics of rivers (Kondolf, 1997). Human activities are stronger with respect to changing river dynamics than natural events as floods, droughts and landslides (Yamani *et al.*, 2011).

3.1 Deforestation

It has been observed that bank erosion has increased by instability of the river behaviour due to deforestation and inadequate land use in the upper reach, which ultimately led to excessive sediment load into the rivers (Arohunsoro *et al.*, 2014; Davinroy *et al.*, 2003). Vegetation stabilizes banks primarily by increasing shear strength of the soil, reducing water velocity, and armoring the bank (Ott, 2000). Of course, the ability of vegetation to stabilize a bank is dependent upon factors such as plant vigor, density and rooting depth, etc. Some studies revealed that bank erosion in the upper reach was primarily due to destruction of riparian vegetation by people's access and the effect of bridge constrictions on high flow, and secondarily to poorly installed channel revetments (Madej *et al.*, 1994).

3.2 Dam and bridge construction

Dam construction (mainly in the middle reach) is another widespread impact on river systems around the world. More than fifty percent of the world's largest river systems (172 of 292) have been affected to some extent by dams (Nilsson *et al.*, 2005). Issues such as erosion and sedimentation have been carefully analysed for many dams around the world. Among them the High Aswan Dam in Egypt received considerable environmental and social attention. Like other dams, Aswan Dam contributes positive benefits to the country: generation of hydropower, increased industrial activities, increase in agricultural land, as well as crop intensification and diversification, etc. But at the same time it caused (a) physical impacts: changes in the level, velocity and discharge of the flow in the Nile River both upstream and downstream of the dam, changes in soil salinity and water logging, erosion of the river banks, beds and delta, sedimentation in the river and Lake Nasser, etc., and (b) biological impacts: changes in flora and fauna, implications for fish production, etc. (Biswas and Tortajada, 2012). However, it is claimed by some researchers that stable conditions have been achieved and erosion has almost stopped. This situation was achieved by limiting the amount of water flowing into Egypt to a maximum daily peak of 230 million cubic meters (Rushdi, 1996).

Erosion problem is also very significant in the case of Three Gorges Dam (TGD). The Three Gorges Dam has been constructed on the Yangtze River in China. It is one of the largest dams in the World. Like other rivers and dams, it has also been observed that severe erosion has occurred in the Yangtze River channels downstream of the dam in the post-TGD period. Since its operation in 2003, TGD has trapped nearly two-third of the sediment from upstream. As a result the downstream riverbed has been converted from deposition to erosion, in particular in the several hundreds of kilometres immediate to TGD (Yang *et al.*, 2007). One major cause of increased river erosion after construction of dams is that all the sediment being carried by river into the reservoir retains there. Then the water released through the dam is very clean and has no sediment (i.e., dam-induced decrease in sediment load along the downstream reaches). Clean water causes more erosion than sediment laden water because it can carry more sediment.

Sometimes structures like bridges cause bank erosion, although bridges ensure and facilitate the communication across the rivers conveniently. These structures may have unfavourable effects on the hydrology and morphology of the rivers. A case study showed how bridge piers constrict the adjacent areas of the river and ultimately result in bank erosion (Biswas, 2010). Surma is a meandering river in Bangladesh. During the study period (monsoon 2008) a bridge at Kazir Bazaar was under construction. Aerial photographs of the bridge location revealed that both the upstream and downstream the river was affected by severe bank erosion. Erosion affected the local economy by engulfing a fish market, rice mills and others. So, it was predicted that if a river becomes constricted by some human intervention, bank erosion might happen, which is not generally expected at the time of planning.

4 River Bank Erosion in the World

River channels can be classified into

- Straight – It is almost non-existent among natural rivers. Extremely short reaches of the river may be straight.
- Meandering – It a sinuous channel of river. A meander is formed when moving water in a river erodes the outer banks and widens its valley, and the inner part of the river has less energy and deposits silt.
- Braided – It is a channel that consists of a network of small channels separated by small and often temporary islands called braid bars. Braided channels occur in rivers with high slope and/or large sediment load.
- Anastomosing – Like braided channel branching of small channels from a single occurs at first, but after that separated channels again merge.

The controlling factor on river development is the amount of sediment that the river carries. Once a water way crosses a threshold value for sediment load, it will convert from a single channel meandering river to a braided channel (Leopold and Wolman, 1963). Bank erosion, however, occurs mainly in meandering rivers. In meandering rivers, river-channel migration takes place through erosion of the cut bank and deposition on the point bar. River-channel migration is the lateral motion of an alluvial river channel across its floodplain due to processes of erosion of and deposition on its banks and bars (Wikipedia definition). Meandering of a river is caused by nature but sometimes by human activities. Due to natural or human or both activities, most rivers in the world are subject to meandering along with bank erosion. But in view of devastation, the Mississippi-Missouri River System of North America, Ganges, Brahmaputra and Mekong Rivers of Asia, Amazon River of South America, and River Nile of Africa are most important among them.

4.1 Americas

The larger the drainage area of a meandering river, the faster is its channel migration. Figure 3 shows the relationship between the river channel migration rate and the drainage area of the river (Hudson and Kesel, 2000). However, the rate of channel migration is not same for all rivers with the same drainage area. This happens because the rate of migration also depends on the material that constitutes the river banks. This is exactly what happens in the case of Guadalupe River (a meandering river) in the United States, where the rate of erosion is less than expected (Gantt and Humberson, 2004).

Figure 3: Relationship between river channel migration rate and drainage area of the Lower Mississippi River. Image adapted from Hudson and Kesel (2000).

Both Mississippi and Missouri Rivers have been facing meander migration. It is a process in which water flow erodes soil on one bank and deposits it on the opposite bank, i.e., a gradual shift of bank line occurs over time (Briaud *et al.*, 2007). The Missouri River bank is eroding at a high rate on the Lower Brule Reservation central South Dakota in the United States. The Lower Brule Sioux Tribe (LBST) has estimated that the reservation is losing its shoreline in some locations at a rate of approximately 8 feet per year (Neitzert *et al.*, 2012). The long-term impact of bank erosion on cultural and environmental losses is under investigation.

A great amount of channel migration of the Mississippi River has occurred over the last 200 years (Maynord and Martin, 1996). In the early 1800s, U.S. Army Corps of Engineers (USACE) began removing snags and dredging the main channel of the Mississippi River and later the main channel of the lower Missouri River was subject to river engineering like channel straightening, dike construction, etc. to increase the ease and safety of river navigation (Alexander *et al.*, 2012). That effort made navigation easier and safer for the time being, but that human-induced channel migration caused substantial bank erosion. The Modification of Mississippi River is still continuing for better navigation. However, recognising the "devastating damage done by modifications to the Upper Mississippi River and the importance of wildlife and people living along the river", the U.S. Congress authorized the Mississippi River Restoration Ecosystem Management Program in 1986 (Prairie Rivers Network, 2012).

The Illinois River is a major tributary of the Mississippi River in the United States. Most of the drainage area is situated in the State of Illinois. The river has been changing its course through bank erosion since the year 1939 mainly due to construction of locks and dams to facilitate the movement of river traffic (Bhowmik, 2008). Bank erosion has been occurring because of a number of natural forces and human induced activities. The analysis has shown that about 74 percent of the bank erosion sites were due to seepage flows. About 28 percent of the bank sections have shown the evidence of river traffic induced impacts. Also there are other factors like eddy currents, disturbed flows due to exposed tree roots, surface drainage, etc. that caused erosion.

4.2 Australia

Bank erosion at the meander bend site due to river navigation has been observed in other countries too (Laderoute and Bauer, 2013). An example is the lower Gordon River in Tasmania in Australia. The wakes generated by river traffic are the main driver of bank erosion, and there people have concerns for quality of the drinking water, loss of property, and loss of aquatic habitat. The wakes generated from large vessels in earlier decades were considered negligible or acceptable. But the effects have become noticeable after the introduction of high-speed craft (HSC) that are capable of carrying vehicles and passengers. The adverse effects of bank erosion by boats like large catamarans, which are used as industrial ferries, are mainly due to their high speeds and large size, producing longer wakes than conventional ships (Parnell *et al.*, 2007). The lower Gordon River is a river being severely impacted by boat wake erosion. For this river there are regulations that permit a maximum wave height for any vessel passage. However, monitoring and experimental testing has demonstrated that most of these regulations are not very effective against erosion as recreational traffic is not being subject of these regulations although it has a disproportionally large impact (Bradbury, 2005).

4.3 Europe

To regulate the flow and to facilitate navigation, sometimes rivers were not allowed to meander in Europe, especially in urban areas. But this process of straightening along with drainage and dredging had impact on most small rivers and brooks (Bech, 2006; Pearce, 2013). Early phases of river modifications protected the settlements against flood and provided new fields for agriculture, but it did not reduce the risk of bank erosion. Straitening of rivers caused bank erosion when a bank protection failure had occurred resulting in significant damages and financial losses. Moreover, the modification of river banks has threatened the ecology of rivers in many areas of Europe.

Table 1: Characteristics of major rivers in Hungary before and after channel and floodplain development 1782 – 1950. (Source: Szalai *et al.*, 2013)

Rivers	Length in km	
	Before development	After development
Danube	494	417
Tisza	1419	966
Drava	409	232

An example is the bank erosion of Danube River (Jones *et al.*, 2007). It is the second longest river (2850 km) in Europe and an important transport route. Danube River is historically described as gravel dominated, laterally active river with elements of both braided and meandering channel types (SEDDON). Danube River basin supports important economic activities and so the banks of the river were modified to facilitate navigation (Table 1). But it did not work as perfectly as it was envisaged. In Hungary, rivers were modified and shortened for flood control and navigation.

Now the Middle Danubian loess bluff is at danger of bank erosion, more than ten settlements are at risk and a large amount of municipal and industrial infrastructure has already been damaged (Szalai *et al.*, 2013). Archaeological sites also are at risk along Bulgarian Danube bank because of erosion (Nikolova *et al.*, 2012). Additional, Danube River is the border line between Serbia and Croatia. Serbian farmers lost their arable lands, which they occupied on the left river banks in Serbia 50 years ago, because of very intensive lateral erosion and vice versa for Croatian farmers (Dragićević *et al.*, 2013).

Now most of the countries in Europe realise the need for restoration of rivers to their natural course and application of bioengineering techniques for river bank erosion control (Evette *et al.*, 2009; Donat, 1995). The idea is to allow natural sediment transport systems with acceptable and manageable erosion and deposition rates. The restoration of rivers, however, is not simple as they encompass cities, industries, hydroelectric dams, etc. For the need of restoration, the cities might have to move, hydroelectric plants would have to be closed, and industries would have to be relocated.

4.4 Africa

The Nile is the longest river (6650 km) in the world and passes from south to north through eleven countries in Africa, namely Ethiopia, Eritrea, Sudan, Uganda, Tanzania, Kenya, Rwanda, Burundi, Egypt, Democratic Republic of the Congo and South Sudan. The Nile meanders through a watershed that is to more than 30 percent arid (Wong *et al.*, 2007). The lateral erosion on the Nile river banks in Egypt is another example of river bank erosion. Nile river meandering and the associated processes of bank erosion and deposition accelerated with human activities. Erosion has its impact on both economy and environment. Bank erosion has caused decrease in agricultural lands which in turn has reduced the agricultural production (Ahmed and Fawzi, 2009). It has been recommended to protect the river bank from further movement and erosion. The recommendations are

- to weaken the secondary currents created by the river bends,
- to regularly monitor the river banks and islands and measure the rates of erosion and deposition, and
- to monitor sand bars and subsurface islands and to identify with flash lights to mitigate navigation problems.

4.5 Asia

The Mekong River flows over 4800 km through six countries, namely China, Myanmar, Laos, Thailand, Cambodia, and Vietnam (cf. MRC, 2010). The channel pattern of the Mekong is meandering with low sinuosity (Wood *et al.*, 2008). The lower Mekong basin includes Laos, Thailand, Cambodia, and Vietnam. The river bank zone in the basin provides places for human settlement and also consumption goods and inputs to production (Miyazawa *et al.*, 2008). Thus, bank erosion in Mekong River not only displaces population but also brings about loss of household income sources. It was reported that about 600 families in Tonpheung district of Bokeo province in Vietnam were forced to migrate from their homes because of river bank erosion over the past three years (Pongkhao, 2008). Villagers had been moving further inland, away from the Mekong River, to escape the problem. It was reported further that these people will be forced to move out again if the bank erosion process continues. Apart from the socioeconomic problem there is also a political problem. The political border between Laos and Thailand (about 1100 km long) is the deepest line (thalweg) of the Mekong river channel. But this political border has shifted due to excessive erosion of the Laos river bank. Moreover, the altered flow channel made an island that was once part of Laos is now part of Thailand (Brown, 1999). As it is a very sensitive issue, the two countries have agreed to settle the border problem.

The Yellow River (or Huang He) is the second largest river in China after the Yangtze River. The river meanders for 5000 km through nine provinces and a watershed of about 680 000 km^2. The river was called "China's Sorrow" because of frequent occurrences of flood along the river and sufferings of millions of people. The worst flood disaster in world history occurred in August 1931 along this river and killed an estimated 3.7 million people. The Sanmenxia Dam on the Yellow River was constructed in 1960 to prevent floods, provide water for irrigation, and produce hydroelectric power. However, significant silt loads in the Yellow River were not adequately considered in the planning stage. The reservoir water basin was largely filled with silt only four years after construction, and the reservoir was subsequently taken out of operation. In subsequent years three more dams were constructed: Liujiaxia Dam in 1968, Longyangxia Dam in 1985, and Xiaolangdi Dam in 1997. Two significant bank erosions were observed: one during 1961 to 1964 associated with completion of Sanmenxia Dam, and the other during 1998 to 2004 associated with completion of Xiaolangdi Dam (Ma *et al.*, 2012).

Bangladesh, a riverine country, is suffering heavily from river bank erosion. Thousands of Bangladeshi population were forced to migrate from their place of origin due to bank erosion. The major rivers of Bangladesh are Padma River, Jamuna River and Meghna River. These three rivers have eroded several thousand hectares of floodplain, several Kilometers of roads and railways and have displaced people. The Ganges-Padma River in Bangladesh is a meandering river. But lately, the Ganges-Padma becomes a braided river because of high sediment transportation by Jamuna and deposition of Ganges-Padma river bed (Yeasmin and Islam, 2011). During 1970 – 2000, two major rivers of Bangladesh, Padma and the Jamuna eroded 180 000 hectares of land and about 200 000 people were displaced (Islam and Rashid, 2011). Displaced people experienced substantial socio-economic impoverishment and marginalisation because of forced migration and inequitable access to land and other resources (Mutton and Haque, 2004). Another erosion afflicted country in Asia is Myanmar. Erosion of river banks along the Irrawaddy and Chindwin rivers in Magwe Division, central Myanmar is common during the rainy season and riverine communities are frequently compelled to migrate (Mann, 2013). Some families moved several times during 1993 to 2012 and lost everything. In spite of government's initiative little has been done to prevent further erosion.

India is also a land of rivers like other Asian countries. Seven major rivers along with their numerous tributaries make up the river system of India. Floods, which are recurrent phenomena in India, cause severe bank erosion. Two rivers that are subject to severe bank erosion are River Ganges and Brahmaputra River, a braided river (Sarma, 2013; Mili *et al.*, 2013; Phukan *et al.*, 2012). So far, various steps like bank embankment have been taken up for flood control. But erosion along the embankments and natural banks of the river systems is still a serious problem. Particular mention could be made of the erosion problem of the embankment systems in some states like Assam, Bihar, West Bengal, etc. (India-WRIS). Since the embankments are under serious erosion by the major rivers and their tributaries, criticism about existing embankments have emerged. Now there are distinctly two opposite views like in other countries, too (Planning Commission, 2011).

One opinion is that the problems of flood can be solved by removal of all the existing embankments and allowing natural bank erosion of rivers. The other is that the flood/erosion problems can be solved by constructing more and more streches of embankments and also by raising and strengthening them.

4.6 Impact of erosion on human life

All continents are more or less affected by river bank erosion. But its impact on population varies as the socio-economic conditions are different for different regions. Table 2 shows percentage of continent-wise displaced population in the world due to all types of natural disasters in the years 2010 and 2011. Worst sufferer was Asia and least sufferer was Oceania. The displacement was caused mainly by hydrological disasters, which include floods, storms, and wet mass movements. In 2010, the contribution due to hydrological disasters was nearly 85 percent (IDMC, 2011) and in 2011 it was more than 71 percent (IDMC, 2012). Rest of the human displacement was due to geophysical (earthquake, volcanic eruptions, etc.), meteorological (storms), climatological (extreme temperature, etc.) and biological disasters (epidemics, etc.).

Table 2: Human displacement in different continents (percent). (Sources: IDMC, 2011, 2012; WPDS, 2011)

Continent	Percentage of total displaced population in the world		Percentage of displaced population relative to the total world population	
	Year 2010	Year 2011	Year 2010	Year 2011
Africa	4.01	3.91	0.0246	0.0084
Americas	19.34	6.76	0.1186	0.0145
Asia	76.43	89.12	0.4685	0.1906
Europe	0.15	0.12	0.0009	0.0003
Oceania	0.07	0.09	0.0004	0.0002

4.7 Human vulnerability across the world

Landscape degradation, environmental and socio-economic impacts are observed in different countries at different scales due to river bank erosion. But quantitative information on socio-economic consequences of river bank erosion (viz., total human displacement, loss of occupation, loss of property, impact on health and education, etc.) for all the cases, however small it may be, is not available unlike at other natural disasters. Recently, few attempts have been made to collect and analyse data at household and community level. Such attempts are highly needed to quantify the human vulnerability due to river bank erosion, and in turn to formulate appropriate public policy.

One such study was the analysis of socio-economic consequences of the Kolubara river bank erosion in Serbia (Dragićević *et al.*, 2013). The analysis was in terms of land loss, land use changes and economic loss. The study area in this analysis had economic importance, and there was significant density of the agricultural population and settlements. Because of bank erosion in the study area, the farmers who had arable land on the river bank lost their land assets by the river. The loss of corn production was 3255 tons and of wheat production was 1271 tons till the year 2010. The level of production losses was steadily increasing over time. It was estimated that the total value of the permanent losses of arable land was 80 560 USD, and the total loss in agricultural production was 634 240 USD till 2010.

Erosion of the reservoir of the Three Gorges Dam and downstream Yangtze River banks is a threat to human settlement and to one of the world's biggest fisheries in the East China Sea. It is expected that more than four million people have been displaced due to construction of dam, downstream bank erosion and other environmental impacts (French, 2007). There is increasing concern that the people displaced due to construction projects and erosion face long-term risks of becoming poorer and are also threatened with landlessness, food insecurity, joblessness, and social marginalisation (Gleick, 2009).

The socio-economic impact becomes more severe when people are more vulnerable to natural disaster. This is what happens in Asia. High population density and poor economic condition of the people (Table 3) in Asia make consequences of natural disasters more devastating. A large section of population is bound to stay in high risk zones like banks of meandering rivers. This is a common scenario in almost all countries in Asia. In Bangladesh, the poor, small landowners who live near the river bank are the most affected victims of bank erosion. Bank erosion affects their well-being in terms of safety and shelter, as well as their sources of livelihood (Brouwer *et al.*, 2007). Riverbank erosion is bringing about unemployment, landlessness and poverty in every year, and is increasing over time. It has been supposed to be responsible for the unstable condition in the country (Rahman, 2013). In Indonesia, those who suffer most during floods are the low income, poor and informal settlers living along river banks and low-lying coastal areas that are most vulnerable to rising tides and increasing water levels (Romualdez, 2013).

Table 3: Population density and per capita income in continents. (Sources: WPP, 2011; WDI)

Continent	Population density (number/km^2)	Per capita GDP (US Dollar)
Asia	95.0	2941
Africa	33.7	1576
North America	22.1	32 077
South America	22.0	9024
Europe	72.5	25 434
Oceania	3.2	39 052

4.8 Relevance of vulnerability study in India

India has also the same experience. Poverty drives many residents to live at increasingly eroded river banks, and they are forced to internally migrate again and again. They live in unbearably humid river bank settlements (Jolly, 2013). However, poor people living on vulnerable river banks are prepared to withstand the impact of recurrent natural hazards (ISDR, 2008). Because of the severity of the river bank erosion in this region, we review the Indian problem in more detail to understand what the real issues are.

5 River Bank Erosion in India

The rivers in India (Figure 4) can be broadly divided into four regions related to erosion problems.

5.1 North West Region

The main rivers in this region are Sutlej, Beas, Ravi, Chenab and Jhelum, the tributaries of Indus, all flowing from the Himalayas. Compared to River Ganges and Brahmaputra River region, the flood and erosion problems are relatively low in this region. The major problem is that of inadequate surface drainage, which causes inundation and water logging over vast areas.

5.2 Central India and Deccan Region

The important rivers in this region are Narmada, Tapi, Mahanadi, Godavari, Krishna and Cauvery. These rivers have mostly well defined stable courses. They have adequate capacity within the natural banks to carry the flood discharge, except in the delta area. The lower reaches of the

Figure 4: Rivers in India. (Source: http://nroer.in/gstudio/resources/imagecollection/colln/35270/)

important rivers on the East Coast have been embanked, thus largely eliminating the flood and erosion problems.

5.3 Brahmaputra Region

This region consists of the rivers Brahmaputra and Barak and their tributaries covering seven states Assam, Arunachal Pradesh, Meghalaya, Mizoram, Northern parts of West Bengal, Manipur, Tripura and Nagaland. Out of its total length of 2880 km the Brahmaputra River flows 1625 km in Tibet as Tsangpo before entering India through Arunachal Pradesh. The river crosses Assam below Dhubri and enters Bangladesh where the river is known as Jamuna and where it flows for 337 km. Its tributaries in India are Dibang, Lohit, Dhansiri, Kameng, Raidak, Jaldhaka and Teesta rivers.

In India, state-wise the drainage area of the Brahmaputra River and its tributaries is shown in Table 4. The Assam and West Bengal portion of the Brahmaputra River basin are mostly plain areas, whereas Arunachal Pradesh, Meghalaya and Nagaland parts are mainly covered by mountain ranges, hills and narrow valleys. In India, among all Eastern and North-eastern states, Assam faces the most severe brunt of Brahmaputra bank erosion.

Table 4: Drainage area of the Brahmaputra River. (Source: MoWR, 1999)

States in India	Drainage area (km^2)	Percentage of state area in Brahmaputra River basin
Arunachal Pradesh	83 740	100.00
Assam	71 216	90.79
West Bengal	12 585	14.18
Meghalaya	11 780	52.52
Nagaland	10 895	65.71
Sikkim	7100	100.00

According to the records of the last century, the Assam valley portion of Brahmaputra River occupied around 4000 km^2 in the 1920s, which is now around 6000 km^2 (Phukan *et al.*, 2012). The satellite image estimation shows that the total land loss per year due to erosion of Brahmaputra ranges from 72.5 to 80 km^2/year during 1997 to 2007 – 2008 (Figure 5). Bank erosion has wiped out more than 2500 villages and 18 towns including sites of cultural heritage and tea gardens, affecting the lives of nearly 500 000 people.

5.4 Ganga (Ganges) Region

The River Ganges and its numerous tributaries cover the states of Uttaranchal, Uttar Pradesh, Jharkhand, Bihar, South and Central parts of West Bengal, parts of Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and Delhi (Figure 4). Even though the Ganges is a long river carrying huge discharges of up to 70 000 m^3/s, the erosion problems are confined to relatively few places. The flood and erosion problems are serious in the lower Ganges region, particularly in West Bengal.

The River Ganges enters West Bengal near Rajmahal in Jharkhand state and then it flows in a South-easterly direction within West Bengal (Figure 6). After flowing through Malda district it divides into two branches near North of Dhulian in the Murshidabad district. One branch enters Bangladesh as the Padma, while the other flows through West Bengal as the Bhagirathi River and Hooghly River in Southern direction. The Bhagirathi is the main river in West Bengal, which flows past the Murshidabad, Nadia, Burdwan and Hooghly districts and contributes to a dominant irreparable loss of land each year.

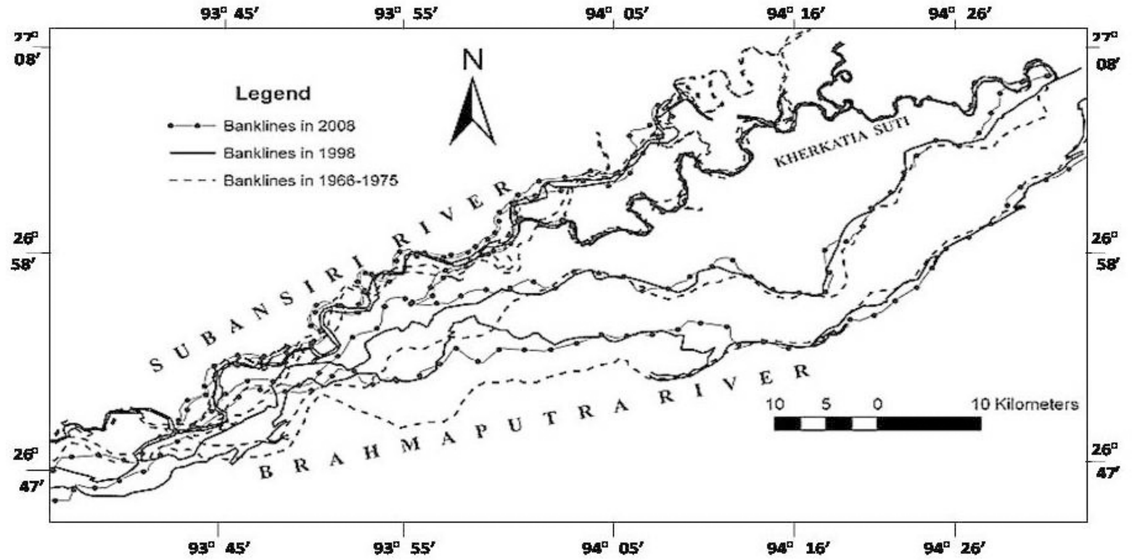
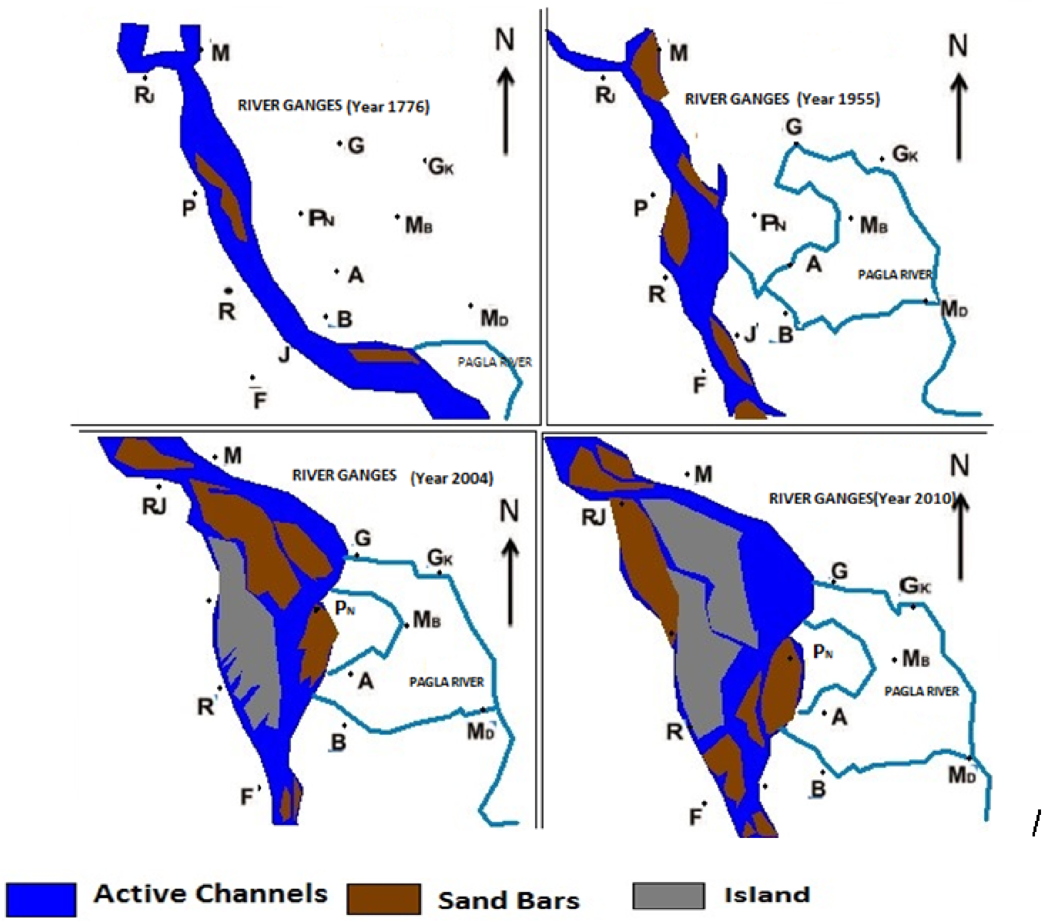


Figure 5: Erosion and fill-ups of Brahmaputra River form 1966 to 2008. Image reproduced with permission from Dutta *et al.* (2010).

Bank erosion is a common phenomenon in any uncontrolled channel of the deltaic tract. But the case of the River Ganges in West Bengal is quite different. The upstream is so clogged with sediment that the river is compelled to alter its course. The course of the Ganges along the Northern river-front of West Bengal has been fast changing due to unabated bank erosion, especially over the last few decades. The Ganges in Malda district in the upstream of Farakka Barrage has been undergoing extensive erosion along the left bank even though it has been strongly protected (Figure 7).

However, the erosion problem is not only restricted in the upstream section, it is also widespread throughout its course in West Bengal. One of the major reasons is Farakka Barrage. Farakka Barrage is a dam on the Bhagirathi River located in West Bengal state in India. It is located about 10 km from the border to Bangladesh. The dam was built to divert the Ganges River water into the Hooghly River during the dry season in order to flush out the accumulating silt, which was a problem at the Kolkata Port on the Hooghly River. Now it is well accepted that the intensity of the Ganges-bank erosion in West Bengal has increased after the construction of Farakka Barrage (Rudra, 2010). Official reports show that on an average 8 km^2 of land are engulfed annually by the river in West Bengal.

Figure 6: Course of river Ganga (Ganges) in West Bengal.



Note: RJ: Rajmahal, P: Phudkipur, R: Radhanagar, F: Farakka, M: Manikchak, PN: Panchanandpur, J: Jagannathpur, G: Gansaipur, A: Alinagar, B: Baishnabnagar, GK: Gopal Kagmari, MB: Mothabari, MD: Mahadipur

Figure 7: Channel configuration of River Ganges during the period 1776 to 2010 (all figures are not to scale). Image adapted from Sinha and Ghosh (2012).

6 Impact of River Bank Erosion

Impacts of river bank erosion are multifarious: social, economic, health, education and sometimes political. The first and foremost impact is social, i.e., homelessness due to land erosion which compels people to migrate (Figure 8). After forced migration they suffer from economic crisis, namely loss of occupation and loss of property, and they are at the risk of poverty and sometimes involvement in criminal activities (Iqbal, 2010). Identity crisis is inevitable to these migrated people as their belongingness to any particular district or state or country is often denied.

Other consequences of bank erosion are the lack of medical and education facilities. Medical care units that were on the eroded land are all lost. In their new settlement generally those are lacking. So, they have to travel longer distances than before and bear extra cost for medical treatment. Similar is the case for education. Moreover, due to loss of occupation they are having difficulties to spend money for purposes other than essential items like food and shelter, even if the medical and education facilities exist in their new occupied placees. Results are their poor health, sickness and illiteracy of their children.

Figure 8: Impact of river bank erosion

6.1 Impact of Brahmaputra river bank erosion

Most of the studies on Brahmaputra river bank erosion in Assam have been aimed at identifying factors causing erosion and assessment of eroded geographical area. Such studies are important for taking erosion control measures and restoration (Sarma and Acharjee, 2012). However, little effort has been made to quantify the loss due to this erosion though it is often reported that Brahmaputra River bank erosion causes poverty, has a long term impact and there is no compensation mechanism (Talukdar, 2012). It has already been mentioned that Brahmaputra bank erosion has wiped out a large area including human settlements, productive crop land and reserve forest area. One of such affected area consists of some community Development Blocks of Barpeta district of Assam. Such a Block is Mandia.

A qualitative study in Mandia Block of Barpeta district revealed that people on the eroded land migrated to the nearest villages, towns and even to some reserve places of Assam due to Brahmaputra River erosion (Khan, 2012). In Mandia Block agriculture was the primary occupation of the majority of the people. But due to bank erosion there was loss of agricultural land, which in turn has increased the number of landless labourers. The percentage of landless labourers among the working class in the study area was nearly 90 percent, whereas it was only 16 percent in Barpeta district, where this block belongs. Decreasing agricultural land due to erosion and at the same time increasing number of landless labourers had obviously an impact on their livelihood. This was observed from a growth in number of poverty stricken people in Mandia Block. The portion of population below the poverty line in this block was more than double of that in Barpeta district.

Poverty in turn escalated illiteracy and malnutrition of the children due to lack of education attainment and improper care for health. Existing medical centres in the previously eroded settlement were affected due to erosion. Moreover, in most of the new occupied places (generally, river embankments, road sides, or low lands, which are mostly inundated by flood) physical (viz., road, electricity, etc.) and social (viz., health centres, schools, etc.) infrastructures were either absent or not adequate. Brahmaputra River erosion created problems of identity, too. Sometimes the displaced persons were suspected as illegal migrants (as the Bangladesh border is very close to the study area), especially when they were in search for jobs for their livelihood. On the other hand, some displaced persons forcibly occupy lands in reserve forests, and caused deforestation which lead to not only ecological degradation, but also scarcity of fuel wood and fodder in the region. Thus, Brahmaputra river bank erosion has caused both socioeconomic and ecological imbalance.

6.2 Impact of Ganges river bank erosion

Another study area was the Shantipur Block in the Nadia District of West Bengal. This place is more than 211 km downstream of Farakka Barrage, and is situated at the left bank of the river Bhagirathi-Hooghly (one branch of River Ganges). The river here resorts to massive bank erosion. The socio-economic impact of bank erosion in some villages of this Block has been assessed in a study by Chatterjee and Mistri (2013). Once, Methiadanga was a village in this block that had been gradually engulfed by the river. People residing there continuously shifted inward as the river was consuming the village. Population in this village shifted several times in nearly 20 years till the date of survey (Figure 9). Finally, when the village was almost eroded, they were relocated about 2 km east of the river. State government provided displaced villagers free land (Patta).

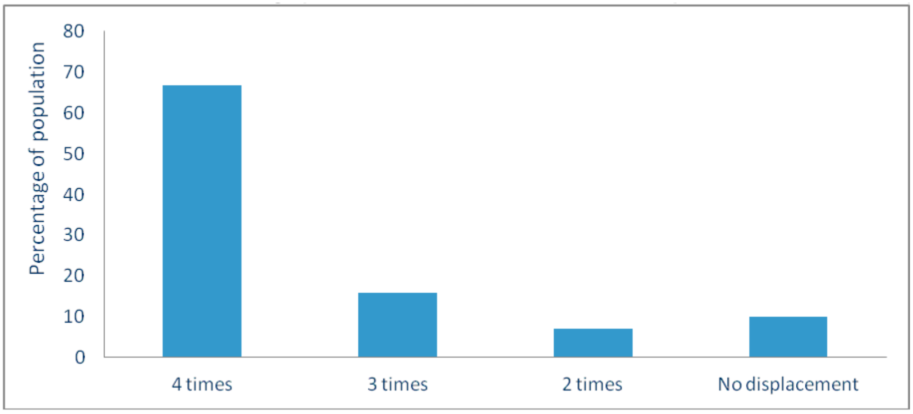


Figure 9: Frequency of displacement of population in Methidanga village. (Source: Chatterjee and Mistri, 2013)

The displaced people lost their houses, industrial set-ups (handlooms), multiple-crop lands and cattle. Their losses were estimated in monetary terms. The range of their losses was 50 000 – 200 000 Indian rupees (Figure 10). Even the loss of a few people exceeded 200 000 Indian rupees. This loss, mainly multiple-crop-land, made them (who were previously farmers) unemployed, and they were bound to do informal jobs like rickshaw-pulling or weaving. Handloom is a cottage industry in Shantipur Block and this industry is famous for “Shantipur Tant (cotton) Saree”. Some of the displaced people in this village were weavers. Due to river bank erosion previous production set-ups were lost, and they had to rebuild their handlooms in new settlements. But this process could not be continued since displacement occurred more than one time. In the long run, their capitals were eroded gradually as they had to shift several times. Some of these distressed people even migrated to Mumbai and Delhi to work as assistants to the jewellers. However, this study is lacking some important analysis, like loss in income and reduction in essential expenditures, to identify their distress. Their deterioration in health and educational status due to forcible displacement was not evaluated, which would be highly required for such studies. Also, social security of the displaced people needs to be assessed.

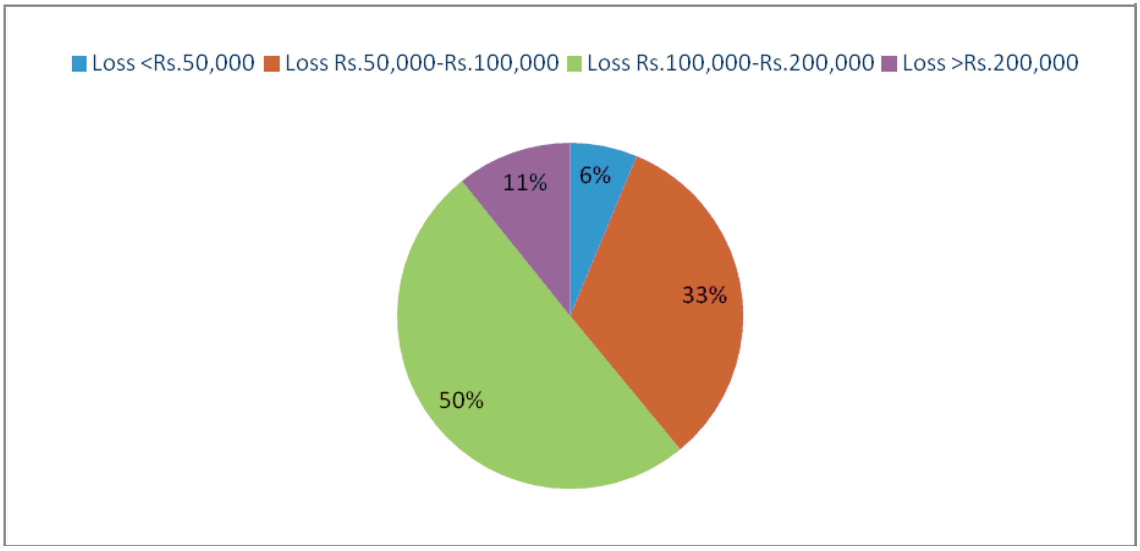


Figure 10: Percentage of population suffering loss. (Source: Chatterjee and Mistri, 2013)

The Ganges bank erosion in other districts of West Bengal is less important compared to the Malda and Murshidabad districts. Until now, more than 700 000 people in these two districts have been displaced due to Ganges bank erosion (Mukherjee, 2008). There is a general tendency of River Ganges to shift towards the left bank above Farakka Barrage (Malda district), and towards the right bank below Farakka Barrage (Murshidabad and other districts). The river has so far eroded 356 km^2 of fertile land from the district of Murshidabad (Rudra, 2005). It has been reported that nearly 80 000 people in this district were displaced only during 1988 – 1994 (Rudra, 2005). Land loss due to erosion in Malda is worse, too. More than 200 km^2 of fertile land in Malda district have been completely wiped out untill 2004.

The displacement of erosion ehich affected people in these two districts is typical. It is of the nature of "continuous forced migration", i.e., displacement, then settlement, then displacement, then again re-settlement and so on (Figure 11). This observation has been supported by analysis of the changing morphometry of the river in this place (Laha and Bandyapadhyay, 2013). The analysis showed a drastic increase in sinuosity (i.e., meandering), braidedness index, and percentage of the island area to the total river reach area over the period of time 1955 – 2010. By increasing sinuosity, the river has been engulfing the large areas of left bank every year, and due to increasing braidedness new areas emerged. Firstly, when their own homeland is submerged due to bank erosion the people rush to land (sand bed) emerging out of the river (locally called "char"). But these fragile lands emerge, submerge and re-emerge continuously. This phenomenon has been explained in Section 2.1.

The frequent "displacement and settlement" of victims is one of the consequences of bank erosion in Malda and Murshidabad. Another consequence is border dispute. Some parts of the river bank lines are considered as inter-state or inter-country borders. This has happened between West Bengal and Jharkhand in the Malda district. River-course changes due to bank erosion (submerge of land on the left bank and emergence of new land on the right bank of the river). The new land is no more considered as a part of West Bengal in spite of land loss in this state (Figure 5). Problems arise when erosion-afflicted people belonging to this lost land move to the newly emerged highland on the opposite side of the river, which is now in Jharkhand. Previously they belonged to West Bengal and they had all the identity documents (namely voter identity card and ration card) of this state. So, they are not recognised as residents of Jharkhand and they suffer from the deprivation of getting civic amenities, like health and education. They even cannot take the advantages of different government programmes, like the National Rural Employment Guarantee Scheme, which provides 100 days of guaranteed work to rural unemployed.

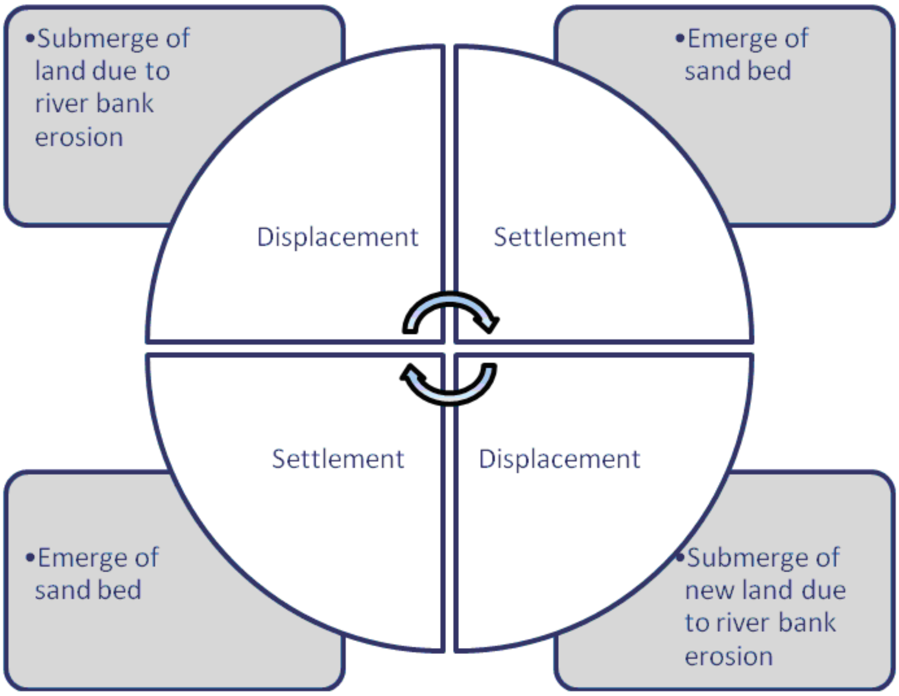


Figure 11: Continuous process of forced migration.

The border dispute due to the Ganges bank erosion in Murshidabad district is, however, related to the inter-country border between India and Bangladesh. One branch of the River Ganges flows into Bangladesh after flowing along the border of Murshidabad for 60 km (Figure 6). The erosion has wiped away the boundary posts at many places on the Indian side. Along with the erosion of the river bank and the border posts on the Indian side (in Murshidabad), new sand lands (i.e., "chars") have developed towards theBangladesh side. As per official estimate, more than 100 km^2 of sand lands have emerged along the opposite bank till 1992 – 1994. A sizeable affected population have migrated from the eroded land on the Indian side to the newly emerged lands on the Bangladesh side. These emerged lands are not easily accessible from the Indian side and the people have to cross the River Padma, taking several hours to come to India. However, Bangladesh is easily accessible from these lands. It takes less than an hour to travel by road from Rajshahi town in Bangladesh to these newly emerged lands. The situation there has become complicated, as the Bangladesh government does not agree to establish any border line across these newly emerged lands and the Indian government cannot provide proper security to the new settlers. So, the migrated people in these islands often are in conflict, especially at the time of harvesting, with Bangladeshi cultivators who have more easy access.

The basic infrastructure (like health centre, school and market) in the new lands is very poor. This is similar true in the new settlements of displaced people of both districts. Due to lack of educational institutions and economic distress, education has got the least priority among these displaced people. It has been observed in these areas that children and even youths have never been to a school and are illiterate. Regarding health, most of the children suffer from malnutrition, and there are several reports of child death due to malnutrition. Immunisation of children cannot be imagined in most of the resettlements. Sometimes deaths of pregnant women were reported because of their delayed arrival at hospitals. The only way to travel from resettled islands (chars) to any hospital on the main land is waterways and the travel time is several hours by boat. These places are also lacking market places or shops, mainly because of economic distress. Thus, an informal sector has not been generated in these places, which can reduce unemployment. This is one of the reasons for these people's involvement in criminal activities.

The other dimension of such displacement-related crisis is women's vulnerability to this kind of disaster. Some State Governments indeed have initiated, although with a vision of very short-term planning, some sort of rehabilitation and compensation programmes. It has been observed in the Malda district, that a considerable proportion of displaced people are women (O'Neil, 2010). Generally, women suffer most in any course of forced migration, because they have to carry the whole responsibility of households chores starting from cooking and looking after children to caring for the old and sick of the family. It becomes difficult for them to perform these day-to-day activities in resettled odd places (like "chars") without civic facilities and easy availability of natural resources. Women's role is always ignored in any rehabilitation programme. Gender-sensitive rehabilitation policies, therefore, are urgently needed to ease women's helplessness in carrying out household's responsibilities during the displacement and rehabilitation process.

The rural population in the Malda district is mainly vulnerable to two types of shock – economic and ecological (DHDR, 2007). The DHD report has specified the conversion of land from agriculture to commercial orchard and other forms of non-agricultural land use as economic shock, and flood and river bank erosion as ecological shock. These two types of shock affect development processes to widen livelihood opportunities among vulnerable sections of rural population, and make their lives more insecure. Moreover, it has been observed through survey investigation that the vulnerable population, in both the cases of ecological and economic shock, is mostly the landless labourers (Figure 12).

6.3 Impact of Ghaghara river bank erosion

River bank erosion is occurring in other regions too, but not to the extent as in Brahmaputra region or lower Ganges region. One example is the river erosion in Uttar Pradesh of the River Ghaghara, which flows from Nepal into Northern India (Figure 4). The River Ghaghara is a major left bank tributary of the River Ganges. It has changed its course since 1995 causing vast erosion of the river bank, especially after 1998 (International Fact Finding Mission, 2005). Due to this erosion more than 5000 thousand households have lost their houses and means of livelihood. Affected households did not get any compensation for their cultivable land, but got offered a relief package of a small amount of money and a housing plot (not sufficient for cultivation) in the same district.

It was supposed that these displaced people who were previously farmers would accept relocated housing plots and go for alternative occupations, like the international refugees who are forced to accept major changes in their livelihood. But here it did not hold true. Most of them did not accept that relief package, mainly because there were no opportunities of earning income in the area where they were relocated. They demanded land for agriculture, which was their occupation, or land in locations where there are means of livelihood. It was reported that people who lost their houses and cultivable land, and did not accept relief package, were working in informal sectors like rickshaw-pulling, labour in brick kilns, etc. As a result, dissatisfaction prevailed among both the

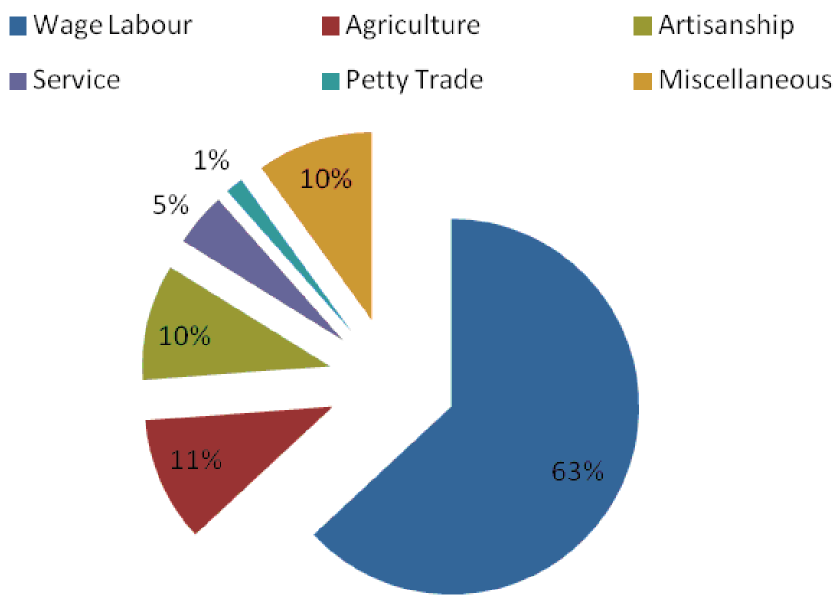


Figure 12: Distribution according to primary occupation. (Source: DHDR, 2007)

authorities and the victims.

However, new sandy land has emerged on the opposite riverbank, and in the middle of the river with the changing course of the river like that in Malda and Murshidabad. This land, untill the time of study, was nobody's land, and these people could be relocated in this newly emerged land to continue their agriculture occupation. But lack of infrastructure is one of the main barriers to settle in such emerged land. Firstly, there is no easy access to this land. Few people, who have already occupied some area of this land, reported that they can cross the river by boat by paying fare, which they cannot afford. Secondly, there is no medical care facility. The combination of these two difficulties caused some cases of death. There was a suggestion for erection of a pontoon bridge to enable the erosion victims an easy access to this land.

6.4 Impact of Mahanadi river bank erosion

Another state which is affected by river bank erosion is Orissa. The river Mahanadi, the biggest river in the state, and its two branches, Kathajodi and Kuakhai, are constantly expanding and changing their course (Pati, 2009). Every year, a few villages are swallowed by these rivers. Thousands of people have already become victim of erosion or are living in a threat of being washed away by these three rivers. These people have no alternative place to migrate and the government is not acknowledging the erosion problem.

7 Conclusion

It is clear from the above discussion that the overall scenario of river bank erosions and their impacts are very depressing. As a result of riverbank erosion and their displacement, forced migrants are at the risk of insecurities in different form. The uncertainties that they face are economic insecurity due to unemployment, erosion of capital and indebtedness, social insecurity due to deprivation of civic rights, health insecurity due to lack of basic infrastructure, etc. All these insecurities caused by forced migration lead to deprivation, destitute, fragility and more vulnerability of the families.

Riverbank erosion thus has negative impact on human life. Conversely, human activities also have impact on riverbank erosion. The poverty of the Malawians has created pressure on catchment areas or rivers. People cultivate on riverbanks because of its fertile land. No fertilisers are needed. River banks provide better yields than upland farms that are depleted of nutrients. Because of these benefits, there is over-cultivation, poor management of cultivated fields, and indiscriminate cutting down of trees (Kaunda and Chapotoka, 2003). All this leads to riverbank erosion along with river sedimentation, water pollution and fish habitat alteration. Therefore, the management of natural resources including riverine resources in poverty-stricken communities is of very complex nature.

The literature survey in this review article opens up two important aspects of the above topic that can be pursued in future research. Firstly, more scientific studies on the impact of human intervention are needed. Also, at the same time, it is needed to analyse to what extent human intervention may be tolerable without disturbing the natural dynamic equilibrium of rivers, because rivers always play a vital role in the social and economic welfare of countries. Moreover, there is increasing pressure on rivers to accrue more benefits to the society. Such studies will help in developing river training work, depending on the reach where there is human intervention.

The second research question is how to maintain riparian buffers, especially in countries that are suffering from over-population and poverty, since bank erosion is a natural phenomenon even if there was no human intervention. Human vulnerability is of greatest extend, where settlements are dangerously close to eroding banks. Therefore, mapping of the spatial distribution of vulnerability of the people residing along the river bank is very much required to understand the severity of the problem (Kienberger *et al.*, 2009). This research topic demands for an interdisciplinary approach: measurement of human vulnerability and spatial mapping. Such studies are lacking in literature on river bank erosion.

Acknowledgements

This study has received funding during the period of revision from the European Union Seventh Framework Programme ([FP7/2007 – 2013] [FP7/2007 – 2011]) under Grant Agreement Number 607960. We also thank Stefan Kienberger of Paris Lodron University of Salzburg, Austria, for his suggestion and future collaborative research on spatial analysis of vulnerability.

References

Ahmed, A. A. and Fawzi, A. (2009), "Meandering and Bank Erosion of the River Nile and its Environmental Impact on the Area between Sohag and El-Minia, Egypt", *Arab Journal of Geosciences*, 4(2), [DOI]. (Cited on page 12.)

Alexander, J. S., Wilson, R. C. and Green, W. R. (2012), "A Brief History and Summary of the Effects of River Engineering and Dams on the Mississippi River System and Delta", *U.S. Geological Survey Circular*, 1375, Reston, VA (U.S. Geological Survey). Online version (accessed 18 September 2014): http://pubs.usgs.gov/circ/1375/. (Cited on page 10.)

Arohunsoro, S. J., Owolabi, J. T. and Omotoba, N. I. (2014), "Watershed Management and Ecological Hazards in an Urban Environment: The Case of River Ajilosun in Ado Ekiti, Nigeria", *European Journal of Academic Essays*, 1(2): 17–23. URL (accessed 18 September 2014): http://euroessays.org/archieve/volume-1-issue-2/v12-3. (Cited on page 8.)

Bech, J. (2006), *Streambank Erosion Hazard Mapping on the Venoge River, Switzerland*, Ph.D. thesis, EPFL, Lausanne, [DOI]. (Cited on page 11.)

Bell, S., Alves, S., Silveirinha de Oliveira, E. and Zuin, A. (2010), "Migration and Land Use Change in Europe: A Review", *Living Reviews in Landscape Research*, 4(2), [DOI]. URL (accessed 18 September 2014): http://www.livingreviews.org/lrlr-2010-2. (Cited on page 5.)

Bhowmik, N. G. (2008), "Bank Erosion of the Illinois River", in Babcock, R. W. and Walton, R., eds., *World Environmental and Water Resources Congress 2008*, May 12 – 16, 2008, Honolulu, Hawai'i, Reston, VA (American Society of Civil Engineers), [DOI]. [Google Books]. (Cited on page 11.)

Biswas, A. K. and Tortajada, C. (2012), "Impacts of the High Aswan Dam", in Tortajada, C., Altinbilek, D. and Biswas, A. K., eds., *Impacts of Large Dams: A Global Assessment*, Water Resources Development and Management, pp. 379–395, Berlin; New York (Springer), [DOI]. [Google Books]. Online version (accessed 18 September 2014): http://www.thirdworldcentre.org/epubli.html. (Cited on page 8.)

Biswas, S. K. (2010), "Effect of bridge pier on waterways constriction: a case study using 2-D mathematical modelling", in Amin, A. F. M. S., Okui, Y. and Bhuiyan, A. R., eds., *Advances in Bridge Engineering-II*, IABSE-JSCE Joint Conference, August 8 – 10, 2010, Dhaka, Bangladesh, pp. 369–376, Dhaka (IABSE). Online version (accessed 18 September 2014): http://www.iabse-bd.org/old/20.pdf. (Cited on page 9.)

Bradbury, J. (2005), "Revised wave wake criteria for vessel operation on the lower Gordon River, Unpublished Nature Conservation Branch Report", Tasmania (Department of Primary Industry, Water and Environment). Online version (accessed 18 September 2014): http://dpipwe.tas.gov.au/Documents/Revised-Wave-Wake-Criteria-2005.pdf. (Cited on page 11.)

Briaud, J.-L., Chen, H.-C., Chang, K.-A., Chung, Y.-A., Park, N., Wang, W. and Yeh, P.-H. (2007), "Establish Guidance for Soils Properties-Based Prediction of Meander Migration Rate", *Technical Report*, FHWA/TX-07/0-4378-1, Austin, TX (Texas Department of Transportation). Online version (accessed 18 September 2014): http://tti.tamu.edu/documents/0-4378-1.pdf. (Cited on page 10.)

Brouwer, R., Aftab, S., Brander, L. and Haque, E. (2007), "Socioeconomic Vulnerability and Adaptation to Environmental Risk: A Case Study of Climate Change and Flooding in Bangladesh", *Risk Analysis*, 27(2): 313–326, [DOI]. Online version (accessed 18 September 2014): http://hdl.handle.net/1871/47994. (Cited on page 15.)

Brown, R. L. (1999), "Vientiane Plain Flood Protection: Urgent Phase", in *Flood Management and Mitigation in the Mekong River Basin*, Proceedings of the Regional Workshop, Vientiane, LAO PDR 19 – 21 March 1998, RAP Publication, 1999/14, Bangkok (FAO). Online version (accessed 18 September 2014): http://www.fao.org/docrep/004/ac146e/AC146E05.htm. (Cited on page 13.)

Chatterjee, S. and Mistri, B. (2013), "Impact of River Bank Erosion on Human Life: A Case Study in Shantipur Block, Nadia District, West Bengal", *International Journal of Humanities and Social Science Invention*, 2(8): 108–111. URL (accessed 18 September 2014): http://www.ijhssi.org/v2i8.html. (Cited on pages 22 and 23.)

Coulthard, T. J. (2005), "Effects of Vegetation on Braided Stream Pattern and Dynamics", *Water Resources Research*, 41: W04003, [DOI]. (Cited on page 8.)

Couture, S. (2008), "River Dynamics and Erosion, Presented to Great Bay Siltation Commission, December 1, 2008", conference paper. Online version (accessed 18 September 2014): http://des.nh.gov/organization/divisions/water/wmb/coastal/ocean_policy/gb_commission.htm. (Cited on page 7.)

CRJC (1996), "River Dynamics and Erosion", *Living with the River*, Charlestown, NH (Connecticut River Joint Commissions (CRJC)). Online version (accessed 18 September 2014): http://crjc.org/erosion.htm. (Cited on page 7.)

Das, S. K. (2010), "'People without Shadows': Ethnographic Reflections on Identity and Justice in Contemporary India", *Peace Prints: South Asian Journal of Peacebuilding*, 2(3). URL (accessed 18 September 2014): http://www.wiscomp.org/pp-v3-n2/peaceprints4.htm. (Cited on page 5.)

Davinroy, R. D., Rodgers, M. T., Brauer, E. J. and Lamm, D. M. (2003), "Bank Erosion and Historical River Morphology Study of the Kaskaskia River: Lake Shelbyville Spillway To Upper End of Caryle Lake", *Technical Report*, M30, St. Louis, MO (U.S. Army Corps Of Engineers, St. Louis District, Water Management). Online version (accessed 18 September 2014): http://mvs-wc.mvs.usace.army.mil/arec/Reports_Geomorphology_Kaskaskia_River.html. (Cited on page 8.)

DHDR (2007), "District Human Development Report: Malda", Kolkata (Development and Planning Department, Government of West Bengal). Online version (accessed 18 September 2014): http://wbplan.gov.in/HumanDev/DHDR.htm. (Cited on pages 25 and 26.)

Donat, M. (1995), "Bioengineering Techniques for Streambank Restoration: A Review of Central European Practices. Watershed Restoration Project Report No. 2", Vancouver, BC (Province of British Columbia, Ministry of Environment, Lands and Parks and Ministry of Forests). Online version (accessed 18 September 2014): http://www.env.gov.bc.ca/wld/documents/wrp/wrpr_2.pdf. (Cited on page 12.)

Dragićević, S., Tošić, R., Stepić, M., Živković, N. and Novković, I. (2013), "Consequences of the River Bank Erosion in the Southern Part of the Pannonian Basin: Case Study – Serbia and the Republic of Srpska", *Forum geografic*, XII(1): 5–15, [DOI]. (Cited on pages 12 and 14.)

Dutta, M. K., Barman, S. and Aggarwal, S. P. (2010), "A study of erosion-deposition processes around Majuli Island, Assam", *Earth Science India*, 3(IV): 206–216. URL (accessed 18 September 2014): http://www.earthscienceindia.info/archiv.php?year=2010&month=October. (Cited on page 18.)

Evette, A., Labonne, S., Rey, F., Liebault, F., Jancke, O. and Girel, J. (2009), "History of Bioengineering Techniques for Erosion Control in Rivers in Western Europe", *Environmental Management*, 43(6), [DOI]. (Cited on page 12.)

Florsheim, J. L., Mount, J. F. and Chin, A. (2008), "Bank Erosion as a Desirable Attribute of Rivers", *BioScience*, 58(6): 519–529, [DOI]. (Cited on page 7.)

French, H. W. (2007), "Dam Project to Displace Millions More in China", *New York Times*, (October 12). URL (accessed 18 September 2014):
http://www.nytimes.com/2007/10/12/world/asia/12china.html?_r=0. (Cited on page 14.)

Gantt, A. and Humberson, D. (2004), "Erosion along the Guadalupe River near Gonzales, Cuero, Victoria, Texas", project homepage, University of Texas. URL (accessed 18 September 2014):
http://www.utexas.edu/depts/grg/hudson/grg360g/EGIS/final_project/spring04_projects/delbert_amier/Guadalupe%20River%20Erosion%20WebPage/Final_Web_page.htm. (Cited on page 10.)

Gleick, P. H. (2009), "Three Gorges Dam Project, Yangtze River, China", in *The World's Water 2008–2009*, pp. 139–150, Washington, DC (Island Press). Online version (accessed 18 September 2014):
http://worldwater.org/water-data/. (Cited on page 14.)

Hudson, P. F. and Kesel, R. H. (2000), "Channel migration and meander-bend curvature in the lower Mississippi River prior to major human modification", *Geology*, 28(6): 531–534, [DOI]. (Cited on page 10.)

IDMC (2011), "Displacement due to natural hazard-induced disasters: Global estimates for 2009 and 2010", Geneva (Internal Displacement Monitoring Centre, Norwegian Refugee Council). Online version (accessed 18 September 2014):
http://www.internal-displacement.org/publications/2011/displacement-due-to-natural-hazard-induced-disasters-global-estimates-for-2009-and-2010. (Cited on page 14.)

IDMC (2012), "Global estimates 2011: People displaced by natural hazard-induced disasters", Geneva (Internal Displacement Monitoring Centre, Norwegian Refugee Council). Online version (accessed 18 September 2014):
http://www.internal-displacement.org/publications/2012/global-estimates-2011-people-displaced-by-natural-hazard-induced-disasters. (Cited on page 14.)

"India-WRIS Wiki: Flood Management", project homepage, National Remote Sensing Centre. URL (accessed 18 September 2014):
http://india-wris.nrsc.gov.in/wrpinfo/index.php?title=Flood_Management&oldid=38886. (Cited on page 13.)

International Fact Finding Mission (2005), "Report on cases of violations of the right to food in Uttar Pradesh, India. November 2004", Oslo (FIAN Norway). Online version (accessed 18 September 2014):
http://www.eldis.org/go/home&id=20723&type=Document. (Cited on page 25.)

Iqbal, S. (2010), "Flood and Erosion Induced Population Displacements: A Socioeconomic Case Study in the Gangetic Riverine Tract at Malda District, West Bengal, India", *Journal of Human Ecology*, 30(3): 201–211. (Cited on page 21.)

ISDR (2008), "Linking Disaster Risk Reduction and Poverty Reduction: Good Practices and Lessons Learned", Geneva (United Nations International Strategy for Disaster Reduction). Online version (accessed 18 September 2014):
http://www.unisdr.org/we/inform/publications/3293. (Cited on page 15.)

Islam, M. D. F. and Rashid, A. N. M. B. (2011), "Riverbank Erosion Displaces in Bangladesh: Need for Institutional Response and Policy Intervention", *Bangladesh Journal of Bioethics*, 2(2): 4–19, [DOI]. URL (accessed 18 September 2014):
http://www.banglajol.info/index.php/BIOETHICS/article/view/9540. (Cited on page 13.)

Jolly, A. (2013), "A Day in the Life of India's Poorest", *India Today*, (August 12). URL (accessed 18 September 2014):
http://indiatoday.intoday.in/story/murshidabad-india-poverty-in-india/1/297697.html. (Cited on page 15.)

Jones, W., Eldridge, J., Pedro Silva, J. and Schiessler, N. (2007), "LIFE and Europe's rivers: Protecting and improving our water resources", *Life Focus*, Luxembourg (European Communities). Online version (accessed 18 September 2014):
http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/nat.htm. (Cited on page 11.)

Kaunda, E. and Chapotoka, O. (2003), "The conflict between poverty and river system management: The case study of Malawi, Southern Africa", Second International Symposium on the Management of Large Rivers for Fisheries, 11 – 14 February 2003, Phnom Penh, Kingdom of Cambodia, conference paper. Online version (accessed 18 September 2014):
http://www.eldis.org/go/home&id=59142&type=Document#.VCAvSdfI9e4. (Cited on page 27.)

Khan, M. H. (2012), "River Erosion and Its Socio-Economic Impact in Barpeta District with Special Reference to Mandia Dev. Block of Assam", *International Journal of Engineering and Science*, 1(2): 177–183. URL (accessed 18 September 2014):
http://www.theijes.com/Vol,1,Issue,2.html. (Cited on page 21.)

Kienberger, S., Amoaka Johnson, F., Zeil, P., Hutton, C., Lang, S. and Clark, M. (2009), "Modelling socio-economic vulnerability to floods: Comparison of Methods Developed for European and Asian Case Studies", Sustainable Development: A challenge for European research, 26 – 28 May 2009, Brussels, conference paper. URL (accessed 18 September 2014):
http://ec.europa.eu/sd/conference/2009/papers/4/stefan_kienberger_-_socioeconomic_vulnerability.pdf. (Cited on page 27.)

Kondolf, G. M. (1997), "Hungry Water: Effects of Dams and Gravel Mining on River Channels, Profile", *Environmental Management*, 21(4): 533–551, [DOI]. (Cited on page 8.)

Laderoute, L. and Bauer, B. (2013), "River Bank Erosion and Boat Wakes along the Lower Shuswap River, British Columbia, Final Project Report", Coldstream, BC (Regional District of North Okanagan, Fisheries and Oceans Canada). Online version (accessed 18 September 2014):
http://www.rdno.ca/docs/River_Bank_Erosion_Lower_Shu_River_Final_Project_Report.pdf. (Cited on page 11.)

Laha, C. and Bandyapadhyay, S. (2013), "Analysis of the Changing Morphometry of River Ganga, shift monitoring and Vulnerability Analysis using Space-Borne Techniques: A Statistical Approach", *International Journal of Scientific and Research Publications*, 3(7). URL (accessed 18 September 2014):
http://www.ijsrp.org/research-paper-0713.php?rp=P191440. (Cited on page 23.)

Leopold, L. B. and Wolman, M. G. (1963), "River Channel Patterns: Braided, Meandering and Straight", *Geological Survey Professional Paper*, 282-B, Washington, DC (USGS). Online version (accessed 18 September 2014):
http://pubs.er.usgs.gov/publication/pp282B. (Cited on page 9.)

Ma, Y., Huang, H. Q., Nanson, G. C., Li, Y. and Yao, W. (2012), "Channel adjustments in response to the operation of large dams: The upper reach of the lower Yellow River", *Geomorphology*, 147-148: 35–48, [DOI]. Online version (accessed 18 September 2014):
http://ro.uow.edu.au/scipapers/4279. (Cited on page 13.)

Madej, M. A., Weaver, E. W. and Hagans, D. K. (1994), "Analysis of Bank Erosion on The Merced River, Yosemite Valley, Yosemite National Park, California, USA", *Environmental Management*, 18(2): 235–250, [DOI]. (Cited on page 8.)

Mann, Z. (2013), "River Bank Erosion Forces Hundreds of Families to Relocate", *Irrawaddy*, (September 3). URL (accessed 18 September 2014):
http://www.irrawaddy.org/refugees/first-japanese-newspaper-becomes-available-in-rangoon.html. (Cited on page 13.)

Maynord, S. T. and Martin, S. K. (1996), "Upper Mississippi River System Navigation/Sedimentation Study. Report 1: Bank Erosion Literature Study", *Technical Report*, HL-96-10, Vicksburg, MS (U.S. Army Engineer Waterways Experiment Station). Online version (accessed 18 September 2014): http://www.dtic.mil/docs/citations/ADA316078. (Cited on page 10.)

Mili, N., Acharjee, S. and Konwar, M. (2013), "Impact of flood and river bank erosion on socioeconomy: A case study of Golaghat revenue circle of Golaghat district, Assam", *International Journal of Geology, Earth & Environmental Sciences*, 3(3): 180–185. URL (accessed 18 September 2014): http://www.cibtech.org/jgee.htm. (Cited on page 13.)

Miyazawa, N., Sunada, K. and Sokhem, P. (2008), "Bank erosion in the Mekong River Basin: Is bank erosion in my town caused by the activities of my neighbors?", in Kummu, M., Keskinen, M. and Varis, O., eds., *Modern Myths of the Mekong: A critical review of water and development concepts, principles and policies*, Water & Development Publications, TKK-WD-01, pp. 19–26, Aalto (Helsinki University of Technology). URL (accessed 18 September 2014): http://www.wdrg.fi/publications/water-development-publications/. (Cited on page 12.)

MoWR (1999), "Integrated Water Resource Development – A Plan for Action. Report of the National Commission for Integrated Water Resources Development Plan", New Delhi (Ministry of Water Resources, Government of India). (Cited on page 17.)

MRC (2010), "State of the Basin Report", Vientiane (Mekong River Commission (MRC)). Online version (accessed 18 September 2014): http://www.mrcmekong.org/publications/reports/basin-reports/. (Cited on page 12.)

Mukherjee, J. (2011), "No Voice, No Choice: Riverine Changes and Human Vulnerability in the 'Chars' of Malda and Murshidabad", *Occasional Paper*, 28, Salt Lake City (Institute of Development Studies Kolkata). URL (accessed 18 September 2014): http://www.idsk.edu.in/common/file/OP-28.pdf. (Cited on page 8.)

Mukherjee, P. (2008), "CRY of Help for Erosion Victims", *Business Standard*, (February 19). URL (accessed 18 September 2014): http://www.business-standard.com/article/economy-policy/cry-of-help-for-erosion-victims-108021901020_1.html. (Cited on page 23.)

Mutton, D. and Haque, C. E. (2004), "Human Vulnerability, Dislocation and Resettlement: Adaptation Processes of River-bank Erosion-induced Displacees in Bangladesh", *Disasters*, 28(1): 41–62, [DOI]. (Cited on page 13.)

Neitzert, K., Honeywell, G. and Thompson, R. (2012), "Monitoring bank erosion on the Missouri River on the Lower Brule Reservation, 2011–2012", Eastern South Dakota Water Conference Program and Abstracts, October 30, 2012, Brookings, SD, conference paper. (Cited on page 10.)

Nikolova, M., Nedkov, S. and Nikolov, V. (2012), "Risk from Natural Hazards for the Archaeological Sites along Bulgarian Danube Bank", in Naydenova, V. and Stamenov, S., eds., *Proceedings of the First European SCGIS Conference 'Best practices: Application of GIS technologies for conservation of natural and cultural heritage sites'*, 21 – 23 May 2012, Sofia, Bulgaria, pp. 90–96, Sofia (SCGIS Chapter Bulgaria). URL (accessed 18 September 2014): http://proc.scgis.scgisbg.org/. (Cited on page 12.)

Nilsson, C., Reidy, C. A., Dynesius, M. and Revenga, C. (2005), "Fragmentation and flow regulation of the world's large river systems", *Science*, 308: 405–408, [DOI]. (Cited on page 8.)

NSS (2012), "India – Employment & Unemployment and Migration Survey: NSS 64th Round: July 2007 – June 2008", New Delhi (Ministry of Statistics and Programme Implementation). URL (accessed 18 September 2014): http://mail.mospi.gov.in/index.php/catalog/123/. (Cited on pages 5 and 6.)

O'Neil, B. (2010), "Women and Displacement: A Case Study of Women displaced by Ganga erosion in Malda district of West Bengal in India", European Population Conference (EPC 2010), held in Vienna, Austria, 1 – 4 September, conference paper. URL (accessed 18 September 2014): http://epc2010.princeton.edu/papers/100534. (Cited on page 25.)

Ott, R. A. (2000), "Factors Affecting Stream Bank and River Bank Stability, with an Emphasis on Vegetation Influences", in Welbourn Freeman, M., ed., *Region III Forest Resources & Practices Riparian Management Annotated Bibliography*, pp. 21–40, Anchorage, AK (Alaska Department of Natural Resources, Division of Forestry). Online version (accessed 18 September 2014): http://forestry.alaska.gov/forestpractices.htm. (Cited on page 8.)

Parnell, K. E., McDonald, S. C. and Burke, A. E. (2007), "Shoreline effects of vessel wakes, Marlborough Sounds, New Zealand", in *Proceedings of the 9th International Coastal Symposium (ICS 2007)*, Gold Coast, Queensland, Australia, 25 – 29 April 2007, Journal of Coastal Research, SI 50, pp. 502–506, Australia (CERF). URL (accessed 18 September 2014): http://www.cerf-jcr.org/index.php/international-coastal-symposium/ics-2007australia. (Cited on page 11.)

Pati, B. K. (2009), "River Bank Erosion in Orissa – The Bitter Truth", *Odisha Diary*, (August 05). URL (accessed 18 September 2014): http://www.orissadiary.com/ShowOriyaColumn.asp?id=13776. (Cited on page 26.)

Pearce, F. (2013), "A Successful Push to Restore Europe's Long-Abused Rivers", *Yale Environment 360*, (10 December). URL (accessed 18 September 2014): http://e360.yale.edu/feature/a_successful_push_to_restore_europes_long-abused_rivers/2718/. (Cited on page 11.)

Phukan, A., Goswami, R., Borah, D., Nath, A. and Mahanta, C. (2012), "River Bank Erosion and Restoration in the Brahmaputra River in India", *Clarion*, 1(1): 1–7. URL (accessed 18 September 2014): http://clarion.ind.in/index.php/clarion/article/view/17. (Cited on pages 13 and 17.)

Planning Commission (2011), "Report of Working Group on Flood Management and Region Specific Issues for XII Plan", New Delhi (Government of India, Planning Commission). URL (accessed 18 September 2014): http://planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_indu_sani.pdf. (Cited on page 13.)

Pongkhao, S. (2008), "Riverbank erosion forces villagers inland", *Vientiane Times*, (June 10). Online version (accessed 18 September 2014): https://groups.google.com/forum/#!msg/lancang-mekong/758LxLfvQ14/_JAuwh9RYIAJ. (Cited on page 12.)

Prairie Rivers Network (2012), "Factsheet: Upper Mississippi River", Champaign, IL (Prairie Rivers Network). Online version (accessed 18 September 2014): http://www.prairierivers.org/downloads. (Cited on page 10.)

Rahman, M. R. (2013), "Impact of Riverbank Erosion Hazard in the Jamuna Floodplain Areas in Bangladesh", *Journal of Science Foundation*, 8(1-2), [DOI]. (Cited on page 15.)

Romualdez, B. (2013), "Floods: Poverty, population and pork", *Philippine Star*, (August 25). URL (accessed 18 September 2014): http://www.philstar.com/opinion/2013/08/25/1131661/floods-poverty-population-and-pork. (Cited on page 15.)

Rudra, K. (2005), "The Encroaching Ganga and Social Conflicts: The Case of West Bengal, India", online resource, Gangapedia (GRBMP). URL (accessed 18 September 2014): http://gangapedia.iitk.ac.in/?q=node/570. (Cited on page 23.)

Rudra, K. (2010), "Dynamics of the Ganga in West Bengal (1764–2007): Implications for science–policy interaction", *Quaternary International*, 227(2): 161–169, [DOI]. (Cited on page 18.)

Rushdi, S. (1996), "The Aswan High Dam Revisited", in *15th IABSE Congress*, Copenhagen, June 16 – 20, 1996, pp. 3–14, Zurich (IABSE), [DOI]. (Cited on page 8.)

Sarma, D. (2013), *Rural Risk Assessment due to Flooding and Riverbank Erosion in Majuli, Assam, India*, Master's thesis, University of Twente, University of Twente. URL (accessed 18 September 2014): http://www.itc.nl/library/papers_2013/msc/gfm/sarma.pdf. (Cited on page 13.)

Sarma, J. N. and Acharjee, S. (2012), "A GIS Based Study on Bank Erosion by the River Brahmaputra around Kaziranga National Park, Assam, India", *Earth System Dynamics Discussions*, 3(2): 1085–1106, [DOI]. URL (accessed 18 September 2014): http://www.earth-syst-dynam-discuss.net/3/1085/2012/. (Cited on page 21.)

"SEDDON: Sediment Research and -management at the Danube River", project homepage, BOKU. URL (accessed 18 September 2014): http://www.seddon.boku.ac.at. (Cited on page 11.)

Sinha, R. and Ghosh, S. (2012), "Understanding dynamics of large rivers aided by satellite remote sensing: a case study from Lower Ganga plains, India", *Geocarto International*, 27(3): 207–219, [DOI]. (Cited on page 20.)

Szalai, Z., Balogh, J. and Jakab, G. (2013), "Riverbank Erosion in Hungary – with an outlook on environmental consequences", *Hungarian Geographical Bulletin*, 62(3): 233–245. Online version (accessed 18 September 2014): http://www.mtafki.hu/konyvtar/hungeobull2013_3_en.html. (Cited on pages 11 and 12.)

Talukdar, B. (2012), "River Bank Erosion – A Perspective", conference paper. URL (accessed 18 September 2014): http://www.iitg.ernet.in/coeiitg/31.pdf. (Cited on page 21.)

"World Development Indicators", web interface to database, World Bank. URL (accessed 18 September 2014): http://data.worldbank.org/data-catalog/world-development-indicators. (Cited on page 15.)

Wong, C. M., Williams, C. E., Pittock, J., Collier, U. and Schelle, P. (2007), "World's Top 10 Rivers at Risk", Gland, Switzerland (WWF International). Online version (accessed 18 September 2014): http://wwf.panda.org/?108620/Worlds-Top-10-Rivers-at-Risk. (Cited on page 12.)

Wood, S. H., Ziegler, A. D. and Bundarnsin, T. (2008), "Floodplain deposits, channel changes and riverbank stratigraphy of the Mekong river area at the 14th-century city of Chiang Saen, Northern Thailand", *Geomorphology*, 101(3): 510–523, [DOI]. (Cited on page 12.)

WPDS (2011), "2011 World Population Data Sheet", Washington, DC (Population Reference Bureau). Online version (accessed 18 September 2014): http://www.prb.org/Publications/Datasheets/2011/world-population-data-sheet/data-sheet.aspx. (Cited on page 14.)

WPP (2011), "World Population Prospects: The 2010 Revision", New York (Population Division, United Nations). Online version (accessed 18 September 2014): http://esa.un.org/wpp/Documentation/WPP%202010%20publications.htm. (Cited on page 15.)

Yamani, M., Goorabi, A. and Dowlati, J. (2011), "The Effect of Human Activities on River Bank Stability (Case Study)", *American Journal of Environmental Sciences*, 7(3): 244–247, [DOI]. (Cited on page 8.)

Yang, S. L., Zhang, J. and Xu, X. J. (2007), "Influence of the Three Gorges Dam on downstream delivery of sediment and its environmental implications, Yangtze River", *Geophysical Research Letters*, 34(10): L10401, [DOI]. (Cited on page 9.)

Yeasmin, A. and Islam, M. N. (2011), "Changing trends of channel pattern of the Ganges-Padma river", *International Journal of Geomatics and Geosciences*, 2(2): 669–675. URL (accessed 18 September 2014): http://www.ipublishing.co.in/jggsvol2no22011abstracts.html. (Cited on page 13.)

Zetter, R. (2012), "Forced migration – changing trends, new responses", *Migration Policy Practice*, 2(October-November): 5–11. URL (accessed 18 September 2014): http://www.iom.int/migration-policy-practice. (Cited on page 5.)