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Does forest cover help prevent flood damage? Empirical evidence from India

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ABSTRACT

Floods in India are regular phenomenon that occurs in almost all parts of the country, causing significant damage to human lives, assets and ecosystem. Rapid change in weather patterns and decline in forest cover are considered to be the main reasons for frequent floods and associated damage to both human and natural system. Does forest cover help prevent frequent occurrences of flood and reduce flood related damages? Empirical evidences on the flood protective role of forest cover do not give a clear picture. While few studies find a strong link between forest cover and reduced flood incidence, several other studies from across the globe have challenged this traditional notion of the protective role of forest cover. The present study makes an attempt to examine the association between forest cover and flood damage using data from Indian states and the flood affected districts of the eastern Indian state of West Bengal, taking into account the social, economic, climatic and infrastructural parameters. The findings suggest that forest cover tends to reduce the extent of flood damage and hence has the ability to protect human lives and properties during flood events. It is essential that mitigation and adaptation strategies are shaped in a way that promotes preservation and regeneration of forest resources. Hence, the present study suggests adoption of ecosystem-based adaptation measures along with traditional hard structure flood prevention measures in order to prevent flood related damages effectively.

1. Introduction

With increased frequency of floods and resultant damage, adoption of appropriate adaptation measures is the key to protect vulnerable people and their livelihoods. Traditionally, hard structures such as embankments, river bank protection, dams are used as preferred measures to prevent floods and flood related damages (Rasid and Paul, 1987; Shrubsole, 2000; Balica et al., 2015; Roth and Winnubst, 2014). However, it is observed that the hard structures are not only often found to be ineffective in preventing damages from flood hazards, but these structures tend to significantly alter the natural adaptive capacity of hazard prone areas, making both natural and social system more vulnerable to flood hazards (Temmerman et al., 2013). However, in recent years, it has been observed that the focus of adaptive strategies tend to have shifted to self-sustaining ecosystem based measures (Gracia et al., 2017). These measures involve activities such as agro forestry, integrated water resource management, sustainable forest management interventions that use nature to reduce vulnerability to climate change (Colls et al., 2009). These measures are often argued to be cost effective and reliable as compared to hard structures.

Forest cover is one such ecosystem-based adaptive measure to control flood damage being widely discussed in empirical literatures (Bhattacharjee and Behera, 2017). A large number of studies show that floods occur largely on account of declining forest area (Dash and Vincent, 2009; Badola and Hussain, 2005; Bhattacharjee and Behera, 2017). Other studies observed that flood disasters cannot be directly linked to forest cover loss (VanDijk et al., 2009). Generally, forests are perceived as barriers against flood hazards, especially in ecosystems such as coastal and river belt areas (Bann, 1998; Alongi, 2008; Jayatissa and Hettiarachi, 2006; Bao, 2011; Harada and Imamura, 2005; Ohira et al., 2012). For instance, frequent occurrences of floods in the Ganga-Brahmaputra belt in India are often attributed to large scale deforestation which increases the rate of sedimentation and accretion, thereby reducing the carrying capacity of the river and thus resulting in frequent inundations (Bangladesh Water Development Board (BWDB, 1987). Loss of forest cover can make human habitation and various natural resources more vulnerable to changing climatic conditions (Wisner et al., 2003). A plethora of studies show that the presence of native forests do reduce the frequency and severity of floods as they trap water during heavy rainfall and release it slowly into streams, reducing the run off rate (EEA, 2015; Laurance, 2007). The rationale behind this belief is that natural forests have a higher evaporation and infiltration rates compared to other types of vegetation, thus are likely to prevent the flood risks (FAO and CIFOR, 2005). Other studies argued

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that forests can prevent flood water in-flow but cannot stop large scale floods completely (Brang et al., 2006). For instance, VanDijk et al. (2009) finds that there is no correlation($r < 0.10$) between forest cover (or forest cover loss) and flood incidences. Scientists often oppose the direct links between forests and floods, on account of the fact that hydrological systems are so complex that it is difficult to find out the exact causality between land use and natural processes (Bruijnzeel, 2004; Enters et al., 2004; FAO and CIFOR, 2005; Calder, 2005; Calder and Aylward, 2006).

The above studies highlight that the association between forest cover and flood occurrences is unclear and differed across space and scale (Wisner et al., 2003; FAO and CIFOR, 2005). It can be argued that forests may be a necessary condition to prevent flood related damages but it may not be a sufficient condition. The other potential factors which are likely to have a significant impact on the flood occurrences and damage include climate variability, density of population (Hamilton, 1985), socio-economic parameters (Brooks et al., 2005) and built environment or infrastructural density (Pregnolato et al., 2017). A detailed review of related literatures on these factors is presented in Section 2.

Floods in India, which is the chief concern of this study, are a regular phenomenon that occurs in almost all parts of the country, causing significant damage to human lives, assets and ecosystem (Intergovernmental Panel on Climate Change (IPCC, 2014). Rapid change in weather patterns and decline in forest cover are considered to be the main reasons for frequent floods and associated damage to both human lives and natural system (Bhattacharjee and Behera, 2017). According to the report of the Flood Control Management Programme of the government of India, annually about 7.55 million hectares of land is affected due to floods and about 1560 human lives are lost due to floods in India. In addition, the report estimates that the damage to crops, houses and public utilities due to floods is estimated to be $300.83 million (Government of India (GOI, 2017). The eastern Indian states that are situated on the Gangetic plain are reported to be frequently and adversely affected by floods, as the region receive higher rainfall compared to other regions (Smith et al., 1998; Mohapatra and Singh, 2003). Among the eastern provinces of India, West Bengal has got a long history of experiencing regular floods that cause significant damage to all aspects of human lives and natural system. According to the report of Irrigation and Waterways Directorate, government of West Bengal, the state records floods mostly on account of heavy rain in the catchment areas of the rivers, which have origin in the neighbouring states and countries (Government of West Bengal (GOWB, 2013). In the last two decades the flood occurrence in the state has increased and approximately 42.3% of the total geographical area of the state is found to be vulnerable to floods (Government of West Bengal (GOWB, 2013).

In this context, the present study makes an attempt to examine the relationship between forest cover and flood damage. In particular, the study aims to examine the effects of forest cover on frequency of flood incidence and flood related damages using secondary data from across Indian states and flood affected districts of West Bengal, controlling for socio-economic status, population density, infrastructural density, and climate parameters.

2. Factors influencing flooding and flood damage: review of related literature

2.1. Association between forest cover and floods

It is argued that the destruction of natural forests or unsustainable forest land use practices can cause increased runoff rates on account of reduced infiltration rates, however, the degree of influence depends on the scale and type of flood events (Calder and Aylward, 2006). A scientific study carried out in 56 developing countries concludes that the flood frequency decreased with increase in natural forest cover and increased with increase in non-natural forest cover (Bradshaw et al., 2007). Another study conducted in eastern Indian province of Odisha finds a negative association between the width of mangrove forests and number of people killed in the super cyclone that struck in 1999 (Dash and Vincent, 2009). This suggests that with increase in forest cover and other natural vegetation cover there is an effective increase in the infiltration rate, evapo-transpiration rate and water retention potential of catchments that result in less severity of floods (EEA, 2015). Hence, it is necessary to manage the forest ecosystem sustainably in order to preserve the flood control property of forests (Wahren et al., 2012). The environmental benefits of forest preservation or afforestation measures are often found to go beyond the local scale level, also far from where actual decisions on tree planting or removal are made (Ellison et al., 2017).

The conventional understanding that forest acts as barriers to floods was first challenged by Hewlett (1982), who argued that presence or absence of forests may not significantly influence the magnitude of large scale flood events. Subsequently, Lecce and Kotecki (2008) observed no relationships between human-induced land cover changes and the severity of flood damages. This is because long lasting intense precipitation can saturate the absorptive property of soils, thereby limiting the flood mitigation potential of forests (Ellison et al., 2017). It was found that a forest cover of less than 10 percent and more than 90 percent have similar influence on the water yield, and the run-off rate is likely to increase with increase in forest cover (Brookhuis and Hein, 2016; Gao et al., 2000). Also, in some other situations the reforestation projects did not always reduce flooding. This is mainly because of other factors, which include soil properties, river bed morphology, moisture content, activities such as drainage, agriculture, construction etc., play key role in influencing water in-flow and inundation process (VanDijk et al., 2009).

2.2. Population density, demographic structure and the extent of flood damage

The extent of flood damage is often positively associated with population density and demographic structure of flood affected regions (Rufat et al., 2015; Güneralp et al., 2015; Kellenberg and Mobarak, 2008; Gupta, 2010). The current global economic development pattern seems to be putting more people at low lying flood risk prone areas such as coastal zones, and cities and towns that are vulnerable to large scale flooding (McGranahan et al., 2007). It is observed that due to increased population density in extremely vulnerable areas, developing countries are experiencing severe environmental degradation often resulting in large scale damages (Enarson, 2000). One classic example is the rising population pressure in coastal regions resulted in the destruction of buffer zones such as mangroves, wetlands, tree and vegetation cover, etc. (Donner and Rodríguez, 2008; Kellenberg and Mobarak, 2008). Thus, it can be argued that increasing population density in low lying and coastal areas may lead to more construction of concrete structures in sensitive and vulnerable ecosystem which in turn may increase the probability of flood incidences. Further, it is observed that as flood prone areas in developing countries get highly populated, the capacity of local communities to cope with disaster get reduced, and with availability of limited options of coping and adaptation strategies the flood damage is expected to be severe (Dawson et al., 2011; Donner and Rodríguez, 2008; Ward and Shively, 2011).

Empirical studies observed that the effects of floods are often found to be determined by several factors such as geographical location, age of population, socio-economic conditions and gender (Dankelman, 2002; Güneralp et al., 2015). For example, large number of rural women population in developing countries are engaged in activities directly linked with the natural environment, which makes them more vulnerable to climate extremes such as floods (Nelson et al., 2002; Pham et al., 2016; Cutter, 2017). Thus, when flood disaster strikes, the women are the most vulnerable group as their physical labour increases both inside and outside their homes. Children and elderly people are