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Forest cover change and flood hazards in India

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ABSTRACT

Forests provide numerous environmental services such as watershed protection, nutrient cycling, pollution control, climatic regulation, carbon sequestration, flood mitigation, and protection from storms, landslides, and soil erosion. Degradation of forest resources is likely to cause adverse effects on the economy and environment both locally and globally. Further, it is observed that the natural forests do reduce the frequency and severity of floods as it traps water during heavy rainfall and releases the same slowly into streams reducing the run off. However, this link between forest covers and flood damages is still unclear and yet to be settled in empirical literatures. Also, the protective role of forests in Indian context has remained largely unexplored and this paper attempts to fill this research gap. The objective of this study is, therefore, to examine the impact of forest cover on the extent of flood damage in India controlling various social, economic and demographic aspects. The study uses secondary data across the Indian states for the period 1998–2011. The data were analyzed using the Poisson and ordinary least square (OLS) regression models. The findings suggest that forest cover in India has an inverse relationship with the flood damages. In addition, socio-economic factors such as literacy, per capita net state domestic product and population size have significant influence on the extent of flood damages. Hence, investments in forest protection and regeneration are necessary to restrict flood damages and protect human lives and properties.

1. Introduction

Among all environmental resources, forests are the most crucial ones in the ecosystems (Reddy et al., 2002; Brang et al., 2006). Apart from providing direct use values such as food, fuel, timber etc., forests provide numerous environmental services including watershed protection, nutrient cycling, carbon sequestration, pollution control, climate regulation, flood mitigation, prevention of adverse effects of storms, regulation of run-offs, river discharge and infiltration, groundwater recharge, soil preservation, and prevention of landslides and soil erosion (DeGroot et al., 2002; Hamilton, 2005; Heal, 2000; Kibria, 2013; Laurance, 2007; Reddy et al., 2002; Upadhyay et al., 2002). Loss of forest cover can make the ecosystem, human habitation and various natural resources more vulnerable to changing climatic conditions in the form of extreme weather events such as floods and other related natural disasters (Wisner et al., 2003). It is observed that the native forests do reduce the frequency and severity of floods as they trap water during heavy rainfall and release the same slowly into streams, reducing the run off rate (EEA, 2015; Laurance, 2007).

Hence, there exists a strong linkage between forest cover and flood hazards (Barua et al., 2010; Bradshaw et al., 2007; Brang et al., 2006; Kibria, 2013; Lang, 2002). Presence of forest cover results in low rate of surface run-offs and soil erosion (Sanderson et al., 2012). It is argued that forest cover reduces flood occurrences by removing a proportion of the storm rainfall and allowing the build-up of soil moisture deficits (Calder and Aylward, 2006). A study comprising of 56 developing countries of the world have shown that frequency of floods decreases with increase in natural forest cover and rises with increase in non-natural forest cover (Bradshaw et al., 2007). However, this particular study does not take into account the flood events occurring independently of the land use patterns, such as hurricanes, making it ambiguous to draw conclusions as to what extent this apply to extreme rainfall events. Another study on Sri Lanka shows that presence of mangrove forests has reduced the intensity of tsunami waves significantly (Adger et al., 2005). Studies carried out in the aftermath of the Odisha super cyclone in the year 1999 and tsunami in 2005 have indicated that forests have a lifesaving ability against storms and waves (Alongi, 2008; Dash and Crépin, 2013; Dash and Vincent, 2009; EJF report, 2006). It is observed that regions with large width of forests have recorded less damage as compared to those with no or considerably less forests (Barua et al., 2010; Dash and Vincent, 2009; Jayatissa and Hettiarachi, 2006).

Incidence of frequent and devastating floods is common in India and its neighbouring South Asian countries (Kundzewicz et al., 2008;

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Stephen, 2012). It is estimated that about 40 million hectares of land in India is flood prone and nearly 8 million hectares of land is affected by floods annually (De et al., 2005). The top flood prone states of India include Gujarat, Bihar, Uttarakhand, Maharashtra, West Bengal, Odisha, Andhra Pradesh and Kerala (NRAA, 2013). It is observed that increasing pressure of population in coastal areas have resulted in rampant removal of trees which have caused numerous floods and consequent losses of human lives and properties (Doocy et al., 2013). During the last decade, deforestation and change in land use patterns have destroyed the forest cover in India (Badola and Hussain, 2005; Brenkert and Malone, 2005). It is observed that there lies a strong association between the elements of land use, soil erosion and stream flow or run-off in the Himalayan region of the country (Tiwari, 2000).

It is argued that forests act as a natural barrier against extreme hydrological hazards (EEA, 2015). However, soil erosion and flooding are not due to only forest loss, it is also caused by torrential rains (Gilmour et al., 1987). Moreover, effectiveness and reliability of the protection provided by forests depend upon the configuration of the coastline, topography, geomorphology, properties of the existing coastal vegetation, and the frequency and intensity of natural hazards (Brang et al., 2006; FAO, 2007). It is often argued that forests trap flood water but may not stop large scale flood events completely (Brang et al., 2006). As the size of the hydrological event increases, the effects of forest cover become less significant (Bathurst et al., 2011). Following Bradshaw et al. (2007), the study made by Van Dijk et al. (2009) found that the correlation between forest cover and/or forest cover loss and flood frequency appears to be very low ($r < 0.10$). The study further observes that if soil infiltration and surface run-off are not affected, the amount of rainfall that enters the soil would be expected to be very similar between forested and non-forested conditions (Van Dijk et al., 2009). Hence, deforestation may not be a sole determining factor of flood events (Ives, 1989). Hewlett (1982) reviewed the evidences on watershed research worldwide and reported no cause and effect relationships between forest degradation in the headwaters and floods in the lower basin. It is essentially argued that forests may not stop catastrophic large-scale floods but it has the potential in significantly delaying and reducing peak floodwater flows for short duration rainfall events which occur on local scales (Enters et al., 2004; Sanderson et al., 2012).

Hence, there exists considerable ambiguity on the linkages between forest cover and floods (CIFOR & FAO, 2005). In this perspective, the objective of the present paper is to examine the impact of forest covers on flood damages in India, where the frequency and severity of flood have risen over the years. The study is carried out using state level data for the time period 1998–2011. The paper is structured in the following way: Section 2 reviews the current empirical literatures on the inter-linkages between changes in forest cover and flood events. Section 3 provides the methodology applied and information on the data sources used in the study. Section 4 reports the summary statistics of the variables used in the models and the regression results, whereas Section 5 deals with the discussion part. Finally, Section 6 summarises the major findings and concludes the paper with policy implications.

2. Inter-linkages between deforestation and flood: a review of related literatures

The traditional belief about the impact of forest cover on occurrences of floods has been that forest cover does help in reducing floods and/or flood damages significantly. This notion was challenged by a study carried out by Hewlett (1982), which showed that presence or absence of forests may not significantly influence the magnitude of large scale flood events. Subsequently, Lecce and Kotecki (2008) found no relationships between human-induced land cover changes and the severity of flood damages. Recent studies reveal that landscape structure do affect flood events with a return period of ≤ 10 years (e.g., Mogollón et al., 2016). This indicates that large-scale floods might not be prevented and/or managed by altering the land use patterns. It is found that large-scale flood events are largely influenced by other drivers such as levels of precipitation and temperature (Sagarika et al., 2014). Also, under maritime climatic conditions, sea-surface temperature is likely to have more impact on extreme climatic events as compared to land use patterns (Bruijnzeel, 2004). This means that high peak flows cannot be prevented from resulting in flood occurrences through afforestation. Hence, it is argued that forest cover may not significantly reduce peak flows during extreme events, but could be effective during more frequent and less intensive rainstorms (Bathurst et al., 2011).

On the other hand, empirical studies found that soil erosion is largely influenced by land use rather than environmental characteristics (Valentin et al., 2008). In China, for instance, deforestation in the catchment area induced soil erosion, resulting in a large amount of sediment deposition in reservoirs, thereby reducing the storage capacity and consequently raising the water level during floods (Zong and Chen, 2000). A similar study in Southern Thailand shows that the loss of forest cover resulted in loss of watershed services as it increased the average surface runoff volumes and peak discharges for a given watershed due to reduced evapotranspiration, thereby resulting in increase in occurrences of flood events (Trisurat et al., 2016). In Malaysia, conversion of inland tropical forests to oil palm and rubber plantations significantly increased the number of days flooded during the wettest months (Tan-Soo et al., 2016). But, this again is a narrow view as such observations may depend upon the species planted in the watershed area and the topography of a place, which makes it hard for generalisation of the results. Therefore, it would be useful if a comparison of the loss of forests comprising of different species is made as there are species which result in increase in run-off with rise in its coverage (Mouri et al., 2016).

Empirical studies also find a non-linear relationship between catchment's forest cover and the generation of its flood control services, implying that even a small level of deforestation can lead to a significant increase in flood risks (Brookhuis and Hein, 2016). This suggests for increasing forest cover and other natural vegetation that can effectively increase the infiltration rate, evapotranspiration and retention capacities of watersheds, and thereby result in less severity of floods (EEA, 2015). In addition to deforestation, climate change can also be an important factor in the fragile ecosystem causing changes in watershed services. It is found that the combined effects of changes in land use patterns and climate may have a stronger impact on water yield as compared to either of the two taken separately (Trisurat et al., 2016). It is also observed that extreme rainfall do not necessarily result in increased incidence of flood, but change in forest cover might be the primary cause of the same (Tarigan, 2016). A study in the context of Amazon flood plain finds that climate related patterns are exacerbated by deforestation and, in turn, the negative effects of deforestation is further aggravated by increasing climate variability and intensity of climate related extreme events (Oviedo et al., 2016).

Brookhuis and Hein (2016) argue that there may be a threshold limit at around 85–90% forest cover, after which the flood control services of the forests begin to decrease rapidly. However, Wang et al. (2011) found no statistically significant relationships between forest cover and precipitation at micro ($< 50\ km^2$) and meso scales ($50–1000\ km^2$), but they were positively correlated at macro ($> 1000\ km^2$) scale. On the contrary, it was found that if forest cover is less than 10 percent, water yield increases with forest cover. On the other hand, when forest cover is greater than 10 percent, the run-off coefficient decreases as forest cover increases (Gao et al., 2000). This implies that a forest cover of less than 10 percent and more than 90 percent have similar influence on the water yield.

Interestingly, the study by Zhang et al. (2012) on the relationship between forest harvest and run-off across different seasons in China showed varied results. It finds a negative impact of forest harvesting on run-off in dry season and positive impact on run-off in annual and wet