Understanding the Relationship between Forests and Floods: Empirical Evidence from India

Kasturi Bhattacharjee*[1] and Bhagirath Behera[2]

Department of Humanities and Social Sciences

Indian Institute of Technology, Kharagpur

Kharagpur-721302

Email: kasturi.bhattacharjee9@gmail.com; bhagirath9@gmail.com

Abstract

Of all environmental resources, forest resources are the most crucial links in the ecosystems. Apart from providing direct use values, forests provide numerous environmental services such as watershed protection, nutrient cycling, pollution control, climatic regulation, carbon sequestration, flood mitigation, prevent storms and landslides, and controls soil erosion. It is argued that degradation of these precious resources affects 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 trap water during heavy rainfall and release it slowly into streams, which lessens the severity of floods. However, the link between forests and floods is still ambiguous and yet to be settled in academic literature. For unravelling this relationship, the objective of this study is to examine the relationship between flood impact and forest cover in India, where the frequency and severity of flood have risen over the years. The study uses secondary data on flood impact (loss of human lives and people affected), forest cover and deforestation across the states of India for the period 1998-2011. The association between flood impact and forest cover is examined taking into account the meteorological factors and socio-economic parameters of the states. The coefficients of Poisson regression and the Ordinary least square regression obtained suggest that the trend of forest cover in the country have an inverse relationship with the flood impact. Socio-economic factors such as literacy, per capita net state domestic product and total population have a significant influence on the magnitude of flood impact. Whereas climatic factors such as rainfall and temperature did not show a significant influence on the flood impact. The relative hazard loss ratio indicates that all the states of India are economically stable enough to be able to cope with the flood damages. The disaggregate level analysis suggest that several Indian states are highly vulnerable to floods due to large scale deforestation and forest degradation. Hence, large scale investment in forest protection and regeneration is needed to prevent persistent flood occurrences and to protect human lives.

Keywords- Forest cover, flood damages, mortality ratio, relative hazard loss ratio, socio-economic parameters

[1] Corresponding Author. PhD Scholar, Department of Humanities and Social Sciences, Indian Institute of Technology, Kharagpur. Tel - +91 9434203472

[2] Associate Professor, Department of Humanities and Social Sciences, Indian Institute of Technology, Kharagpur Tel: + 91 9933077258

INTRODUCTION

Of all environmental resources, forests are the most crucial links in the ecosystems. Apart from providing direct use values such as food, fuel etc., forests provide numerous environmental services such as watershed protection, nutrient cycling, carbon sequestration, pollution control, climate regulation, flood mitigation, prevents storms, landslides and soil erosion (Reddy et al., 2001; Laurance, 2007; Upadhyay et al., 2002). It is argued that degradation of these precious resources affects the economy and environment both globally and locally (Calder, 2006). Further, it is observed that the native forests do reduce the frequency and severity of floods as it trap water during heavy rainfall and release it slowly into streams, which lessens the severity of floods (Laurance, 2007). However, the link between forests and flood impact is still imprecise and not yet established in academic literature (Bradshaw et al., 2009).

Moderating climate change and disaster mitigation is among various principal functions of forests (Kibria, 2013). Ecosystem processes and services provided by the forests include maintenance of temperature and rainfall, storm protection, flood mitigation, water regulation, regulating run-off, river discharge and infiltration, groundwater recharge, soil retention, prevention of damage from erosion and siltation (Heal, 2000; DeGroot et al., 2002; Hamilton, 2005). Loss of forest cover predominantly makes the coastal habitation and the coastal resources more vulnerable to climate hazards (Wisner et al., 2003).

There exists a strong linkage between forests and flood hazard (Lang, 2002; Brang et al., 2006; Bradshaw et al., 2007; Kibria, 2013; Barua et al., 2003). Soils under natural forests are relatively porous and have high infiltration rate. Thus presence of forests results in a low rate of surface runoff and soil erosion. Theoretically, it can be said that forests reduce floods by removing a proportion of the storm rainfall and by allowing the build-up of soil moisture deficits (Calder and Aylward, 2006).A study considering 56 developing countries of the world have opined that flood frequency decreases with increase in natural forest cover and rises with increase in non-natural forest cover (Bradshaw et al., 2007). Recurrent floods and consequent loss of lives and property were experienced in the mountainous watershed region of Asia on account of loss of natural forests (Achouri et al., 2005). The studies made after the Odisha cyclone in 1999 and tsunami event in 2005, have found that forests have a lifesaving ability against storms and waves (Dash and Vincent, 2009; Dash and Crépin, 2013; Alongi, 2008; EJF report, 2006). A study conducted in Sri Lanka showed that the presence of mangrove forests have reduced the intensity of tsunami waves (Adger et al., 2005). It has been evident from the studies conducted in different parts of the Asia, that region with large width of forests have recorded less damage as compared to the regions with no forests at all (Barua et al., 2010; Dash and Vincent, 2009; Jayatissa and Hettiarachi, 2006). And adding to this evidence, it was observed that the countries which were hit hardest by the tsunami such as Indonesia, Sri Lanka, India and Thailand, have experienced net loss in forest cover just before the event took place (EJF report, 2006).

Devastating floods are common in India and its neighbouring countries (Stephen, 2012; Kundzewicz, 2008). About 40 million hectare of land in India is flood prone and every year nearly 8 million hectares of land is affected by floods (De et al., 2005). The year 1961 is recorded as the year of worst flood with a total area affected as 1.795×10^6 sq. km (Chowdhury and Mhasawade, 1991). The top ten flood prone state of India are; UP, Bihar, Punjab, Rajasthan, Assam, Uttarakhand, Himachal Pradesh, Maharashtra, Rajasthan, West Bengal, Haryana, Odisha, Andhra Pradesh, Gujarat and Kerala (NRAA, 2013). It is found that increasing pressure of population in coastal areas have resulted in rampant cutting of trees and this in turn have caused numerous floods and consequent losses (Doocy et al., 2013). Along the Indian coast which is vulnerable to floods and cyclones, wide forests were present in the past. But during the last decade, intense deforestation and change in land use patterns have destroyed the forest cover (Brenkert and Malone, 2005; Badola and Hussain, 2005). It is claimed that tropical forests are among the most threatened habitats in the world, this is because of degrading livelihood opportunities on account of too much dependence on nature and rising pressure of population on land (Upadhyay et al., 2002; Bahinipati and Sahu, 2012). If destruction of forests continues, flooding of the coast would occur incessantly. Therefore, in India, promotion of forestry has been taken up as an effective means of reducing flood impact and is a part of watershed management programs funded by both national and international agencies (Calder and Aylward, 2006).

A study outlined diverse ways in which coastal forests may reduce tsunami impact and asserted that a forest is effective in mitigating tsunamis for several reasons: it stops trash and other debris; it reduces water flow velocity and inundation depth by reducing tsunami energy; it provides a life-saving entrap for people who are swept off by a tsunami run-down; and it hoards wind-blown sand and create dunes, which serve as a natural barriers against tsunamis (Harada and Imamura, 2005). However, it is also said by the same study that huge tsunamis can destroy forest trees and these floating trees causes' secondary damages by collapsing houses. So, we can say that there are studies which have found that forests act as a natural barrier against extreme climate hazards in coastal areas. However, the effectiveness and reliability of the protection provided by the forests depend upon the configuration of the coastline, topography, geomorphology, the properties of the existing coastal vegetation, frequency and intensity of natural hazards (Brang et al., 2006; FAO, 2007). However, it is also said that forests can trap flood water but cannot stop large scale flood events completely (Brang et al., 2006). And there exist a considerable debate on the linkage between forest loss and floods (Bradshaw et al., 2009). The objective of the study is to examine the relationship between flood impact and forest cover in India, where the frequency and severity of flood have risen over the years. The flood impact is measured by the number of people affected, number of lives lost and mortality ratio. All the states of India are taken into account for the study, considering the time period of 1998 to 2011. The paper is structured in the following way; Section 2 gives the data sources and the methodology used in the study. Section 3 discusses the results of the study. Section 4 deals with the discussion followed by the conclusion and policy implications in Section 5.

SOURCES OF DATA, METHODOLOGY & VARIABLE DESCRIPTION

Vulnerability to disaster is a function of both physical and social factors (Ajibade et al., 2013). The term vulnerability is used in many different ways by various research communities belonging to field such as food security, natural hazards, disaster risk management, public health and climate change (Fussel and klein, 2006). Vulnerability definition as per IPCC is given by, "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and role of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity." This definition of vulnerability by IPCC includes both external and internal aspects of vulnerability. Here external aspect is concerned with the exposure of a system to climate variations. Internal aspect includes sensitivity and adaptive capacity of the system. This indicates that vulnerability is determined by both biophysical and socio-economic factors.

Taking into consideration the concepts of vulnerability discussed above, here exposure is given by the total population, and sensitivity of the states is given by literacy and the meteorological parameters such as rainfall and temperature of the state. The adaptive capacity is given by the economic potential i.e. per capita net state domestic product (NSDP) of the state and marginal labour population. This study examines the association of forest cover and deforestation with the flood impact taking into consideration the above mentioned meteorological and socio economic parameters. The flood impact is measured by the number of people affected, number of lives lost and mortality ratio. Here the mortality ratio is measured as the ratio between number of people killed and the number of people affected. The very first step involves estimation of the number of people affected (Yi), number of lives lost (Xi) and mortality ratio (Mi).

$$Yi = f\begin{pmatrix} forest\ cover, deforestation, rainfall, temperature, total\ population, literacy, NSDP, \\ marginal\ population \end{pmatrix}\_1$$

$$Xi = f\begin{pmatrix} forest\ cover, deforestation, rainfall, temperature, total\ population, literacy, NSDP, \\ marginal\ population \end{pmatrix}\_2$$

$$Mi = f\begin{pmatrix} forest\ cover, deforestation, rainfall, temperature, total\ population, literacy, NSDP, \\ marginal\ population \end{pmatrix}\_3$$

These functions can be re-written as follows-

$$Yi = f(\ Fi, Di, Ri, Ti, Pi, Li, NSDPi, MPi)\_4$$

$$Xi = f(Fi, Di, Ri, Ti, Pi, Li, NSDPi, MPi)\_5$$

$$Mi = f(Fi, Di, Ri, Ti, Pi, Li, NSDPi, MPi)\_6$$

Here, i indicates state and Y_i represents number of people affected of a ith particular state, X_i is number of people killed in ith particular state, M_i is the mortality ratio of ith particular state, F_i is the forest cover of ith particular state, D_i is the deforestation of ith particular state, R_i is the rainfall of ith particular state, T_i is the temperature of ith particular state, P_i is the total population of ith particular state, $NSDP_i$ is the per capita net state domestic product of ith particular state and MP_i is the marginal population of ith particular state.

In equation 4 and 5, the dependent variable is a non-negative count variable. Also it is clustered with large number of zeros and the range of non-zeros is very wide. Thus, a linear regression or OLS regression would not be fit for estimating the model. So, in this study we have used Poisson regression model for estimating the first two equations. And for equation 6, where the dependent variable is continuous, we have used OLS regression model for estimation.

Incase of Poisson regression model[1] the explanatory variables can take any real values and the outcome variable has to be non-negative and count variable. If Y(say) is the outcome variable, which is said to have a Poisson distribution with mean μ(say). Then Y can take any integer values y = 0,1,2,3,…. with probability –

$$Pr(Y = y) = \frac{e^{-\mu}\mu^{y}}{y!} \quad for\ (\mu > 0).\_\ 7$$

Here μ is the mean.

[1] Rodríguez, G. (2007). Chapter 4, Poisson Models for Count Data. Lecture Notes on Generalized Linear Models. Available at http://data.princeton.edu/wws509/notes/

The mean and the variance of this distribution is given by-

$E(Y/X) = Var(Y) = \mu\_8$

Here the mean is equal to the variance. So, any factor that affects one will also affect the other. Therefore, the issue of homoscedasticity is not appropriate in this case.

For this study, we have considered all the states of India to examine the association between forest cover and flood impact after controlling for meteorological and socio-economic parameters. From the literature surveyed it is found that the extent of flood damage in a particular area depends upon the meteorological factors of the place and its socio-economic parameters. Meteorological factors considered for this study are rainfall and temperature. And the socio-economic factors considered are; literacy, net state domestic product(NSDP), total population and marginal labour population.

Table 1. Description of the Variables taken in the Model

Variables	Description of the variable
Forest Cover[2]	Width of forest cover in each state
Deforestation[3]	Area of forest cover converted to non-forest cover
Rainfall and temperature[4]	Determines the intensity of floods
Total population[5]	Determines the proportion of people exposed to the hazard
Literacy[6]	Determines the level of awareness among the people in a particular region
Net State Domestic Product[7]	Determines the economic potential of a particular region
Marginal labour population[8]	Determines the proportion of population who are socially and economically backward and

[2] Bradshaw, C.J.A., Brook, B.W., Peh, K.S.H. and Sodhi, N.S. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Change Biology, 13, 2379–2395*

[3] Bradshaw, C.J.A., Brook, B.W., Peh, K.S.H. and Sodhi, N.S. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Change Biology, 13, 2379–2395*

[4] Alongi, D.M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science, 76, 1—13*

[5] Das, S. (2010). Sustaining mangrove forests to reduce vulnerability of coastal villages from climate change. http://www.researchgate.net/publication/50434142

[6] Das, S. (2010). Sustaining mangrove forests to reduce vulnerability of coastal villages from climate change. http://www.researchgate.net/publication/50434142

[7] Das, S. (2010). Sustaining mangrove forests to reduce vulnerability of coastal villages from climate change. http://www.researchgate.net/publication/50434142

[8] Das, S. (2010). Sustaining mangrove forests to reduce vulnerability of coastal villages from climate change. http://www.researchgate.net/publication/50434142

	don't have fixed income source.

Apart from finding out the association between forests and flood impact, the economic potential of a state to bear the flood damages are also measured using the relative hazard loss ratio across all the Indian state for the period 2000 to 2011. This ratio gives the direct damages of a particular state due to floods relative to the economic potential (NSDP) of that particular state. This shows whether a state is economically sound enough to cope with its flood damages. Here, the direct damage is the sum of estimated damages to crops, public utilities and houses due to floods.

The data on flood relating to total number of people affected, number of lives lost and meteorological factors are obtained from the web portal www.indiastat.com. Data on forest cover and forest loss is obtained from the annual reports of forest survey of India for the respective study period. Census report of India for the year 1991, 2001 and 2011, has been considered for obtaining data on literacy, total population, NSDP and marginal labour population. Statistical software STATA13 has been used to perform the test.

RESULTS

Summary Statistics[9]

The state which has recorded the highest average forest cover is Madhya Pradesh with forest width 76,294.07 sq. km. It records an average number of people affected as 8,02,687.5 and average number of lives lost as 26.14. The state of Bihar records the highest average number of lives lost and people affected; 246.07 and 7,77,7357.14 respectively. This state has an average forest cover of 7425.64 sq. km. The statistics of the socio-economic parameters of Bihar reflect that it is the most backward region of the country. This coupled with low width of forests might be the reason of its high magnitude of devastation caused due to flood events. Average number of lives lost is quite high in states of Andhra Pradesh, Assam, Gujarat, Maharashtra, Uttar Pradesh and West Bengal. And the states which have recorded a high average number of people affected were Chhattisgarh, West Bengal, Uttarakhand, Andhra Pradesh and Assam.

The maximum values of the number of lives lost shown in figure 1, indicates that Gujarat, UP and West Bengal have recorded highest number of flood related human fatalities. Figure 2, shows that Chhattisgarh followed by Uttarakhand and Gujarat have experienced highest maximum number of people affected due to floods. From the figures 3 and 4, it is observed that the maximum forest cover and deforestation values have been recorded by Madhya Pradesh and Kerala respectively. The per capita NSDP and literacy in Maharashtra is quite high but the magnitude of people affected in floods is also high. This indicates that apart from social and economic parameters, there are certain other factors such as physical or meteorological factors that determine the flood impact.

[9] Summary statistics of the variables are shown in table 2 and in figure 1,2,3,4.

Table 2. Mean Values of the Variables

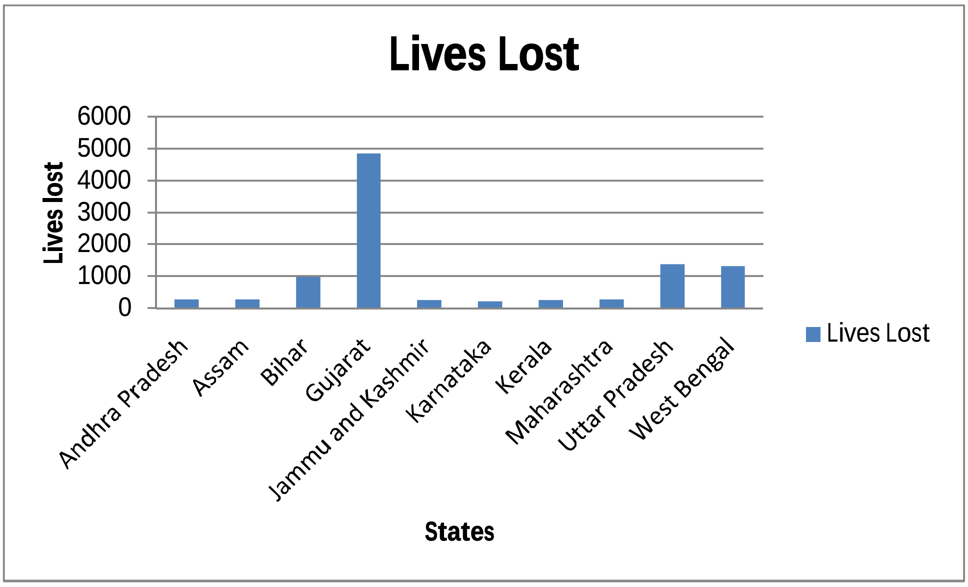
States	Lives Lost	People Affected	Mortality ratio	Forest cover(sq. km)	Deforestation(sq. km)	Rainfall(mm)	Temperature(max)	Literacy	Per capita NSDP	Total Population	Marginal Population
Andhra Pradesh	74.57	4958230.76	3.13-05	39822.35	559.21	1763.5	39.25	57.42	25253.9	74728919.3	10651933.43
Arunachal Pradesh	4.21	1141692.31	1.6-05	67914.28	206.07	2339.3	_	52.39	23001.2	1068362.92	22973.28
Assam	64.71	4315000	3.95-05	26857.92	660.57	2394.8	34.37	61.66	15229.6	26071701.5	3555130.86
Bihar	246.07	7777357.14	0.00011	7425.64	157.85	1446.7	40.56	46.23	7869.6	85229138.3	11079872.57
Chhattisgarh	10.71	39970642.8	9.76-05	55979.27	134.86	1246.0	_	60.40	17166.4	21262111.6	3102456.45
Goa	0.43	287.5	_	3533.07	139.07	3109.9	38.87	81.09	66920.2	1317471.71	39263.93
Gujarat	116.57	1206888.88	0.00072	13477.29	427.28	1402.91	40.57	68.09	32070.2	49362757.7	4418138.78
Haryana	_	153758.33	_	1445.14	203.64	508.89	_	65.87	37055.2	20442003.2	1129832.5
Himachal Pradesh	33.71	796727.27	6.73-05	14157.14	267.21	1015.8	31.12	74.23	31042.2	5939730.93	266395.1
Jammu and Kashmir	20.5	_	_	21342.57	121.29	981.5	32.05	_	18988.2	10361663.8	378575.82
Jharkhand	0.93	25000	0.00012	20207.71	215.93	1200.2	56.49	51.87	15489.5	27495129.4	3172642.64
Karnataka	41.64	2612000	4.19-05	36445.64	740.21	5347.3	34.14	64.99	26172.4	51752322.8	5096567.57
Kerala	43.93	372384.62	6.97-06	15074.28	765.43	2818.3	36.06	90.85	30878.8	31365382.5	1525737.57
Madhya Pradesh	26.14	802687.5	0.00022	76294.07	800.85	1922.3	42.26	59.95	14975.8	62475039.2	6635628.14
Maharashtra	112.14	10255583.33	0.0087	46142.07	462.21	2714.4	34.91	74.71	36456.4	94140868.8	9091888.43

Manipur	_	60071.43	4.76-06	17265.29	275.07	1930.9	31.69	68.87	16040.2	2124979.79	122496.5
Meghalaya	0.5	38142.86	1.29-06	16714.29	241.93	2162.7	24.48	61.37	22273.2	2248531.64	151413.86
Mizoram	0.93	10000	_	19594	498	1946.1	_	87.58	26248.5	860871.71	34829.64
Nagaland	0.143	16000	_	13877.79	276.36	1930.9	_	66.46	26971.6	1821964.29	41890.21
Odisha	12.86	3395857.14	3.93-05	45061.78	380.5	1423.0	40.69	60.78	15841.7	36071430.4	4382842.57
Punjab	8.36	67055.55	0.00167	6964	309.5	530.4	41.41	67.71	31981	23727088.2	1209156.14
Rajasthan	8.41	66166.55	0.00171	6696	310	864.7	43.057	56.13	18066	54688449	3120538.35
Sikkim	11	12571.42	0.00036	4493.5	21.57	2607.8	_	67.17	30902.3	517032.71	18509.36
Tamil Nadu	36.93	76400	0.00074	20800.14	829.57	952.2	40.5	71.61	31640.2	61698618.4	6841264.29
Tripura	0.714	106076.92	4.65-05	7610.57	384.86	1791.6	35.64	71.46	23428.4	3138397.29	238845.86
Uttar Pradesh	186.29	3222857.14	5.58-05	15328.43	486.93	2049.1	42.71	53.94	12205.6	162794886.	11967453
Uttarakhand	25.36	7203572.72	0.00123	24378.73	223.18	1550.6	_	72.27	31558	8634525.64	317197.36
West Bengal	137.78	6217642.85	1.23-05	11495.85	595.12	3482.9	37.87	66.84	21743.2	78376570	6184400.36

I. Chandigarh is not taken because of unavailability of data

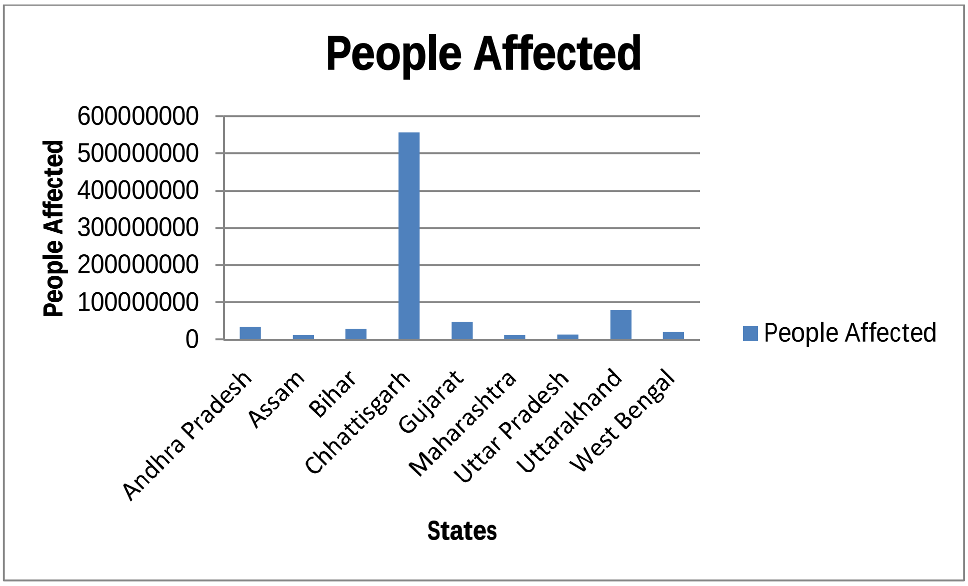
II. _ indicates either the value is negligible or nil.

Figure 1. State Wise Maximum Lives Lost



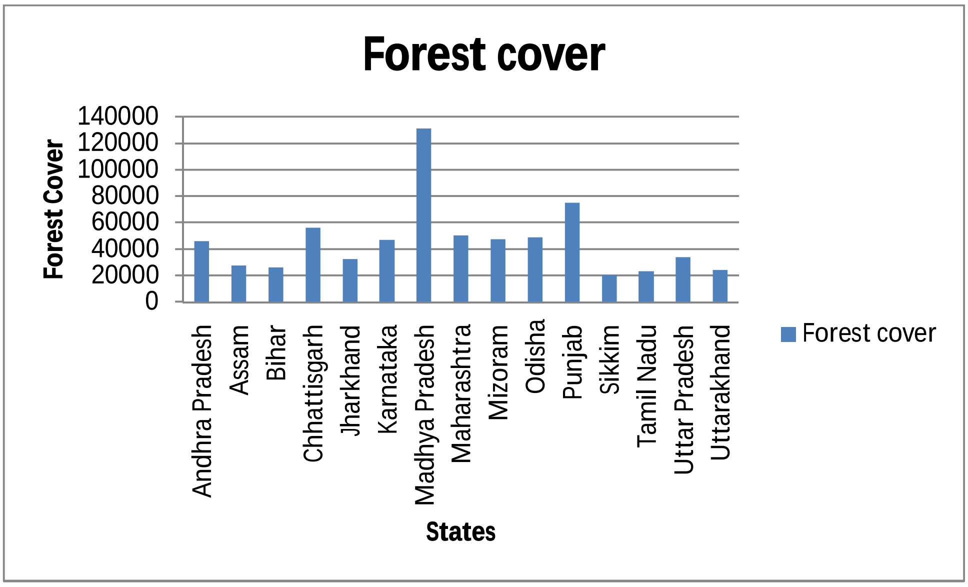
**The graph shows the states which have recorded more than 200 lives lost*

Figure 2.State Wise Maximum People Affected



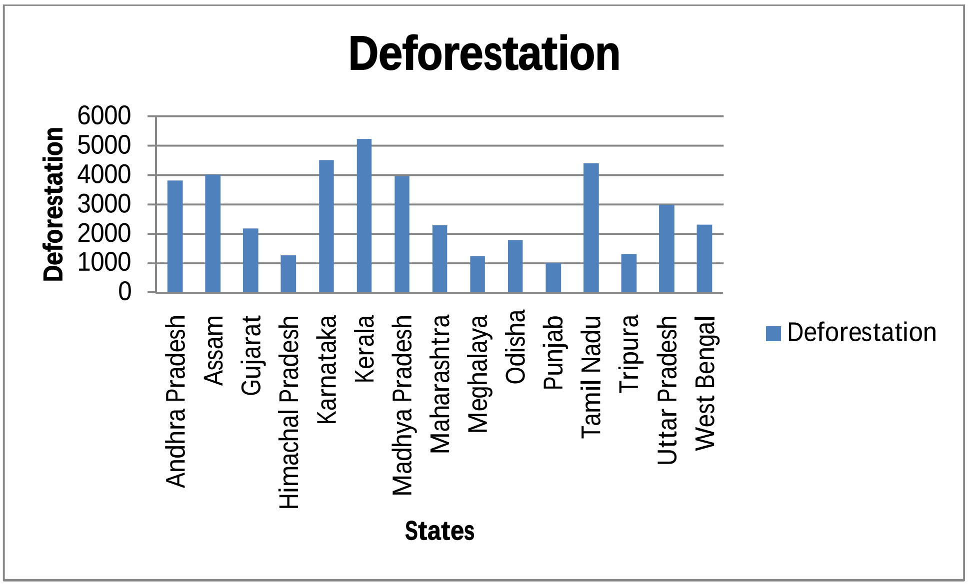
**The graph shows the states which have recorded a maximum of more than 10 million people affected due to floods*

Figure 3. State Wise Maximum Forest Cover



**The graph shows the states which have recorded a forest cover of more than 20,000 sq km.*

Figure 4. State Wise Maximum Deforestation



**The graph shows the states which have recorded deforestation of above 1000sq km*

Poisson regression results examining the association between forest cover and people affected in floods

The Poisson regression coefficient (table 3) of the states having high magnitude of number of people affected are Chhattisgarh (-0.0006819), Bihar (-0.0000846), West Bengal (-0.00065), Uttarakhand (0.0033421), Andhra Pradesh (0.000021) and Assam (0.0012). As the Poisson coefficient is less than 1 or zero, it indicates inverse or highly weak positive association between the forest cover and the number of people affected. This indicates that as forest cover increases, the number of people affected from floods reduces across all the Indian states. For some states the association between deforestation and people affected is found to be positive and for others it is found to be negative. The negative association might be because in some states the deforestation has been reduced but floods continue to devastate the region because of other socioeconomic and demographic factors.

The analysis found that the association between forest cover and people affected is inverse taking into consideration the socio-economic parameters and meteorological factors of each particular state. It is found that literacy, NSDP and total population have significant impact on the number of people affected in each of the state. Here the literacy and NSDP have got a significant negative association with number of people affected. Also there exist a significant positive association between the people affected and total population. Incase of majority of the states, rainfall has shown a weak positive influence on the number of flood affected people. But the variable temperature shows a positive impact stronger than rainfall. Therefore, it can be said that a state's economic potential, level of awareness and total exposure have a strong influence on the people affected due to floods.

Table 3. Poisson Regression Coefficient Taking People Affected As a Dependent Variable

States	Forest cover	Deforest ation	Rainfall	Temper ature	Literacy rate	Per capita NSDP	Total Population	Chi square
Andhra Pradesh	0.000021* (939.3)	-0.0003* (-834.5)	0.002* (6015.2)	0.1645* (2578.6)	-0.263* (-3176.3)	-0.00009* (-6507.7)	2.79* (3944.5)	854.7
Arunachal Pradesh	0.00035* (4038.4)	-0.004* (-1144.1)	-0.005 (-434.9)	_	-0.241* (-1781.5)	0.081* (708.3)	0.00005* (1144.1)	689.1
Assam	0.0012* (77.1)	0.0002* (28.4)	0.00008 (7.05)	0.1894 (57.9)	-3.0610* (-89.3)	0.000014* (9.3)	6.07* (90.2)	42222.7
Bihar	-0.00008* (-67.2)	0.0009* (58.4)	0.003*(110.5)	0.102 (124.6)	0.307* (84.6)	-0.00006* (-28.7)	-1.62* (-65.9)	32964.1
Chhattisgarh	-0.0007* (-12.6)	0.0006* (7)	0.001 (34.3)	_	-1.612* (-20.3)	0.00003* (9.5)	-2.88* (-28.3)	5908.6

Goa	0.00009* (11.4)	0.0001*(24.8)	-0.004 (-40.9)	0.089* (57.7)	-0.088* (-11.5)	0.00009* (42.7)	1.7* (15.4)	8770.8
Gujarat	0.00006* (11.1)	-0.002* (-60.2)	-0.002* (-89.5)	-0.253 (-65.6)	0.616* (70.4)	0.00006* (37.5)	4.65* (43.54)	58217.5
Haryana	0.008* (16.2)	-0.021* (-63.6)	-0.0003 (-2.9)	_	-1.367* (-13.8)	-0.0001* (-57.7)	4.34* (12.3)	755022
Himachal Pradesh	0.0012* (93.4)	0.00004* (3.5)	0.004 (81.8)	-0.045 (-23.7)	-0.590* (-116.7)	0.00004* (35.1)	5.14* (107.7)	63190.1
Karnataka	-0.00003* (-9.4)	-0.014* (-51.3)	-0.0005 (-19.8)	1.136 (104.1)	-2.610* (-60.5)	-0.0002* (-134.3)	2.84* (56.5)	41557.1
Kerala	0.0004* (22.2)	0.0002* (39.8)	0.0002 (8)	-0.093* (-12.7)	0.574* (44.5)	0.00005* (49.8)	-1.58* (-40.4)	12815.3
Madhya Pradesh	-0.00001 (-34.4)	-0.0001 (-10.9)	-0.0011 (-24.2)	0.021* (3.9)	0.095 (46.4)	-0.0003 (-129.7)	1.25* (49.5)	79219.5
Maharashtra	0.00015 (19.9)	-0.0006 (-40.1)	-0.0011 (-33.6)	-0.439 (-35.9)	1.851 (39.8)	6.63 (4)	-1.28 (-40.9)	94550.9
Manipur	0.0005* (227.5)	0.0001* (11.3)	-0.0002 (-114.6)	0.015 (10.9)	0.091 (67.2)	-0.00003 (-63.7)	-1.40 (-37)	111.8
Meghalaya	-0.001* (-138.9)	0.0005* (47.5)	0.002* (182.9)	1.07 (200.2)	-0.038* (-11.5)	-0.0001* (-126.2)	6.2* (7.6)	128.8

Odisha	0.0002* (35.9)	- 0.00004* (-2.6)	0.001 (40.9)	-0.054 (-23.5)	0.04* (4.7)	0.00004* (30.3)	-5.4 (-3.1)	17522.1
Punjab	-0.00002* (-3.4)	-0.0078 (-35.3)	0.007 (51.6)	0.553 (131.4)	-0.295* (-86.1)	-3.20* (-3.7)	3.1* (611.3)	766060
Rajasthan	0.000024* (7.3)	-0.013 (-49.7)	0.005 (60.1)	0.002 (126.8)	-0.108* (-57.04)	-0.000075* (-23.3)	1.32* (651.4)	606519
Sikkim	0.00009* (113.7)	0.088* (68.5)	0.005 (462.1)	_	0.714 (54.5)	-0.00004* (-11.4)	-0.00011 (-56.7)	706.8
Tamil Nadu	-0.00004* (-16.8)	-0.0005 (-48.9)	-0.016 (-67.2)	0.191 (1083)	0.384 (44)	-0.00007* (-90.4)	-3.7 (-4.6)	20702.2
Tripura	-0.0008* (-427.6)	0.002* (750.3)	0.0001 (25.9)	0.236 (2135.3)	-0.864* (-803.1)	0.00015* (648.2)	0.00002 (898.9)	1178690
Uttar Pradesh	0.00012 (4600.5)	0.0005 (2211.4)	0.005 (9039.9)	0.18 (1288.1)	1.413 (6735.8)	0.0003* (5210.4)	4.81* (6012.2)	269.8
Uttarakhand	0.0033* (414.7)	0.033 (243.5)	-0.062 (-322.5)	_	_	0.0002* (329.9)	9.03* (527.5)	262.1
West Bengal	-0.0006* (-60.9)	-0.00075 (-110.9)	-5.68 (-0.9)	_	-1.063* (78.7)	-0.00002* (-13.7)	6.93* (65.4)	25730.7

I. *_ indicates 5% level of significance. The figures in parenthesis are z values.*

II. *For each of the state the Prob > Chi- square = 0.00, this indicates that all the models are statistically significant.*

III. *Poisson coefficients of Chandigarh, Jammu & Kashmir, Jharkhand, Mizoram and Nagaland couldn't be calculated because number of people affected were nil in these cases.*

IV. *Marginal population is dropped from the model because of Multicollinearity problem.*

Poisson regression results examining the association between forest cover and lives lost in floods

The Poisson regression coefficient (table 4) between forest cover and human lives lost in floods, taking into account the socio-economic parameters indicates that there exist a negative association between forest cover and lives lost in flood events across states in India. The states which have recorded highest number of lives lost are; Bihar (0.000013), Andhra Pradesh (-0.0004), Assam (-0.002), West Bengal (-0.0042), Uttar Pradesh (0.00012), Maharashtra (0.000022), Gujarat (-0.00008). As the values are either less than 1 or zero, this indicates that there exists a negative or highly weak positive association between forest cover and lives lost in flood events. For majority of the states the association between deforestation and lives lost across states have been found to be negative or weakly positive. This might be because of the reason that deforestation has reduced but the rise in flood related lives lost is due to factors other than forest loss.

Socio economic factors like literacy, net state domestic product and total population have a significant influence on the flood related lives lost. Literacy and NSDP has got a significant negative relation with lives lost. Whereas incase of total population, some states have got a significant positive relationship with the lives lost while some other states have negative association. This variation in result might be because in some states even if the population is high, some other significant factors have lessened flood related casualties. Therefore, awareness, economic potential and total exposure is again found to be the robust determinants of flood impact.

Table 4. Poisson regression coefficients taking human lives lost as dependent variable

States	Forest cover	Deforestation	Rainfall(mm)	Temperature(max)	Literacy rate	Per capita NSDP	Total Population	Chi-square
Andhra Pradesh	-0.0004* (-6.1)	0.0002* (8.3)	0.00055* (4.3)	0.142* (5.4)	-0.287* (-15.8)	-2.19 (-0.04)	2.07* (15.2)	2098.4
Arunachal Pradesh	0.0002* (3.6)	-0.003 (-1.1)	0.0004 (0.5)	_	-0.244* (-2.3)	-0.0378 (-0.4)	0.0002* (4.6)	5413
Assam	-0.002* (-11.9)	0.00008 (1.14)	0.0013 (9.6)	0.54* (10.9)	-4.615* (-13.9)	-0.00013* (-8.3)	-9.23* (-14)	605.7

Bihar	0.00001* (4.8)	-0.009* (-8.1)	-0.0003 (-2.3)	0.129* (26.5)	-0.092* (-6.1)	-0.00005* (-6.4)	6.08* (6)	1314.0
Chhattisgarh	0.0005 (2.2)	-0.0033* (-3.1)	0.003* (8)	_	-0.439* (-1.9)	-0.00012* (-3.4)	1.86 (1.7)	1347.2
Gujarat	-0.00008* (-14.3)	0.00002* (0.2)	0.00097 (9)	0.0534 (0.001)	0.342* (12.3)	0.000013* (2.7)	-4.38* (-12.4)	1822.9
Himachal Pradesh	0.0013* (9.1)	-0.00004 (-0.3)	-0.0002* (-0.4)	0.0422 (2.3)	-0.611* (-8.9)	-0.00004* (-4.6)	5.14* (6.5)	16363.8
Jammu and Kashmir	-0.0007* (-2.7)	0.012* (9.5)	0.005 (7.1)	0.139 (0.9)	_	0.0009* (17.1)	-1.57* (-10.3)	6927.5
Karnataka	0.0002* (13.6)	-0.0006* (-5.9)	0.0004 (3.2)	-0.034 (-1.1)	1.922 (5.9)	0.00002 (1.7)	-2.48* (-6.1)	9967.9
Kerala	-0.002* (-4.4)	0.00069* (3.9)	0.006 (7.7)	1.723* (9.4)	-0.920 (-2.7)	-0.00011* (-6.3)	1.33* (1.2)	25473.4
Madhya Pradesh	-0.0007* (-5.2)	-0.0006* (-3.5)	-0.0003 (-1.1)	-0.394* (-5.5)	-1.909* (-5.6)	0.00005 (0.9)	8.57 (4.9)	177.51
Maharashtra	0.00002* (7.1)	-0.0004 (-2.6)	0.001* (11.5)	-0.446 (-14.4)	0.339 (12.8)	0.000027* (6.3)	-1.07 (-7.6)	428.3
Odisha	0.00006* (2.3)	-0.0003 (-1.6)	0.009* (10.5)	0.202* (4.3)	-0.232* (-2.8)	-0.00009* (-3.6)	-1.71 (-1.2)	2215.2
Punjab	3.18 (0.6)	-0.0005 (-1.8)	0.002 (1.9)	-0.086* (-2.4)	0.085 (3.4)	-0.00004 (-3.2)	9.35* (19.1)	502.37

Rajasthan	0.00006* (7.2)	-0.007 (-8.9)	-0.003 (-3.2)	-0.096 (-0.9)	0.442 (7)	-0.0006* (-13.4)	9.04 (0.65)	8813.14
Tamil Nadu	0.0002* (3.8)	-0.0005 (-7.4)	0.00004 (0.1)	0.091 (103.3)	0.031 (0.6)	-0.00002* (-5.8)	-1.39 (-0.3)	10300.4
Uttar Pradesh	0.0001* (32)	0.00014* (2.3)	0.00014 (1.1)	0.122 (258.4)	-0.454* (-7.7)	0.00028* (15.9)	1.42* (6.8)	8091.1
Uttarakhand	0.0002* (23.8)	-0.0012* (-3.3)	-0.0009 (-8.8)	_	0.254 (5.5)	-8.17* (-2.6)	-1.76 (-4.5)	1609.7
West Bengal	-0.004* (-28.2)	-0.004 (-5.8)	-0.001 (-13.7)	_	-5.828* (-14.9)	0.0005* (30.9)	4.38 (13.8)	18884

I. *_indicates 5% level of significance and the figure in parenthesis are z values.*
II. *For each of the state the, Prob > Chi- square = 0.00, this indicates that all the models are statistically significant.*
III. *Poisson coefficients of Chandigarh, Goa, Tripura, Haryana, Jharkhand, Mizoram, Manipur, Meghalaya, Sikkim and Nagaland couldn't be calculated because number of fatalities were nil in these cases.*
IV. *The variable marginal population is dropped because of multicollinearity problem.*

Ordinary Least Square (OLS) regression results between forest cover and mortality ratio.

States which have recorded a high mortality ratio are Bihar, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Sikkim, Tamil Nadu and Uttarakhand. Incase of Bihar the regression coefficient is found to be $-9.9x10^{-10}$, indicating that inverse relationship exists between mortality ratio and forest cover. That is an increase in forest cover by 1 unit would result in decline of mortality ratio by $-9.9x10^{-10}$ units. Majority of the states have shown a negative relationship between forest cover and mortality ratio. Indicating that increase in forest loss results in higher mortality ratio. Among the socio-economic factors, literacy and total population have been found to have a significant impact on the mortality ratio for each of the states. The mortality ratio is found to be a negatively associated with literacy and positively associated with total population. Apart from this in most of the states, flood related mortality ratio have a negative link with rainfall. It indicates that rainfall events might have increased but due to some other significant factors flood related mortalities have reduced. So far as deforestation , temperature and NSDP is concerned, the association with mortality ratio is not found to be consistent, that is for some states it is negative and for others it is positive.

Table 5. OLS Regression Coefficients Taking Mortality Ratio as a Dependent Variable

States	Forest cover	Deforestation	Rainfall(mm)	Temperature (max)	Literacy rate	Per capita NSDP (const price)	Total Population	R Square value	P value
Andhra Pradesh	-0.366 (-1.1)	-.001 (-0.8)	0.185 (0.6)	0.087 (0.2)	0.223 (0.2)	5.16-06 (0.02)	-4.7-07 (-0.36)	0.233	0.949
Arunachal Pradesh	-0.0004 (-0.05)	-.0006 (-0.1)	0.006 (1.6)	_	-1.03 (-0.5)	0.0002 (0.5)	0.00004 (0.5)	0.406	0.750
Assam	3.61-07 (0.91)	-8.06-09 (-0.39)	-1.95-07(-3)	0.00001 (.73)	-.460* (-577)	-.330 (-.4)	1.12* (719.6)	0.305	0.884
Bihar	-9.9-10 (-.06)	-4.83-07 (-1.0)	-4.7-07(-.8)	-0.00004 (-.84)	-.00002 (-.3)	-9.53-09 (-0.2)	1.23-11 (0.2)	0.244	0.949
Chhattisgarh	-2.49-07 (-1.1)	3.14-07 (0.9)	-1.35 (-.8)	_	-.009* (-76.6)	-6.52-09 (-.45)	1.18* (76.9)	0.421	0.401
Gujarat	9.69-09 (.55)	-9.31-08 (-.59)	8.68-08(.4)	7.58-06 (0.25)	0.0037* (6.28)	-3.32-09 (-.40)	-3.07-09* (-5.86)	0.975	.0002
Himachal Pradesh	3.41-07 (0.88)	-5.72-08 (-.43)	-1.63-07(-0.5)	-2.02-06 (-.14)	-.00063 (-.61)	-6.20-10 (-.04)	3.23-10 (-.33)	0.292	0.899
Karnataka	-.00007* (-22.5)	.000014 (1.4)	-7.87-06(-.3)	-0.0015 (-.24)	-0.338* (-11.62)	6.21-07 (0.24)	3.59-07* (10.76)	0.646	0.301
Kerala	0.00009 (.15)	-.000015 (-.16)	.00011 (.19)	0.0378 (.23)	0.1349 (0.22)	-2.9-06 (-0.07)	-3.65-07 (-.29)	0.192	0.972
Madhya Pradesh	.000012 (2.31)	-.00006 (-0.47)	.00074 (2)	-0.0071 (-.08)	-.075* (-3.51)	.000044 (1.51)	-2.47-08 (-.087)	0.791	0.086

Maharashtra	-.00002 (1.15)	-.00044 (-1.92)	.0005 (1.41)	-0.032 (-.22)	-0.133 (-1.47)	-4.1-06 (-0.27)	4.42-08 (0.78)	0.723	0.174
Odisha	-8.37-06 (-.65)	0.0001 (0.23)	-.0002 (-.23)	0.017 (0.23)	-.102 (-.33)	.00003 (0.57)	1.35-07 (0.21)	0.476	0.627
Punjab	-.00006 (-1.47)	0.003 (1.51)	-.0016 (-1.28)	-.614* (-1.64)	-1.42 (-1.66)	0.0003 (1.68)	2.2-06* (1.58)	0.689	0.226
Rajasthan	9.33-07 (0.09)	0.0004 (0.46)	-.0011 (-1.55)	0.018 (0.21)	-.059 (-1.03)	0.00007 (1.02)	7.39-09 (0.13)	0.605	0.377
Tamil Nadu	-.00004 (-.89)	-0.0001 (-.70)	-.0010 (-.88)	0.112 (.65)	0.079 (0.47)	2.31-06 (0.11)	-8.88-08 (-.67)	0.530	0.524
Uttar Pradesh	-8.15-09 (-.37)	-6.8-08 (-.38)	-3.7-07 (-.72)	.00015 (1.03)	-.00007 (-.35)	-1.09-07 (-1.51)	2.23-11 (0.32)	0.467	0.646
Uttarakhand	-3.11-06 (-.61)	-3.53-06 (-.58)	5.88-06 (3.23)	_	-.00012 (-.26)	8.33-09 (0.07)	-5.12-10 (-.55)	0.605	0.516
West Bengal	.00024 (1.07)	0.0005 (1.87)	-2.37-06 (-.02)	0.0092 (0.14)	-.331 (-.76)	-.00005 (-1.48)	2.46-07 (0.79)	0.840	0.043

I. *_indicates 5% level of significance, figure in parenthesis indicates t- values.*

II. *OLS regression coefficients of Chandigarh, Goa, Tripura, Haryana, Jharkhand, Jammu and Kashmir, Mizoram, Manipur, Meghalaya, Sikkim and Nagaland couldn't be calculated because mortality ratio was nil in these cases.*

III. *The variable marginal population is dropped because of multicollinearity problem*

Relative hazard loss ratio[10] across states

Table 6 shows the values of relative hazard loss ratio, which is derived from the ratio between direct damages caused by floods and Net state domestic product of each particular state. This ratio indicates the economic capacity of the states to cope with the flood damages. A state scoring a relative hazard loss ratio less than 1 is economically stable to cope with damages caused due to floods. This is because the net state domestic product of that particular state is more than the direct flood damages caused. And states scoring a relative hazard loss ratio more than 1 are economically weak relative to the flood damages recorded. So, from the result table we can observe that all the states have recorded a higher economic potential compared to direct flood damages during the study period of 2000-2011. This indicates that they have got adequate resources to cope with the flood losses during the study period. The states which have recorded high average direct damages are Andhra Pradesh, Arunachal Pradesh, Bihar, Himachal Pradesh, Karnataka, Kerala, Uttar Pradesh, and West Bengal. But the relative hazard loss ratio is still less than one for each of these states. This indicates that the states have got sufficient amount of resources to bear the flood damages during the study period.

Table 6. State Wise Relative Hazard Loss Ratio for the period 2000-2011

States	Average Direct Damages (In Crores)	Average NSDP (In Crores)	Relative Hazard Loss Ratio
Andhra Pradesh	389.74	25253.93	0.015
Arunachal Pradesh	132.64	23001.29	0.0057
Assam	74.75	15229.64	0.0049
Bihar	2345.15	7869.64	0.2979
Chhattisgarh	30.01	17166.43	0.0017
Goa	71.46	66920.21	0.0011
Gujarat	43.62	32070.21	0.0014
Haryana	0	37055.21	0
Himachal Pradesh	222.09	31042.21	0.0072
Jammu and Kashmir	0	18988.21	0
Jharkhand	0.18	15489.5	1.1298E-05
Karnataka	564.21	26172.43	0.0216
Kerala	224.31	30878.86	0.0073
Madhya Pradesh	56.91	14975.86	0.0038
Maharashtra	49.62	36456.43	0.0014
Manipur	0.11	16040.29	7.06554E-06
Meghalaya	0.49	22273.28	2.22913E-05
Mizoram	0	26248.5	0
Nagaland	0	26971.64	0
Odisha	44.88	15841.78	0.0028
Punjab	0.33	31981	1.01936E-05
Rajasthan	44.94	18065.93	0.0025
Sikkim	0.45	30902.36	1.44272E-05
Tamil Nadu	0.71	31640.21	2.23424E-05
Tripura	0.0058	23428.43	2.48985E-07
Uttar Pradesh	364.00	12205.64	0.029822484

[10] Ash, K.D., Cutter, S.L., Emrich, C.T. (2013). Acceptable losses? The relative impacts of natural hazards in the United States,1980–2009. *International Journal of Disaster Risk Reduction, 5, 61–72.*

Uttarakhand	0	31558.09	0
West Bengal	773.59	21743.21	0.0356

Source-Author's calculation

DISCUSSION

In India, the restoration of forests has been promoted both by the central and the state government. There are studies which have claimed that forests act as a barrier against natural disasters (Alongi, 2008; Badola and Hussain, 2005; Dash and Vincent, 2009). This study found significant evidence proving that the impact of flood events is determined by the presence of forest cover. The factors which have got significant impact on the people affected by floods are forest cover, literacy, total population and net state domestic product (NSDP). This indicates that higher the width of forest cover less will be the number of people affected in floods. High impact of literacy indicates that more awareness among the people will make them more prepared for the flood risks and thereby lessen the flood impact. Similarly, higher the economic potential of a state which is given by NSDP, higher will be the amount of resources available for enhancing the adaptive capacity of the people. The total population determines the level of exposure to the hazard and thus is positively related to the magnitude of damage. Similar is the case of flood related casualties, it is found the forest cover, NSDP, literacy and total population have got a significant role.

Mortality ratio is derived from the flood related number of lives lost and number of people affected. This is done in order to know the proportion of people who have lost their lives compared to the number of people affected. It is found that in majority of the states, total population have a positive association with the mortality ratio. Total population determines the total exposure to flood hazards and therefore have got a significant positive relationship with flood related mortality. This indicates that more a state is populated more number of people will be exposed to the natural disasters and thus its vulnerable to flood related fatalities rises. Literacy level which indicates the awareness among the people has been found to have a significant negative relationship with the flood related mortality. This implies that if the people of a state are more aware then their chances of getting affected by the disasters are less.

Relative hazard loss ratio of the states is given by the ratio between direct damages due to floods and the net state domestic product. This ratio points out the states which are economically well off to be able to cope with the flood damages and those states which are economically weak to be able to do co. During the study period for all the states of India, it has been found that the relative hazard loss ratio is less than 1, indicating economic stability compared to flood losses. As the per capita NSDP is more than the flood damages for each individual state, this indicates that the states were economically stable enough to cope with the flood consequences. And also, they have had the adequate amount of resources to implement coping strategies to deal with flood damages.

The findings of the study opine that the presence of forest cover protect from the adverse impact of floods. The higher the width of forests, lower would be the magnitude of flood destruction. It is obtained that socio-economic parameters factors have got a significant influence on the flood severity. The study gives an overall picture of the state of forest cover across states of India and how this lessens flood impact considering the social, economic and meteorological factors. This needs to be examined with a wider data set and also under different scenarios to make them more policy relevant. District wise analysis of the states which are frequently affected by floods could give a more vivid representation. The study doesn't consider other relevant damages caused by floods such as crop damaged, livestock affected, houses collapsed, animals killed etc. Social and economic parameters taken into account in this study could also be expanded further. This could include age and gender structure of the people affected, proportion of minority population in each state, per capita income, women work participation, migration status, employment pattern etc. Consideration of these parameters could give more precise results and trace a new dimension of flood vulnerability.

CONCLUSION

The protective role of forests has remained under researched in India and this paper looks for establishing this role by taking into account all the states of India. Our study analyses the role of forests in protecting human lives and people affected on account of floods for the period 1998 to 2011. The impact of forests on the flood damages is examined controlling for social, economic and meteorological factors of the states. The results have shown a negative association between forest cover and flood damages. This indicates that forests cover reduces human casualties and people affected during flood events.

The states having higher literacy were found to have lower number of people affected and casualties. This establishes a negative association between literacy and flood impact. Indicating that higher the literacy more would be the awareness related to flood risks. This would in turn help them to prepare themselves against adverse consequences of floods and thus reduce their vulnerability. Secondly, the economic potential of the states is also found to be a significant determinant of flood impact. A state which is more economically sound and stable would be able to face hazardous situation in a better way as compared to those states which are economically backward. Coping strategies undertaken by the states to fight against disasters depend upon the availability of resources. So, higher the economic potential of a state more would be their size of resources available to cope with flood damages. This would reduce their vulnerability to adverse consequences. Apart from this the total exposure determined by the total population of a state is also found to be a strong determinant of the degree of vulnerability to flood damages. This indicates that high population growth of a particular state makes it more prone to the natural disasters.

Mortality ratio has been found to be significantly influenced by a state's literacy level and total population. The results indicate that higher the literacy and lower the total population less will be the flood related mortality. The regression coefficients of majority of the states have shown that forest cover and mortality ratio have got a negative association. Indicating that more forest cover a state has, less prone it will be to flood related mortalities. Now, so far as the relative hazard loss ratio for the study period is concerned, it is found that all the states in India were economically stable to be able to cope with the flood losses.

In the past the vulnerable Indian coastal region had recorded broad width of mangrove forests. But due to rampant urbanization and unsustainable economic development these are cut, making them more vulnerable to floods and other such climatic hazards. India has faced numerous flood events in the past and recently in 2013. The study gives a robust evidence of the protective role of forests incase of preventing flood impact. So, protection of the forests and restrictions on the conversion of forest areas to non-forest areas should be given the chief priority given the rise in intensity and frequency of extreme weather events. Thus, for formulating climate change mitigation and adaptation policies we need to look at the protective services and benefits provided by the forests.

REFERENCES

Achouri, M., Aylward, B., Brooks, K.N., Byron, N., Byron, Y., Calder, I., ……, Upadhaya, K. (2005). Forests and floods; Thriving in fiction and drowning on facts? *Center for International Forestry Research. Food and Agriculture Organization of the United Nations.*

Adger, W. N., Hughes, T. P., Folke, C., Carpenter, S. R. and Rockstrom, J. (2005). Socialecological resilience to coastal disasters. *Science, 309, 1036–39.*

Ajibade, I., McBean, G. and Kerr, R.B. (2013). Urban Flooding in Lagos, Nigeria: Patterns of Vulnerability and Resilience among Women. *Global Environmental Change, 23, 1714–1725*

Alongi, D.M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science, 76, 1—13*

Ash, K.D., Cutter, S.L. and Emrich, C.T. (2013). Acceptable losses? The relative impacts of natural hazards in the United States,1980–2009. *International Journal of Disaster Risk Reduction, 5, 61–72.*

Badola, R., and Hussain, S. A. (2005). Valuing ecosystems functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation, 32, 85–92.*

Bahinipati, C.S. and Sahu, N.C. (2012). Mangrove Conservation as Sustainable Adaptation to Cyclonic Risk in Kendrapada District of Odisha, India. *Asian Journal of Environment and Disaster Management, 4, 183–202.*

Bann C. (1998). The Economic Valuation of Mangroves: A Manual for Researchers. *Economy and environment programme for southeast Asia, 1998.http://idl-bnc.idrc.ca/dspace/bitstream/10625/14541/6/108379.pdf.*

Barua, P., Chowdhury, S. N. and Sarkar, S. (2010). Climate Change and Its Risk Reduction by Mangrove Ecosystem of Bangladesh. *Bangladesh Research Publications Journal, 4, 208-225.*

Bradshaw, C.J.A., Brook, B.W., Peh K.S.H. and Sodhi N.S. (2007). Global evidence that deforestation amplifies flood risk and severity in the developing world. *Global Change Biology, 13, 2379–2395.*

Bradshaw, C.J.A., Brook, B.W., Peh, K.S.H. and Sodhi, N.S. (2009). Flooding Policy Makers with Evidence to Save Forests. *Ambio, Royal Swedish Academy of Sciences, 38.http://coreybradshaw.files.wordpress.com/2011/03/bradshaw-et-al-2009-ambio.pdf*

Brang, P., Schönenberger, W., Frehner, M., Schwitter, R., Thormann, J.J. and Wasser, B. (2006). Management of protection forests in the European Alps: an overview. *For.Snow Landsc. Res., 80, 23–44*.

Brenkert, A.L. and Malone, E.L. (2005). Modeling vulnerability and resilience to climate change: a case study of India and Indian States. *Climatic Change, 72, 57-102.*

Calder, I.R. and Aylward, B. (2006). Forest and Floods. *Water International, 31, 87-99.*

Chowdhury, A. and Mhasawade, S.V. (1991). Variations in meteorological floods during monsoon over India. *Mausam, 42, 167-170.*

Das, S. and Crépin, A.S. (2013). Mangroves can provide protection against wind damage during Storms. *Estuarine, Coastal and Shelf Science, 134, 98-107.*

Das, S. (2010). Sustaining mangrove forests to reduce vulnerability of coastal villages from climate change. *http://www.researchgate.net/publication/50434142*

Das, S. (2011). Mangroves provide protection during Cyclone: Evidences from the Super Cyclone of October 1999 in India. *http://www.feem-web.it/ess/files/das.pdf*

Das, S. and Vincent, J. (2009). Mangroves protected villages and reduced death toll during Indian super cyclone. *PNAS, 106, 7357–7360.*

De Groot, R.S., Wilson, M.A. and Boumans, R.M.J. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics 41, 393–408.*

De, U.S., Dube, R.K. and PrakasaRao, G.S. (2005). Extremeweather events over India in the last 100 years. *J.Ind. Geophys. Union, 9, 173-187.*

Doocy, S., Daniels, A., Murray, S. and Kirsch, T.D. (2013). The Human Impact of Floods: a Historical Review of Events 1980-2009 and Systematic Literature Review. *PLOS Currents Disasters. Edition1. doi: 10.1371/currents.dis.f4deb457904936b07c09daa98ee8171a.*

EJF. (2006). Mangroves: Nature's defence against Tsunamis— A report on the impact of mangrove loss and shrimp farm development on coastal defences. *Environmental Justice Foundation, London, UK.ISBN No. 1-904523-05-7.*

Food and Agriculture Organization of the United Nations. (2007). Coastal protection in the aftermath of the Indian Ocean Tsunami: What role for forests and tress?. *Proceedings of the Regional Technical Workshop, Khao Lak, Thailand, 28-31 August 2006.*

Fussel, H.M. and Klein, R.J.T. (2006). Climate Change Vulnerability Assessments: An Evolution Of Conceptual Thinking. *Climatic Change, 75, 301–329.*

Forest Resources Assessment (1990). *The United Nations Food and Agriculture Organization, Rome, 1993.*

Glimpse of disaster impact in India (1998)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/7477/data.aspx

Hamilton, L.S. (2005). Forests and water. A thematic study prepared in the framework of the global forest resource assessment 2005. *Food and agricultural organization of the United Nations, Rome.*

Harada, K. and Imamura, F. (2005). Effects of coastal forest on tsunami hazard mitigation-a preliminary investigation. *Advances in Natural and Technological Hazards Research, 23, 279-292.*

Heal, G. (2000). Valuing ecosystem services. *Ecosystems, 3, 24–30.*

Intergovernmental Panel On Climate Change (IPCC). (2013). Summary for Policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. *Cambridge University Press, Cambridge.*

India state of forest report 1997, Forest Survey of India, Government of India.

http://www.fsi.nic.in/documents/sfr_1997_hindi.pdf

India state of forest report 1999, Forest Survey of India, Government of India.

http://www.fsi.nic.in/documents/sfr_1999_hindi.pdf

India state of forest report 2001, Forest Survey of India, Government of India.

http://www.fsi.nic.in/documents/sfr_2001_hindi.pdf

India state of forest report 2003, Forest Survey of India, Government of India.

http://www.fsi.nic.in/documents/sfr_2003_hindi.pdf

India state of forest report 2005, Forest Survey of India, Government of India.

http://www.fsi.nic.in/details.php?pgID=sb_18

India state of forest report 2009, Forest Survey of India, Government Of India.

http://www.fsi.nic.in/documents/india_sfr_2009.pdf

India state of forest report 2011, Forest Survey of India, Government of India.

http://wipl.net.in/fsi_report_20011/final_2011.pdf

Jayatissa, L.P. and Hettiarachi, S. (2006). Nature's protection against nature's fury: apost tsunami assessment of non-mangrove plants as elements to build a green belt against tsunami. *Ruhuna Journal Of Science, 1, 96–103.*

Kibria, G. (2013). Mangorve Forests; Its role in livelihoods, carbon sinks and Disaster mitigation. *http://www.researchgate.net/publication/261178318*

Kundzewicz, Z. W., Mata, L. J., Arnell, N. W., Döll, P., Jimenez, B., Miller, K., Oki, T., Şen, Z. & Shiklomanov, I. (2008). The implications of projected climate change for freshwater resources and their management. *Hydrol. Sci. J. 53(1), 3–10.*

Lal, R.(2001). Soil degradation by erosion. *Land Degradation and Development 12 (6), 519–539.*

Lang, G. (2002). Forests, Floods, and the Environmental State in China. *Organization & Environment, 15,109-130.*

Laurance, W. F. (2007). Environmental science: Forests and floods. *Nature, 449, 409-410.*

Meteorological sub division/season wise actual and normal rainfall in India (1997- 1998 to 2011-12)

http://www.indiastat.com/meteorologicaldata/22/rainfall/238/meteorologicalsubdivisionwiseyearlyrainfall19712014/722488/stats.aspx

NRAA, 2013, Contingency and Compensatory Agriculture Plans for Droughts and Floods in India- 2012. Position paper No.6. *National Rainfed Area Authority*, NASC, New Delhi

Reddy, K.N., Jadhav, S.N., Reddy, C.S, and Raju, V.S. (2002). Life forms and Biological spectrum of Marriguda Reserve Forest Khammam district, Andhra Pradesh. *Indian Forester, 128(7), 751-756.*

Rodríguez, G. (2007). Chapter 4, Poisson Models for Count Data. Lecture Notes on Generalized Linear Models. *http://data.princeton.edu/wws509/notes/*

Shuto, N. (1987). The effectiveness and limit of tsunami control forest. *Coastal Engineering in Japan, 30 (1): 143–153*.

State wise damage due to heavy rains, flood and cyclone in India (1999)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities19532012/722452/22003/data.aspx

State wise damage due to heavy rains, flood and cyclone in India (2000)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities19532012/722452/16540/data.aspx

State wise damage due to floods and heavy rain in India (2001)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/299223/data.aspx

State wise damage due to floods and heavy rain in India (2002)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/299230/data.aspx

State wise damage due to floods and heavy rain in India (2003)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/299232/data.aspx

State wise damage due to floods in India (2002-2004)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/397509/data.aspx

State wise damage due to floods and heavy rain in India (2004)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/299234/data.aspx

State wise damage due to floods and heavy rain in India (2005)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/382949/data.aspx

State wise damage due to floods and heavy rain in India (2007)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/439335/data.aspx

State wise extent of damage due to heavy rains, floods and cyclone in India (2007 part1 & part 2)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/445442/data.aspx

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/445441/data.aspx

State wise extent of damage due to heavy rains, floods and cyclone in India (2008)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities/722452/461196/data.aspx

State wise damage due to floods and heavy rain in India (2009)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities19532012/722452/715192/data.aspx

State wise damage due to floods and heavy rain in India (2011)

http://www.indiastat.com/table/meteorologicaldata/22/physicalstatusundernaturalcalamities19532014/722452/836359/data.aspx

State wise literacy rate in India (1991, 1997 and 2001)

http://www.indiastat.com/table/education/6370/literacyrate/367615/6377/data.aspx

State wise per capita net state domestic product at constant prices in India (1980-81) for the period (1990-91 to 1998-99)

http://www.indiastat.com/table/percapitaavailability/24/income/131/61289/data.aspx

State wise per capita net state domestic product at constant prices in India (1993-94) for the period (2000-01)

http://www.indiastat.com/table/percapitaavailability/24/income/131/58150/data.aspx

State wise per capita net state domestic product at constant prices in India (1999-2000) for the period (1999-2000 to 2008-09)

http://www.indiastat.com/table/percapitaavailability/24/income/131/439029/data.aspx

State wise per capita net state domestic product at factor cost in India (constant prices) for the period (1980-81 to 2013-14) Part 1, 2, 3

http://www.indiastat.com/table/percapitaavailability/24/income/131/292905/data.aspx

http://www.indiastat.com/table/percapitaavailability/24/income/131/292908/data.aspx

http://www.indiastat.com/table/percapitaavailability/24/income/131/292914/data.aspx

State wise population by residence and sex in India (as per 2011 census)

http://www.indiastat.com/table/demographics/7/population2011census/527359/527360/data.aspx

State wise population by residence and sex in India (as per 2001 census)

http://www.indiastat.com/table/demographics/7/populationasper2001census/16661/112506/data.aspx

State wise total population in India (as per 1991 census)

http://www.indiastat.com/table/demographics/7/populationasper1991census/585619/585631/data.aspx

State wise marginal workers in India part 1 (as per 2011 census)

http://www.indiastat.com/table/labourandworkforce/380987/marginalworkers2011census/770011/770012/data.aspx

State wise marginal workers in India part 2 (as per 2011 census)

http://www.indiastat.com/table/labourandworkforce/380987/marginalworkers2011census/770011/770066/data.aspx

State wise marginal workers in India part 1 (as per 2001 census)

http://www.indiastat.com/table/labourandworkforce/380987/marginalworkers2001census/28658/28798/data.aspx

State wise marginal workers in India part 2 (as per 2001 census)

http://www.indiastat.com/table/labourandworkforce/380987/marginalworkers2001census/28658/30116/data.aspx

State-wise mean Maximum and Minimum temperature in India (2000)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/36362/data.aspx

State-wise Maximum and Minimum temperature in India (2005)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/395191/data.aspx

State-wise Maximum and Minimum temperature in India (2006)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/465820/data.aspx

State-wise Maximum and Minimum temperature in India (2007)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/465821/data.aspx

State-wise Maximum and Minimum temperature in India (2008)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/465822/data.aspx

State-wise Maximum and Minimum temperature in India (2009)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/526755/data.aspx

State-wise Maximum and Minimum temperature in India (2010)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/547817/data.aspx

State-wise Maximum and Minimum temperature in India (2011)

http://www.indiastat.com/table/meteorologicaldata/22/temperature/26881/628655/data.aspx

Stephen, A. (2012). Natural disasters in India with special reference to Tamil Nadu. *J. Acad. Indus. Res, 1.ISSN: 2278-5213.*

Upadhyay, V. P., Ranjan, R. and Singh, J.S. (2002). Human-mangrove conflicts: the way out. *CurrSci, 83, 1328–1336*

Wisner, B., Blaikie, P., Cannon, T. and Davis, I. (2003). At Risk: natural hazards, people's vulnerability and disasters. *Second edition. UNDP, Hyogo Framework for Action 2005.*