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Addressing Coastal Vulnerability at the Village Level: The Role of Socio-economic and Physical Factors

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"Mangroves save lives in storms"
(Software required to Play/Run this Movie Real / 3GP / VLC Player etc.)

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Addressing Coastal Vulnerability at the Village level: The role of Socio-economic and Physical factors

Saudamini Das[a]

Abstract

Vulnerability to extreme events is usually addressed for macro units (districts or provinces) whereas the relative vulnerability of micro units may be more useful to a policy maker. The present study addresses the vulnerability of coastal villages to cyclones and storm surge risks and identifies the physical and socio-economic factors strongly impacting the vulnerability of the villages. Rather than using a composite or aggregative index, we define the vulnerability index as the probability of facing non-zero deaths due to severe cyclones and calculate the indexes from a cyclone impact (human casualty) function using both Logit and Poisson specifications. We use human casualty data of the Super cyclone of Oct 1999 in India and other geo-physical and socio-economic data for the same year and study the 262 villages lying within 10 km of the coast in Kendrapada district, a highly vulnerable district in India. We find 112 to 132 villages qualifying as least vulnerable with a death probability of less than 0.1; 72-82 villages as moderately vulnerable with a death probability ranging between 0.1 and 0.3; 34-37 villages rated as more vulnerable with a death probability in between 0.3 to 0.5; and 21 to 34 villages displaying high vulnerability with a death probability greater than 0.5. In general, villages established in the mangrove habitat areas after cutting down the forest and the ones with a higher percentage of marginal workers were found to be more vulnerable while those with mangrove vegetation behind them and situated near a big river were seen as being less vulnerable. The results have important implications in identification of the vulnerable or the most vulnerable hotspots in an otherwise vulnerable area.

Key Words: Coastal vulnerability, Cyclone risk, Mangroves, Marginal workers, Probability of Death, Vulnerable villages

JEL Codes: Q54, Q57, R1

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1. Introduction

Vulnerability, the state of being wounded or susceptible to receiving wounds (Oxford English Dictionary, 2006), has been defined in several ways depending on the subject as well as the object of vulnerability (who or what is vulnerable to what?). Similarly, the techniques used to measure it have also varied according to the objective and the discipline trying to assess it. The Third Assessment Report of the Inter Governmental Panel on Climate Change defines vulnerability due to climate change as the extent to which a natural or social system is susceptible to sustaining damages from climate change. It is defined as a function of the sensitivity of the system to change in climate (hazard), its adaptive capacity and the degree of exposure of the system to climatic hazards (McCarthy et al., 2001). The present analysis follows this definition of vulnerability in analyzing the tropical cyclone-related vulnerability of coastal villages.

Coastal vulnerability and ranking of the costal regions in terms of their exposure to different climatic extreme events are the most debated issues after the predictions of climate change theories. The coastal regions of the world have been categorized and relative vulnerability indices have been developed taking into account various factors (UNEP, 2005; IPCC CZMS, 2002; Shaw et al., 1998; Gormitz et al., 1994; Turner et al., 1993). The IPCC Working Group II report on vulnerability assessment gives a comprehensive assessment of the degree of vulnerabilities faced by different coastal regions of the world due to sea level rise and increased storm surge threats, the two prominent consequences of climate change (IPCC, 1997; 2007). Some of the prominent studies on development of coastal vulnerability indexes for different countries are namely: Hughes et al. (1992, 1993) for South Africa; Gormitz et al. (1994) for USA; Shaw et al. (1998) for Canada; Carmen et al. (2006) for Colombia etc. The coastal regions of India face a maximum threat from tropical cyclones as these are situated at the coast of one of the core area of cyclogenesis,[1] the Bay of Bengal. The vulnerability indexing of these areas due to cyclone and storm surge risks have also been attempted by quite a few studies (Jayanthi, 1998; Kavi Kumar, 2003; Patwardhan et al., 2003; and Sharma and Patawardhan, 2007). However, some of the commonly found limitations of vulnerability studies are as follows: (i) vulnerability is addressed and indices are developed for macro units (usually districts) where as the vulnerability of micro units will be more useful to policy makers, (ii) the determining factors of the different components of vulnerability used for calculating the indices are the averages over the districts and thus, the micro or regional-level discrepancies are not reflected in vulnerability indexes, (iii) most of the indexes are either the multiplicative or average values and do not show the importance of individual factors, (iv) the socio-economic factors are mostly represented by population density or total population while different characteristics of population are entirely ignored, (v) the underlying assumption of uniform distribution of population and linear response of different population groups over the macro region (or district) may not be true, at least for developing countries and finally (vi) the presence of natural environment that can act as deterrent to the impacts of natural calamities (Das, 2007b) and add to the resilience of the region (Carmen et al., 2006) has hardly been taken into account in developing the indexes.

The present study tries to address these limitations and develops vulnerability indices due to cyclone and storm surge threats for villages lying within 10 km areas from the coastline in Kendrapada district of Orissa which is one of the most vulnerable districts

[1] Bay of Bengal, North Pacific Ocean and South China Sea are the three core areas of cyclogenesis (IPCC, 1997).

of India (Patawardhan et al., 2003). Compared to the previous studies where vulnerability indexes are defined as either the multiple or averages of the different threat parameters, we define these indices on the basis of the probability of witnessing non-zero human casualty due to very severe cyclones hitting these areas. We take into account hydrological, environmental, meteorological, infrastructural and socio-economic factors to define the vulnerability indices and present a disaggregated picture of the factors impacting vulnerability in diverse ways. We use cross section data on village-level human casualties witnessed in these areas during the super cyclone of Oct 1999, as also infrastructural and socio-economic data of the area for the same year to do our analysis.

2. Studies on Cyclone Vulnerability of the Indian Coast

Indian coastal areas face maximum threats from tropical cyclones and associated storm surges compared to other climatic extreme events. Of the 65 coastal districts of the country, 24 are highly cyclone prone and Kendrapada district of Orissa is ranked as one of the top most cyclones-prone districts (Das, 2007a) and is either the most vulnerable (Patwardhan et al., 2003) or the second most vulnerable (Jayanthi, 1998; Kavi Kumar, 2003) district of India.

Jayanthi (1998) addressed vulnerability at the state (province) level and developed vulnerability parameters for the coastal regions of India. She ranked the coastal areas in a vulnerability scale ranging 1 to 5. The cyclone vulnerability was defined as the multiple of cyclone frequency, topography and population density (F*T*P), where topography was defined as the combination of bathymetry and elevation of an area. The elevation data for Indian coastal areas being unavailable, only the bathymetry factor [2] was taken

[2] Bathymetry is the sloping depth of the continental shelf of a region and an important determinant of the storm surge height experienced in that region.

into account in the calculation of indices. The effect of bathymetry was captured by multiplying the maximum shoaling factor [3] with F and P. This is the only study that included some elements of natural environment in addressing vulnerability and concluded that West Bengal and Bangaladesh formed the most vulnerable coast followed by coastal areas of Orissa.

Patwardhan et al. (2003) addressed vulnerability at the district level and computed the differential vulnerability indices of the coastal districts of India. They defined vulnerability in terms of three different components, i.e. hazard, exposure and adaptive capacity of exposed area. These were computed in terms of nine different indices (three for each component) for the 14 most cyclone-affected districts and the districts were ranked for vulnerability by cluster methods. Jagatsinghpur and Kendrapada district of Orissa emerged as being highly vulnerable along with *Nellore* in Andhra Pradesh, Nagapattinum and Tanjavur in Tamil Nadu and Junagarh and Porbander in Gujurat. Sharma and Patwardhan's (2007) analysis was on similar lines as Patwardhan et al. (2003) with the exception that they ranked the coastal districts by addressing the hazard, exposure and impact (human death) parameters, ignoring adaptive capacity and developed only five different indices of the three components. They found Jagatsinghpur and Kendrapada districts of Orissa and Krishna district of Andhra Pradesh to be the most vulnerable ones.

Kavi Kumar (2003) defined vulnerability due to cyclones as a function of cyclone impact on the region and resistance and resilience of the region to the impact and

[3] Shoaling factor is defined as the ratio of peak surge (the maximum height of storm surge) at any point on the coast line to that of peak surge in a standard basin. The standard basin (a hypothetical one) is defined as a basin with a straight coastline in which the depth profile seaward has one-dimensional constant slope (Ghose, 1995). The basis is considered as a hypothetical mean for all basins.

computed the composite vulnerability index for Indian coastal districts by using the following: (i) demographic (population density, annual population growth), (ii) physical (coast length, insularity, frequency of cyclones, probable maximum surge heights), (iii) economic (agricultural dependency, income), and (iv) social (literacy, spread of institutional set up) factors to construct the indexes. Composite indexes were calculated by taking the averages of all the standardized observations of each district over all the components. The districts along the east coast of India were found to be more vulnerable and from among the east coast districts, 24 Parganas in West Bengal, Baleswa*r* in Orissa and Krishna in Andhra Pradesh were found as the most vulnerable ones.

The spatial units addressed are either districts or a combination of districts and micro discrepancies have not been addressed by the studies. Moreover, vulnerability also depends on many other factors than the ones addressed by the researchers so far and some of the prominent ones could be the presence of natural buffers like mangroves, wide spread water channels, sand dunes, etc. or the efficiency of a cyclone warning system that can substantially influence the impact (at least deaths) of a cyclone. A strong case for inclusion of the natural ecosystem and its historical distribution in vulnerability indexing of coastal areas has been made by Carmen et al. (2006).

The present paper takes one of the most vulnerable districts identified by the previous studies and readdresses vulnerability further at the village level. We take into account multiple factors including the physical ecosystems that can impact vulnerability either directly or indirectly.

3. Study areas

The study area consists of 262 villages lying within 10 kilometres from the coastline in Kendrapada district of the state of Orissa. This region is the most cyclone prone region of India and the annual cyclone probability of this area is nearly 1, implying that it faces at least one cyclone (of different intensity) every year on an average (Das, 2007a). Every cyclone that originates in the Bay of Bengal during the monsoon months (June, July, August), passes through this part of the Indian coast, although the tracks of cyclones during the other periods follow no such fixed pattern (IMD, 2000). The cyclone record of the state of Orissa reveals the frequency of very severe cyclones (very severe cyclonic storms and super cyclones) to have increased in recent decades, the annual probability being 0.00 for 1900 – 1920, 0.1 for 1921 – 1940, 0.05 for 1941 – 1960, 0.15 for 1961 – 1980 and 0.15 for 1981 – 2000 (Chittibabu et al., 2004).

The super cyclone of October 1999 (T7 category) that battered the state of Orissa had its landfall at Ersama, lying 20 km south west to Kendrapada and the entire district was severely affected by cyclonic wind and heavy rain. Of the seven *tahasils* of the district, four (Mahakalpada, Rajnagar, Patamundai and Marshaghai) were affected by storm surge and cyclonic wind and the rest by wind (Gupta and Sharma, 2000). The villages of the study area are from Mahakalpada, Patamundai and Rajnagar *tahasil*. Before the landfall of the cyclone, the state government issued a cyclone warning, evacuated people, but in spite of that, 136 persons died from these villages within a range of 0 to 13 per village. The Mahakalpada region witnessed more deaths being closer to cyclone landfall.

Kendrapada is a predominantly agricultural district with 78 per cent of its population depending on the primary sector, just 5 per cent on the secondary sector and more than 50 per cent of the population in all the *tahasils* (except Kendrapada *tahasil*) living below the poverty line (District Statistical Handbook, 2001). The district has a single railway track; very limited spread of metallic road, but widespread river channels and water bodies. Infrastructural facilities are nearly absent for near the coast areas. However, there are dikes to facilitate agriculture and they are also used as village roads. As per the forest map of the area that existed prior to 1952, [4] Kendrapada district and the adjoining areas had vast stretches of mangrove forests along their coast line. With the exception of mangroves of the Bhitarkanika region of Rajnagar t*ahasil,* the mangroves of other areas witnessed massive destruction over the years. Figure 1 (a) shows the spread of the villages, the road and railway track of the district while figs 1 (b) and 1 (c) show the spread of the mangrove forest over the region in 1999 and 1950, respectively. These areas were planted with casuarinas under the coastal shelterbelt plantation scheme of 1974 after the very severe cyclone of 1971 caused massive loss of lives and properties. However, casuarinas are found only in some patches (Fig.1b) with near uniform width (02 to 0.4 km) and this may be due to the unsuitability of the entire coastline as casuarinas habitat (Mohanty, 1992). In 1999, the natural cyclone barriers in coastal Kendrapada were formed by the mangroves and the casuarinas.

4. Methodology and Estimation:

Following the IPCC III Assessment Report (McCarthy et al., 2001), the vulnerability to cyclone risk is defined as the net impact or the residual effect of the cyclone on a village after controlling for the hazard intensity, exposure and the adaptive capacity of the village. We approximate the net impact as the number of human deaths; [5] hazard intensity by velocity of cyclonic wind and storm surge; exposure by total population, population

[4] Mangrove destruction is reported to have started after the abolition of princely states in 1952 (Mohanty, 1992; Orissa District Gazetteer, Cuttuck, 1996).

[5] A more appropriate measure of cyclone impact would have been the sum of different damages witnessed in the village during cyclone, but getting village-level estimates of damages other than human deaths was difficult.

characteristics and physical features and adaptive capacity by economic well-being, governmental help and also the population characteristics of the villages. Thus in step 1, we estimate the impact (human casualties) function and then in step 2, we calculate the vulnerability indexes (probability of facing non-zero deaths) for villages with the help of the estimated coefficients.

$$Vulnerability_i = Cyclone\ Impact_i\ (=human\ death_i) = f(hazard_i, exposure_i, adaptive\ capacity_i) \quad \textbf{(1)}$$

or

$$Y_i = f\ (population_i, cyclonic\ wind_i, maximum\ storm\ surge_i, physical\ features_i, infrastructure_i, population\ characteristics_i, governmental\ institutions_i), \quad \textbf{(2)}$$

where subscript i represents village and Y_i is the number of deaths in the ith village during a cyclone.

The above specification is also justified as human casualties due to cyclone depends on the intensity of the cyclone (velocity of wind, storm surge, etc), as well as on the total population, geo-physical factors surrounding the village, socio-economic well-being and also on the efficiency of cyclone warning and evacuation efforts of the government.

Following Das (2007b), we approximate the explanatory variables of equation 2 by including their various determinants (Table 1) in the human casualty function and write equation 2 as the following:

$$\begin{aligned} Y_i = f\,(& population_i, dcypath_i, surge_i, dcoast_i, topodymy_i, mangrove_i, \\ & mhabitat_i, casuarinadummy_i, dmajriver_i, d\min river_i, droad_i, roadumy_i, \\ & scheduledcaste_i, literate_i, cultivator_i, aglabor_i, hhwor\ker_i, otwor\ker_i, \\ & m\arg wor\ker_i, tahasildar_i) \end{aligned} \quad \textbf{(3)}$$

In equation 3, Y_i is the village wise human casualties and we approximate cyclonic wind by $dcypath_i$, storm surge velocity by $surge_i$ and $dcoast_i$, physical features by variables $topodumy_i$, $mangrove_i$, $mhabitat_i$, $casurinadummy_i$, $dmajriver_i$, and $dminriver_i$; infrastructure by $droad_i$ and $roadumy_i$; other socio-economic factors and population characteristics by *scheduledcaste*$_i$, *literate*$_i$, *cultivator*$_i$, *aglabor*$_i$, *hhworker*$_i$, *otworker*$_i$, and *margworker*$_i$; and governmental institution by *tahasildar*$_i$ dummy. The definition of these variables and their expected role in impacting human death during cyclones are all explained in Table 1 below.

We expect the dependant variable Y_i (the human casualty in a village), either to be a count (if detailed data is available) or a dichotomous variable and thus, the equation 3 is expected to take either a Poisson [6] (or some other count model) or a Logit approximation. Once the estimates are obtained, the vulnerability index can be calculated in the next step.

The vulnerability index is defined as the probability of witnessing non-zero human casualty in a village due to cyclone.

$$\therefore VI_i = P(Y_i > 0) = 1 - P(Y_i = 0), \qquad \textbf{(4)}$$

where VI_i is the vulnerability index of ith village, P is the probability and Y_i is the number of human casualties expected to be witnessed due to cyclones in the ith village.

For a Logit specification of equation 3, the vulnerability index (VI) will be thesame as estimated or fitted probability ($VI_i = P(Y_i > 0)$) if we assume Y_i to take the value 1 for non-zero deaths and 0 for zero deaths. However, for a count specification, the fitted values are the mean values and the vulnerability index can be calculated from the probability density function as $1 - P(Y_i = 0)$. Under Poisson specification, the vulnerability index will be given by $1 - P(Y_i = 0) = 1 - \exp(-\hat{\lambda}_i)$, where $\hat{\lambda}_i$ is the predicted or fitted mean value of the Poisson model for the ith village.

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[6]The Poisson specification has a single parameter which is taken as the mean as well as the variance of the distribution. This assumption of equality between the mean and the variance results in lower standard errors and inflated z-values and if the sample mean is different than the variance, then the test of inference becomes unreliable. To check the presence of over dispersion (mean ≠ variance), negative binomial estimates should also be calculated along with Poisson. Negative binomial specification can control for over dispersion and also provides the results for the tests of specifications for Poisson versus negative binomial.

The probability density function for Poisson distribution is given by,

$$P(Y_i = y_i) = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i!}, \; y_i = 0,1,2,..., \quad \textbf{(5)}$$

where $P(Y_i = y_i)$ is the probability that the variable Y_i takes the non negative integer value y_i and λ_i is the mean (and the variance) of the Y_i variable which is assumed to be having a Poisson distribution. λ_i is estimated with the help of an equation like:

$$\lambda_i = E(Y_i / X_i) = \exp(\beta_0 + \beta_1 x_1 + \beta_2 x_2 + ---) = e^{X_i'\beta}, \quad \textbf{(6)}$$

where the X's are the explanatory variables impacting Y.

After getting the estimated coefficients, we get $P(Y_i = 0) = \exp(-\hat{\lambda}_i)$ by assuming $y_i = 0$, and $P(Y_i > 0) = 1 - \exp(-\hat{\lambda}_i)$.

$$\therefore VI_i = P(y_i > 0) = 1 - P(y_i = 0) = 1 - e^{-\lambda_{i_i}}. \quad \textbf{(7)}$$

Thus, in the Logit model, the predicted values are the probabilities for positive deaths and in the Poisson model, the probability of positive deaths are calculated after estimating the probability of zero deaths with the help of the estimated coefficients.

In order to identify the variables impacting vulnerability strongly, we calculate the marginal effect of the variables on the probability of non-zero deaths. This marginal effect in the Logit model is defined by,

$$\beta_j [P_i(1 - P_i)], \quad \textbf{(7)}$$

where β_j is the partial co-efficient of the jth regressor and P_i is the probability of witnessing non-zero deaths in the ith village. However, the average marginal effect over the villages in logit can be obtained straight forward with the help of statistical packages.

In case of the Poisson model, the marginal effect of variables on the probability of non-zero deaths can be obtained as shown below.

$$\frac{\partial VI_i}{\partial X_j} = \frac{\partial[1-e^{-\lambda_i})]}{\partial X_j} = -\frac{\partial \exp(-\lambda_i)}{\partial X_j} = \exp(-\lambda_i)\frac{\partial \lambda_i}{\partial X_j}, \quad \textbf{(8)}$$

$\frac{\partial \lambda_i}{\partial X_j}$ is the marginal effect of the jth variable on the mean value of the ith village and the average of this marginal effect over the villages can be easily calculated with the help of statistical packages. The first term, exp ($-\lambda_i$), the inverse of the exponential of the mean value of the ith village can be calculated manually.[7]

5. Data

We needed information on village-level data on human casualties and other climatic and socio-economic indicators to estimate the human casualty function. Such micro information on previous cyclones being unavailable, we used the village-level cross section data on human death during the Oct 1999 super cyclone and the related information for the same year to estimate the model. We have used four different types of data namely, information on cyclone impact (village-level human casualties), meteorological data on cyclone (cyclone parameters, sea elevation, etc.), geo-physical and spatial distances for the villages (*mangrove*$_i$, *mhabitat*$_i$, *cariarinadumy*$_i$, different distances from rivers, road, etc.) and information on socio-economic variables (population, share of literates, scheduled castes and different category of workers, etc.). The details of data used and the respective sources are described below in Table 2.

[7] The marginal effect of the jth variable on the vulnerability index can also be written as the following:

$$\frac{\partial VI_i}{\partial X_j} = e^{(-\lambda_i)}\frac{\partial \lambda_i}{\partial X_j} = e^{(-\lambda_i)}\frac{\partial e^{(X_i'\beta)}}{\partial X_j} = e^{(-\lambda_i)}e^{(X_i'\beta)}\beta_j =$$

$$\exp(-e^{(X_i'\beta)})\exp(X_i'\beta)\beta_j = \exp\{X_i'\beta - e^{(X_i'\beta)}\}\beta_j.$$

For generating the geo-physical and spatial variables, we used GIS files on village boundary, rivers, roads, coastline, forest cover, etc. They were purchased from a private source, Digital Cartography and Services, Bhubaneswar, Orissa. The Indian Remote Sensing Satellite IRS-1D, LISS III Pan censor images of 11 October 1999 with 23.9 metre resolution was used to measure the coastal forest cover (both mangroves and casuarinas) before the cyclone. For demarcating the historical spread of the mangroves in the study area, we used the jpg image (1: 250000 scale) from the archives of US Army Corps (NF 45-14 Series U502, "Cuttack" sheet). The digitized data were then combined with the help of the GIS Arc View 3.2. We demarcated the cyclone track by joining the cyclone landfall point with the locations over which the cyclone eye passed through as described in the NCDM report (Gupta and Sharma, 2000). Geo-referencing of all the images was done at the 1:50000 scale.

Different distances (distance from cyclone path, from coastline, from a major river, from a minor river, from metallic road, etc.) were measured as the minimum distances from the centre of the village to cyclone track, coast line, river, road, etc. The widths of the 1999 mangrove and the historical mangrove for each village were measured as the width (distance between the coast and the interior boundary of the forest) of these forests along the minimum distance between the village and the coast. We measure the sea elevation ($surge_i$) from the surge envelop curve that was estimated by the Indian meteorologist (Kalsi et al., 2004) for the super cyclone by taking into account all the factors that influence the generation of storm surge.

The socio-economic variables for each village were obtained from the Primary Census Abstract of Orissa for 1991 and 2001. The average annual compound rates of growth for the decade 1991 to 2001 were estimated for different variables and then the 1991 figures were extrapolated for the year 1999 by making use of the respective growth rates.

6. Estimation and Discussion

Table 3 describes the summary statistics of the data used for the analysis. The study area villages were located within 22 to 72 km north from the centre of the eye of the super cyclone and 0.3 to 10 km west from the Bay of Bengal coast. The maximum height of the sea elevation at the coast ranged between 0.7 to 4.7 metres. On an average, the villages have a 0.6 km of mangrove forest between them and the coast, whereas in the past, the average width of this forest was nearly 2 km. Only 13 per cent (34 of the 262) of the villages have casuarinas plantation (width 0.2 to 0.4 km) between them and the coast. Interestingly, 28 per cent (75 of the 262) of the villages have been established in the mangrove habitat areas after cutting down the forest. There is a wide spread river net work in the area as the villages have a major river (directly connected to the sea) within 2.4 km and a minor river within 3 km. Infrastructure wise, 61 per cent of the villages have a village road but the minimum distance of a village from a metallic road is more than 4 km on an average. The dependency ratio is high with 62 per cent of the people as dependants (non workers) and farming is the main occupation of the workers with 16 per cent of the population working as cultivators and 6 per cent as agricultural labour.

During the cyclone, 136 persons died in 52 of the 262 villages in a range of 1 to 13 per village. The average death was 0.52 per village, but very high (1.4 per village) for the 75 villages established in the mangrove habitat areas; 105 of the 136 deaths being from these villages. The *death* variable was positively correlated with *surge* ($r = 0.26$, $P<0.01$), *mhabitat* ($r = 0.19$, $P<0.01$), *topodumy* ($r = 0.30$, $P<0.01$) and *pop99* ($r = 0.40$, $P<0.01$). The only variable with a negative and significant correlation with *death* was *mangrove* ($r = -0.17$, $P<0.01$). Of the different explanatory variables, *surge* and *dcypath* had a high and significant correlation ($r = -0.66$, $P<0.01$), the distance from the cyclone eye being the main determinant of sea elevation during cyclone or surge. Though, there was a significant correlation between a few other variables (*mhabitat, surge; casurinadummy, surge; dminiriver, surge*), the value of the correlation coefficient was around 0.45. The socio-economic variables were not correlated with each other.

We estimated equation 3 using both the Logit and Poisson specification [8] and used only *surge* to capture the cyclone impact.[9] Table 4 shows the estimated Logit and Poisson coefficients of the human casualty equation.

The variables increasing death significantly are *topodumy* (dummy for mangrove habitat villages), proximity to small rivers, village population, and the percentage of marginal workers in a village. *Topodumy* takes value 1 for the villages established in mangrove habitat areas and these villages witnessed high deaths, probably due to their low elevation. Villages nearer to small rivers faced more deaths due to the low carrying capacity of small rivers. These rivers are connected to large rivers and get highly inflated during storm surge. However, this variable was significant only in the Logit specification. The significance of marginal workers proves that all poor people are not equally vulnerable (scheduled castes and agricultural labour are also poor), but the ones without any secured or regular job are specially so. The marginal workers don't have any fixed pattern of job and probably were out working during the cyclone.

[8]The over dispersion tests were rejected and both the goodness of fit and LR test of $\alpha = 0$ favored Poisson against Negative binomial. Because of the predominance of zeros in the dependant variable, we also corrected for zero inflation by using both Zero Inflated Poisson and Zero Inflated Negative Binomial estimation with Pop99 as the inflation variable. As expected ZINB was rejected by both the Vuong test and LR test of $\alpha = 0$, but the Vuong test favored ZIP. However, variables significant in ZIP were the same as in Poisson.

[9] As mentioned $dcypath_i$ and $surge_i$ were highly correlated, but retaining or dropping $dcypath_i$ along with $surge_i$ in estimating the equation brought no change either in level of significance or coefficient of variables.

Variables that helped reduce death significantly are width of mangrove forest, proximity to major rivers and nearness to coast (?). Mangrove forests provide protection during cyclone (Das, 2007b; Badola and Hussain, 2005) and this is proved here. Major rivers carry away surge water to interior areas and thus, help reduce the velocity of surge. The significance of coastal distance with a positive sign, though against expectation, could be due to the evacuation of people from villages very near to the coast before cyclone.

7. Vulnerability Indexes for Villages

In the next step, we calculate the vulnerability indexes i.e. the probability of witnessing non-zero death, for each village and rank the villages on the basis of the index. We do this both with the help of Logit and Poisson coefficients. Under both the specifications, the probability of positive death varies from as low as 0.0004 to as high as 0.999 for different villages. We put the 262 villages of our study area under four different categories on the basis of their risk assessment. The categories are as follows: (i) least vulnerable (Pro $\leq$ 0.10), (ii) moderately vulnerable (0.10< Pro $\leq$ 0.30), (iii) more vulnerable (0.30 < Pro $\leq$ 0.50), and (iv) highly vulnerable (Pro > 0.50). Table 5 below shows the distribution of villages under the four categories mentioned above. As expected each village within the 10 km boundary from the coast is not equally vulnerable.

In the study area, 52 villages witnessed human casualties, but the vulnerability index shows that around 130 to 150 villages have more than 10 a per cent chance of witnessing death, of which around 20 to 35 villages are highly vulnerable with a probability of more than 0.5 to experience death if a severe cyclone strikes the area and thus requires complete evacuation.

Table 6 lists the most vulnerable villages of the study area with death probability exceeding 0.7 or with more than a 70 per cent chance of experiencing death during severe cyclones. Both Poisson and Logit distribution identify nearly 16 villages as the most vulnerable ones and the village Kharanasi is found to be at the top of the vulnerability chart.

Next we identified the villages which are least expected to witness death during severe cyclones, even though situated within a 10 km distance from the coastline. These are the villages with a death probability less than 0.006 and are listed in Table 7 below. A common feature of most of these villages is that they are behind the mangrove forest of Rajnagar *Tahasil*, although thickly populated.

8. What impacts Vulnerability more?

In order to identify the variables that have the maximum impact on the vulnerability indexes of the villages, we compare the marginal effects of the variables on the probability of positive deaths.

We find six variables (*dcoast, mangrove, topodumy, dmajriver, pop99 and margworkers)* impacting the vulnerability indexes of villages significantly and these results are robust (see Table 8). We ignore *tahasildar dummies, dminriver* and *mhabitat* as the results on these variables are not robust and we also ignore village population (*pop99*) and coastal distance *(dcoast)* as the marginal impact of *pop99* is very low and significance of *dcoast* reducing vulnerability is probably due to the evacuation of people as explained before. Comparing the magnitude of marginal effects shown in cols 2 and 4, we find one physical factor (*topodumy*) and one socio-economic factor (*margworker*) having a very strong adverse impact on the vulnerability and two physical factors (*mangrove and dmajriver*) are seen to have reduced the vulnerability of the villages. The marginal effect of *topodumy* is 0.32 in Logit and 0.29 in Poisson, but its coefficient being larger than 1 in both the models (see Table 4), its actual marginal effect on the vulnerability of the villages could be much higher than this (Halversen and Palmquist, 1980). The marginal effect of marginal workers is also very high; 1 per cent increase in the percentage of marginal workers in the village will increase the probability of facing death by 39 per cent as per Logit model and by 36 per cent as per Poisson. Thus, the villages situated in mangrove habitat areas and the ones with more marginal workers are the most vulnerable ones compared to others. In contrast, the presence of mangroves behind a village and the proximity to a major river has a negative impact on the vulnerability; 1 per cent increase in width of mangrove forest will reduce the probability of witnessing deaths in a village by 13 per cent as per Logit and by 11 per cent as per Poisson results and that of a major river by 4 per cent and 3 per cent respectively.

9. Conclusion

The present paper did a micro level analysis of vulnerability by looking at the vulnerability of villages lying within 10 km from the coast in Kendrapada district; one of the most vulnerable districts of India. Vulnerability was defined as the probability of facing death due to severe cyclones and associated storm surge risks and a wide range of factors were taken into account to derive and analyze the vulnerability indexes for villages. Of the 262 villages, 112 to 132 villages were found least vulnerable, 72 to 82 moderately vulnerable, 34 to 37 more vulnerable and 21 to 34 highly vulnerable requiring complete evacuations before a calamity. The most vulnerable and the least vulnerable villages were also identified and this can help the administration in evacuation and rescue work. In general, the villages established in the mangrove habitat areas and the ones with a large number of marginal workers were found to be highly vulnerable while those situated behind mangrove forests or in close proximity to a major river directly connected to the sea were least vulnerable. Thus every coastal village is not vulnerable or all population groups or all poor people are not equally vulnerable. The paper helps to identify the most and the least vulnerable from among the group of vulnerable people in coastal Kendrapada district of Orissa, India.

The findings of the paper are based on the human casualty data of a single cyclone and needs to be examined with a wider data set and also under different scenarios to make them more policy relevant. Looking at the age and sex composition of the deceased or even the health status can give an insight into the different dimensions of cyclone vulnerability. Mangroves are seen to be reducing vulnerability by reducing surge velocity and it should be interesting to examine this relation for different levels of sea elevation or to see how effective the mangrove protection will be if cyclone land fall occurs in mangrove area.

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References: -

Badola, Ruchi, and S. H. Hussain, "Valuing ecosystem functions: An empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India", *Environmental Conservation*, **32,** 1-8 (2005).

Carmen, L. S., Iris Moller, and T. Spencer, " The need for an Ecosystem Inclusive Vulnerability Index for coastal areas in Colombia", ongoing research paper, Cambridge Coastal Research Unit, Department of Geography, University of Cambridge, UK (2006). http://www.ehs.unu.edu/file.php?id=294

Chittibabu, P. *et al*. "Mitigation of flooding and cyclone hazard in Orissa, India". *Natural Hazards* **31**, 455-85 (2004).

Das, Saudamini, "Storm Protection Values of Mangroves in Coastal Orissa", in P. Kumar and B. Sudhakara Reddy (ed) *Ecology and Human Well-Being*, New Delhi, Sage Publications, (2007a).

Das, Saudamini, "Storm Protection by Mangroves in Orissa: An Analysis of the 1999 Super Cyclone," SANDEE Working Paper No 25-07, Kathmandu, Nepal, December, (2007b).

Ghosh, S. K., 'Storm Surges and their Numerical Prediction along Indian Coasts', *Indian Meteorological Department Forecasting Manual*, IV-24, Govt. of India, August (1995).

Gormitz, V. M., R. C. Daniels, T. W. White, and K. R. Birdwell, "The development of a coastal risk assessment database: Vulnerability to sea level rise in the US South east", *Journal of Coastal Research, Special Issue*, No 12: 327-338(1994).

Gupta, M. C., and V. K. Sharma, '*Orissa Super Cyclone, 99*', National Center for Disaster Management, Indian Institute of Public Administration, New Delhi: New United Press, (2000).

Halversen, R. and R. Palmquist, "The interpretation of Dummy Variables in Semi-logarithmic Equations", *American Economic Review*, **70**: 474-75 (1980).

HDR, Human Development Report (Prepared by Nabakrushna Choudhury Centre for Development Studies), Planning and Co-ordination Department, Bhubaneswar: Government of Orissa (2004).

Hughes, P., G. B. Brundrit, D. H. Swart, and A Bartels, "The possible impacts of sea level rise on the Diep River/ Rietvli System, Cape Town", *South African Journal of Science,* **89**: 488-490 (1993).

Hughes, P. and G. B. Brundrit, "An index to asses South Africa's vuilnerability to sea level rise", *South African Journal of Science,* **88**: 301-311 (1992).

IMD, '*Tracks of Cyclones in Bay of Bengal and Arabian Sea, 1890-1990'*, Indian Meteorological Department, Govt. of India, (2000).

Jayanthi, N., "Cyclone Hazard, Coastal Vulnerability and Disaster Risk Assessment along the Indian Coasts", *Vayu Mandal*, **28** (1-4): 115-119 (1998).

IPCC 'Summary for Policy Makers', In Parry M L., O. F. Canziani, J. P. Palutikof, P. J. van der Linden and C. E. Hanson (ed) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Forth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, Cambridge University Press, UK: 7-22. (2007)

IPCC CZMS 'A Common Methodology for Assessing Vulnerability to sea level rise'. 2ndEdition. In: Global Climate Change and the Rising Challenge of the sea. IPCC-CZMS, Ministry of Transport, Public Works and Water Management, The Hague, The Netherlands, Appendix C. (2002).

IPCC 'The Regional Impacts of Climate Change: An Assessment of Vulnerability'. In: Watson R. T., M. C. Zinyowera, R. H. Moss, and D. J. Dokken (ed) Special Report by Working Group II: Summary for Policy Makers, Cambridge, Cambridge University Press, UK: 517 (1997).

Kalsi, S.R., N. Jayanthi, and S.K. Roy Bhowmik, '*A Review Of Different Storm Surge Models And Estimated Storm Surge Height In Respect Of Orissa Supercyclonic Storm Of 29 October, 1999*', Indian Meteorological Department, Govt. of India, January, (2004).

Kavi Kumar, K.S., "Vulnerability and Adaptation of Agriculture and Coastal Resources in India to Climate Change", EERC Working Paper Series, NIP-4 (2003).

McCarthy J.J., O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White (eds) 'Climate Change 2001: Impacts, adaptation and vulnerability'. Cambridge, Cambridge University Press, (2001) UK.

Mohanty, N. C., 'Mangroves of Orissa', Project Swarajya Publication, Nayapalli, Bhubaneswar (1992).

Patwardhan, A., K. Narayan, D. Parthasarathy and U. Sharma, "Impacts of Climate Change on Coastal Zone" in P. R. Sukla, S. K. Sharma, N. H. Ravindranath, A. Garg and S. Bhattacharga (ed), Climate Change and India: Vulnerability Assessment and Adaptation, Hyderabad, University Press, India: 326-359 (2003).

Orissa District Gazetteer, Cuttuck, The Gazetteers Unit, The Department of Revenue, Bhubaneswar, Government of Orissa (1996).

Oxford University Press, Oxford English Dictionary, 2nd Edition (2006)

http://www.oed.com

Sharma, U. and A. Patwardhan, "Methodology for identifying vulnerable hotspots to tropical cyclone hazards in India", *Mitigation and Adaptation Strategies for Global Change*, DOI 10.1007/s11027-007-9123-4 (2007).

Shaw, J., R. B. Taylor, D. L. Forbes, M. H. Ruz, and S. Solomon, "Sensitivity of Canadian coast to sea level rise", Geographical Survey of Canada, Bulletin 505(1998).

Turner, R. K., P. Doktor, and N. Adger, "Key Issues in the Economics of Sea level rise", CSERGE Working Paper, PA 93-04 (1993).

UNEP, "Assessing Coastal Vulnerability: Developing a global index for measuring risk", UNEP/DEWA/RS.05-1, Nairobi, Kenya (2005).

Table 1: List of Variables, Definitions and Expected Roles

	Variables	**Definition of variables (all distances in kilometres)**	**Expected role in cyclone damage equation**
Cyclone impact (damages)	Y_i (Death)	Number of human casualties in a village.	Dependant variable.
Government Institution	Tahasildar	Dummy variable for local administration.	Capture differences in administrative efficiency or unobserved locational factors between tahasils.
Cyclone variables	Dcypath	Minimum distance of a village from the centre of the eye of the cyclone or from the cyclone path.	This is a proxy for cyclonic wind at village level.
	Surge	Level of sea elevation (in meters) at different coastal points.	Surge along with dcoast will capture the intensity of storm surge at an interior point.
	Dcoast	Minimum distance of a village from the coast.	
Mangrove related variables	Topodmy	Low elevation dummy (=1 for villages that have or had mangrove earlier and = 0 for others).	Captures the impact of low elevation of mangrove habitat areas.
	Mhabitat	Width of the historical mangrove forest (as existed in 1950) in coastal distance of a village or in between a village and the coast.	Captures the impact of unobserved factors of mangrove habitat areas.
	Mangrove	Width of existing mangrove forest in coastal distance of a village.	Captures the impact of vegetation.
	Casurindumy	Dummy variable for the presence of casuarinas forest in coastal distance of a village.	Captures the impact of casuarinas trees and the topography of casuarinas plantation area.
Hydrological variables	Dmajriver	Minimum distance of a village from a major river (directly connected to sea).	Major rivers carry away surge water and help in reducing the surge velocity to flooding. Nearness to major river should reduce death.
	Dminriver	Minimum distance of a village from a minor river (a tributary of major river).	Minor rivers get inflated and bring in more water to interior areas and cause more death.
Infrastructural variables	Droad	Minimum distance of a village from a metallic road.	Proximity to metallic road increases economic well being and good health and less death.
	Roadumy	Dummy variable for the presence of village road (=1, if village road exists, =0, otherwise).	Same impact as droad on death. Village roads are the dikes in near coast areas and thus captures the impact of dikes on storm surge.
Population at risk	Pop99	Total population of a village in 1999.	Total damage will depend on the total population.
Socio-economic variables	Literate	Percentage of literate people in a village.	They are expected to be better informed and precautionary during disaster.
	Schdulcaste	Percentage of scheduled caste people in a village.	Economically and socially most backward and expected to suffer more.
	Cultivator	Percentage of cultivators in a village.	Economically well off people in the study area.
	Aglabour	Percentage of agricultural labourers in a village.	Economically very backward
	Hhworker	Percentage of people working in (own) household industries in a village.	Economically well off, but have their sources of livelihood at home.
	Otworker	Percentage of other workers (doctor, teacher, engineer, barber, washer man, priest, etc.) in a village.	Economically well off and much better informed than other rich people.
	Margworker	Percentage of marginal workers in a village.	Economically very poor and as they don't have fixed jobs, could be taking risk and thus more exposed during cyclone.

Table 2: Data used and Sources of Data

Data Head	Description	Source
Damages due to super cyclone	Details of Human Casualties in each village	Emergency Offices, Kendrapada and Bhadrakh district of Orissa
Meteorological Information	Landfall wind velocity, radius of cyclone eye, and sea elevation at different coastal points	Cyclone Warning Division, Mausam Bhawan, Government of India, New Delhi
	Track of the cyclone	National Center for Disaster Management (NCDM), Indian Institute of Public Administration, New Delhi
Physical and spatial Information	Distances of different villages from coastline, cyclone track, river channels, metallic roads and width of present and historical mangrove forests	GIS files and forest cover of coastal Orissa from Private Source: Digital Cartography and Services, Bhubaneswar, Orissa.
Socio-economic Information	Total population, percentage of literates, scheduled caste and different types of workers in different villages before cyclone	Primary Census Abstract of the State of Orissa for the year 1991 and 2001

Table 3: Summary Statistics (number of villages = 262)

Variables	Mean (St Dev)	Min (Max)
Death	0.52 (1.62)	0 (13)
Dcypath	46.84 (13.74)	22.19 (72.83)
Surge	1.10 (0.61)	0.7 (4.7)
Dcoast	5.41 (2.82)	0.3 (9.99)
Mangrove	0.63 (1.09)	0 (6.9)
Mhabitat	1.97 (2.36)	0 (11.62)
Topodumy	0.28 (0.45)	0 (1)
Casurinadumy	0.13 (0.34)	0 (1)
Dmajriver	2.41 (1.93)	0.12 (9.21)
Dminriver	3.04 (2.51)	0.09 (11.82)
Droad	4.41 (2.99)	0.12 (18.17)
Roadumy	0.61 (0.49)	0 (1)
Pop99	662 (809.75)	2 (6098)
Literate	0.55 (0.14)	0 (1)
Schedulcaste	0.09 (0.15)	0 (1)
Cultivator	0.16 (0.14)	0 (1)
Aglabor	0.06 (0.09)	0 (1)
Hhworker	0.002 (0.007)	0 (0.07)
Margworker	0.11 (0.12)	0 (0.46)
Outworker	0.05 (0.07)	0 (1)
Nonworker	0.62 (0.16)	0 (0.89)

Table 4: Logit and Poisson Coefficients of the human death regression models due to the super cyclone of Oct 1999 in Orissa (n=262 villages lying within 10 km from coast in Kendrapada district)

Dependant Variable = Death (No of deaths in a village)

Variables	Logit coefficients	Poisson coefficients
Mahakalpada tahasil	0.87 (1.02)	**1.38*** (3.30)**
Patamundai tahasil	-1.64 (1.52)	-0.87 (1.12)
Surge	-0.18 (0.41)	0.17 (1.22)
Dcoast	**0.25** (2.12)**	**0.16** (2.23)**
Mangrove	**-1.25*** (3.10)**	**-1.11*** (3.07)**
Mhabitat	-0.18 (1.25)	**-0.22** (2.85)**
Topodumy	**2.22*** (3.11)**	**1.77*** (4.08)**
Casurinadumy	-0.27 (0.32)	-0.42 (1.07)
Dmajriver	**0.36*** (2.77)**	**0.245*** (3.49)**
Dminriver	**-0.24** (2.16)**	-0.04 (0.60)
Droad	-0.088 (1.12)	0.007 (0.17)
Roadumy	0.23 (0.46)	0.43 (1.36)
Pop99	**0.002*** (3.43)**	**0.005*** (7.02)**
Literate	-1.51 (0.77)	**-1.65* (1.60)**
Schedulcaste	0.492 (0.37)	-1.006 (0.98)
Cultivator	0.41 (0.26)	0.54 (0.58)
Aglabor	-0.51 (0.17)	0.29 (0.17)
Hhworker	17.89 (0.66)	9.57 (0.49)
Margworker	**3.84** (1.99)**	**3.60*** (3.19)**
Outworker	-1.25 (0.25)	-2.66 (1.02)
Constant	**-3.39** (1.96)**	**-3.16*** (3.12)**
	N=262, LR Chi 2 (20)=84.23, P=0.00, Pseudo R^2 = 0.32	N=262, LR Chi 2 (20)=262.58, P=0.00, Pseudo R^2 = 0.53

Notes: - Figures in parenthesis show the z-values, ***, ** and * imply significance at 1%, 5% and 10% level of significance, respectively.

Table 5: Number of Villages falling under different vulnerability categories

Vulnerability Category	No of villages under Poisson specification	No of villages under Logit specification
Least vulnerable (P≤0.1)	112	132
Moderately vulnerable(0.1<P≤0.3)	82	72
More Vulnerable(0.3<P≤0.5)	34	37
Highly vulnerable(P>0.5)	34	21

Table 6: Name of the most Vulnerable Villages (Pro of death >0.7)

Most vulnerable villages under Poisson	Most vulnerable villages under Logit
Badatubi(0.86), Barakolikhala(0.98), Batighar(0.96), Baulakani(0.999), Barahipur(0.75), Bahakuda(0.86), Bhateni(0.83), Gogua(0.79), Hariabanka(0.96), Kalatunga(0.73), Kharinasi(0.999995), Jambo(0.9997), Panikhia(0.998), Petachela(0.9994), Ramnagar(0.99993), Suniti(0.9997)	*Badatubi(0.77), Badatota Chhapal(0.87), Barakolikhala(0.99), Batighar(0.98), Baulakani(0.999), Bahakuda(0.76), Bhateni(0.78), Gogua(0.87), Hariabanka(0.97), Kharinasi(0.99991), Jambo(0.9998), Panikhia(0.72), Petachela(0.9994), Ramnagar(0.9992), Suniti(0.996)*

Notes: - Figures in parenthesis are the probability of facing non-zero deaths due to cyclones in these villages.

Table 7: Name of the least Vulnerable Villages (Pro of death < 0.006)

Least vulnerable villages under Poisson	Least vulnerable villages under Logit
Ajagarpatia (0.005), Badapal (0.005), Bagapatia (0.006), Bagapatia Uttar (0.002), Balarampur (0.004), Balungapatia (0.004), Banabiharipur (0.006), Barunei (0.003), Bekta kolha (0.006), Bimis nagar (0.005), Gopaljew Patna (0.00007), Junus Nagar (0.002), Pataparia (0.0004), Sailendra Narayan pur-1 (0.006), Sailendra Narayan pur-2 (0.0008), Singadapalli (0.006), Sourendrapur (0.0007)	*Ajagarpatia (0.003), Badapal (0.002), Bagapatia (0.003), Bagapatia Uttar (0.0006), Balarampur (0.003), Balungapatia (0.005), Banabiharipur (0.006), Bektakolha (0.001), Bimis Nagar (0.002), Chakmanpur (0.005), Dibakarpur (0.002), Gopalhew Patna-1 (0.0004), Gopalhew Patna-2 (0.0004), Gothakolha (0.002), Handia Garh (0.006), Junus Nagar (0.001), Narayanpur (0.004), Pataparia (0.0008), Purushotampur (0.006), Sailendra Narayan pur-2 (0.0004), Sankarnath Peta (0.002)*

Table 8: Marginal Effects of Variables (dy/dx) on the Probability of non-zero death in a village due to severe cyclones (values based on the poisson and logit estimates of table 4)

Variables	Marginal effect in logit (y=pro of +ive death)	Marginal effect in Poisson	
		Y = predicted mean death	Y = probability of +ive death ♣
Mahakalpada tahasil	0.11	**0.28*** **	**0.22*** **
Patamundai tahasil	**-0.098*** **	-0.08	-0.06
Surge	-0.02	0.02	0.02
Dcoast	**0.026** **	**0.021** **	**0.02** **
Mangrove	**-0.127*** **	**-0.144*** **	**-0.111*** **
Mhabitat	-0.018	**-0.028*** **	**-0.022*** **
Topodumy	**0.322*** **	**0.38*** **	**0.294*** **
Casurinadumy	-0.025	-0.046	-0.045
Dmajriver	**0.036*** **	**0.034*** **	**0.025*** **
Dminriver	**-0.025** **	-0.005	-0.004
Droad	-0.009	0.0009	0.0006
Roadumy	0.023	0.05	0.04
Pop99	**0.0002*** **	**0.00006*** **	**0.00005*** **
Literate	-0.153	-0.21	-0.16
Schedulcaste	0.05	-0.13	-0.10
Cultivator	0.04	0.06	0.05
Aglabor	-0.05	0.04	0.03
Hhworker	1.81	1.24	0.958
Margworker	**0.39*** **	**0.466*** **	**0.36*** **
Outworker	-0.13	-0.34	-0.26

Notes: -***, ** and * imply significance at 1%, 5% and 10% level of significance.

♣ The marginal effect on the probability of positive death (column 4) was calculated by multiplying the marginal effects shown in column 3 with the average value of exp (-predicted mean value) i.e. 0.77256.

Figure 1: (a) Villages of Kendrapada District

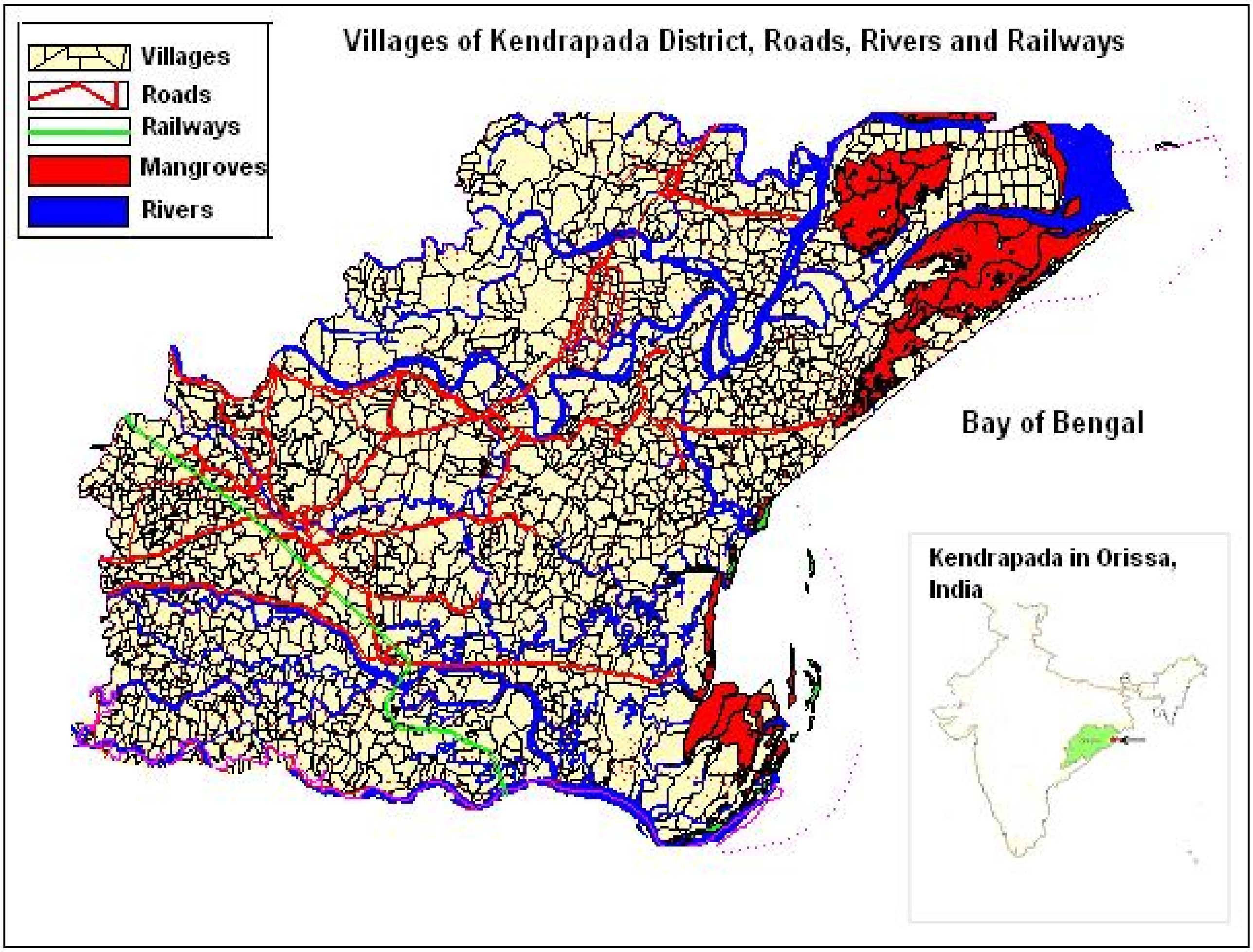


Figure 1: (b) Mangroves of 1999, the rivers and super cyclone eye track

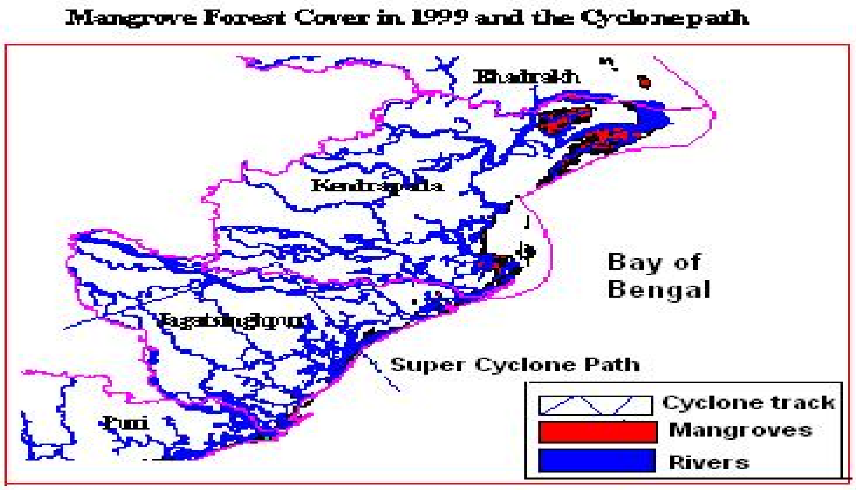
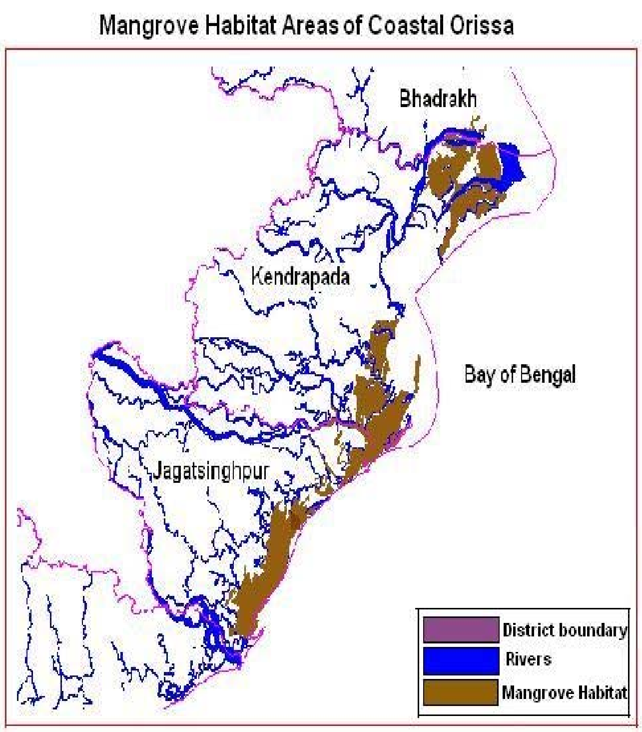


Figure 1: © Mangroves habitat areas of Coastal Orissa



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