Assessment of flood vulnerability at village level for Kandi block of Murshidabad district, West Bengal

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Kandi block of Murshidabad district, West Bengal is situated in the Mayurakshi–Dwarka Plain. This is one of the maximum flood-affected blocks in Murshidabad. The average frequency of occurrence of floods in the last decade is 8. This study prepares a vulnerability map of Kandi block at village level combining physical, social and economic indicators of flood hazard. PCA analysis has been applied for computation of vulnerability indices. The results reveal that there is a difference in biophysical exposure and vulnerability index.

Keywords: Composite index, flood vulnerability, PCA analysis, village-level assessment.

THE Gangetic Plain is one of the largest flood plains with a highly dense population. Almost every year there are floods in the plains causing major losses. With developmental activities like construction of railways and highways in an inappropriate geographical setting, the intensity of floods has aggravated. It is more challenging in the Gangatic Plain, where agriculture has remained the major economic activity. Utilization of resources and implementation of polices have never occurred at a gainful level. Like other programmes, existing flood management measures have been unsustainable, as they adversely affect the river ecology. Frequent incidence of destructive floods poses a challenge to economic development. We have failed to draw an integrated plan to minimize losses. The alternative plan requires a proper integration of hydrological data with socio-cultural and economic data. Although the Irrigation and Waterways Department (IWD) of Government of West Bengal has broadly identified flood-prone areas of the state, there have been no attempts to coordinate the hydrological facts with socio-economic or infrastructural data.

In India, as in many other countries of the developing world, crucial flood management plans are handicapped by financial crunch. To optimize the use of funds, therefore, it is crucial that planners should be equipped with accurate flood risk maps to enable them to identify the most vulnerable zones. Vulnerability measurement is increasingly being considered as a key step towards effective risk reduction. With the increasing frequency of disasters and continuing environmental degradation, measuring vulnerability is a crucial task.

The Kandi block is situated in the western part of Murshidabad district, West Bengal, which lies in the upper deltaic region. The study area lies in the Mayurakshi river basin area. The Kandi area is traversed by the rivers Mayurakshi, Kuye, Dwarka, the Brahmani and the spill channels, viz. the Manikarnika, Kana Mor and Gambhira. The Mayurakshi meets with its major tributaries, namely the Dwarka–Brahmani system and the Kopai–Bakreswar system in Hijal Beel. The river Babla originates here and ultimately discharges into the Bhagirathi, through two outfall channels, viz. the Babla and the Uttarasan. The total area of the block is 227.48 sq. km with a total population of 220,145 (census 2011). About 3.3% of the total population of the district lives in this block. The percentage of area likely to be flooded and the vulnerable population of the block are 75.6 and 92.43 respectively[1]. The average frequency of occurrence of floods in the last decade is 8. The central part of the block, i.e. Hijal Beel and its surrounding areas and areas along the river Dwarka are affected by floods almost every year.

The region to the west of Bhagirathi where the study area is located, forms the northern part of Rarh Plain. The part, by and large, is undulating and filled with marshes and abandoned palaeo channels. This region is drained by the streams originating from the Western plateau and meets the Bhagirathi.

In this region the slope is comparatively high, i.e. 30.1% in the upper region and average slope is 3.5% (along line AB in Figure 1 *a*) in the northern part of the study area. In the south (along line CD in Figure 1 *a*) the maximum slope reduces to 14.6% and the average slope to 1.5%. Consequently, the rivers like Bansloi, Pagla and Brahmani flow rapidly due to sudden change in slope in the northern region. The northern part of the Dwarka–Mayurakshi Plain shows the maximum slope (24.3% and average slope 1.6%). Below this, the average slope reduces to 0.6% in the southern part of the Dwarka–Mayurakshi Plain (along line CD in Figure 1 *b*). This change of slope in the Dwarka–Mayurakshi Plain from north to south causes rapid flow of huge quantum of trans-boundary water from the upstream area during monsoon.

There are several prominent and permanently marshy depressions of various shapes and sizes in the study area. Some of them are Hijal Beel, Patan Beel, Belun Beel, Langolhata Beel, Karul Beel, etc. They are mostly areas of incomplete morphogenesis. Among them, Hijal Beel is extensive, covering about 130 sq. km and presents a very low topographic aspect (Figure 2 *a*). This part of the block is lesser in height than the other parts, thus forming a saucer-shaped depression and is easily inundated. Recently, the Mayurakshi and Hijal Beel have lost their carrying capacity and storage capacity. Estimated volume of sand deposition of the river Mayurakshi is about 0.786×10 m^3 over the last 54 years. Ability to carry discharges of all the rivers collectively has reduced to about

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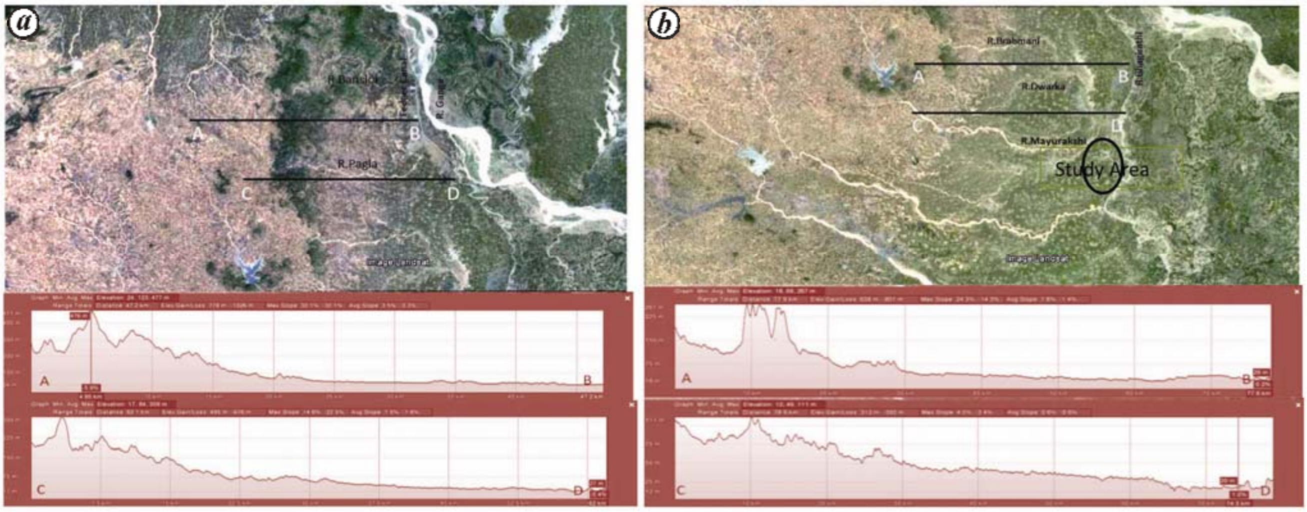

Figure 1. ***a***, Slope pattern in the northwestern part of Murshidabad district. AB: Max slope – 30.1; average slope – 3.5; CD: Max slope – 14.6; average slope – 1.5 (Source: Google Earth, 2012). ***b***, Slope pattern in the Mayurakshi–Dwarka plain; AB: Max slope – 24.3; average slope – 1.6; CD: Max slope – 4.0; average slope – 0.6 (Source: *Google Earth*, 2012).

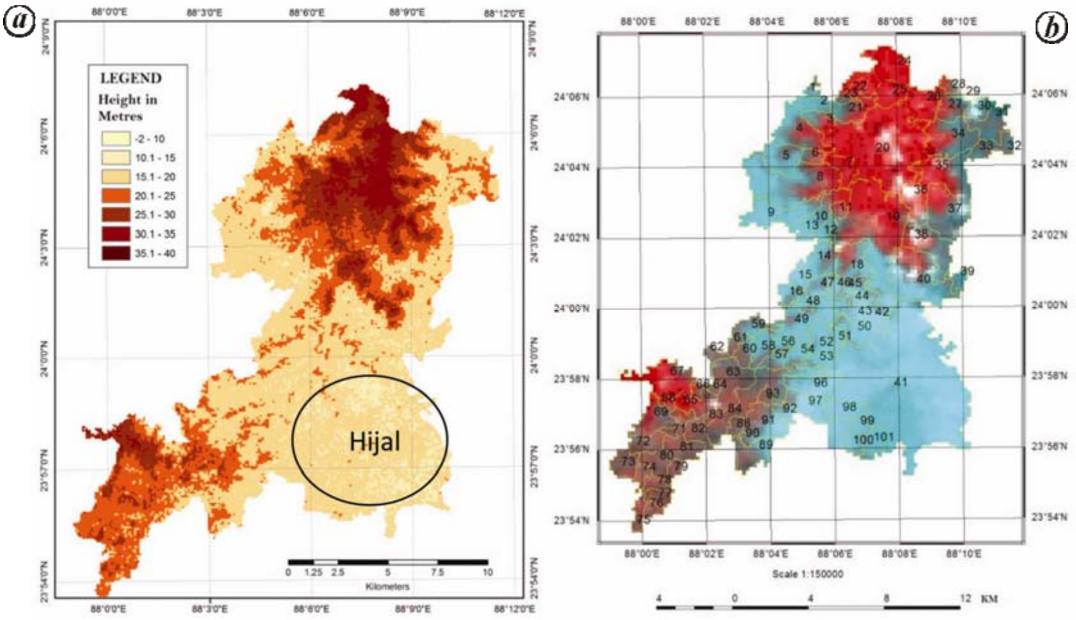

Figure 2. ***a***, Elevation pattern of Kandi block. ***b***, Inundation pattern of Kandi block in 2000 (Source: Prepared from SRTM, 2010 (elevation) and IRS-1D WiFs image, 28 September 2000 (inundation)).

0.786×10^6 m^3. Storage capacity of the Hijal Beel area has been reduced to about 1.90×10^6–1.56×10^6 m^3 over the last five decades[2].

Figure 3 shows detailed features of the drainage network of the study area. It is found that there are two confluence points which play an important role in inundation pattern. The single channel from the Hijal Beel flowing some distance divides into two channels – one in the northern part called river Uttarasan which meets the river Bhagirathi near Uttarabad village, and another channel in the south called river Babla which meets the river Bhagirathi near Kalyanpur village. During monsoon the water level of the Bhagirathi goes above a threshold limit, causing reversal of flow in the above-mentioned confluences. Thus the surrounding low-lying area inundates immediately.

Vulnerability has two sides – (i) external risks and shocks to which an individual or household is subject to extreme environmental condition and (ii) internal, which is defencelessness, meaning a lack of means to cope with disaster[3]. Vulnerability is linked with the capacity to anticipate, cope with, resist and recover from the impacts of

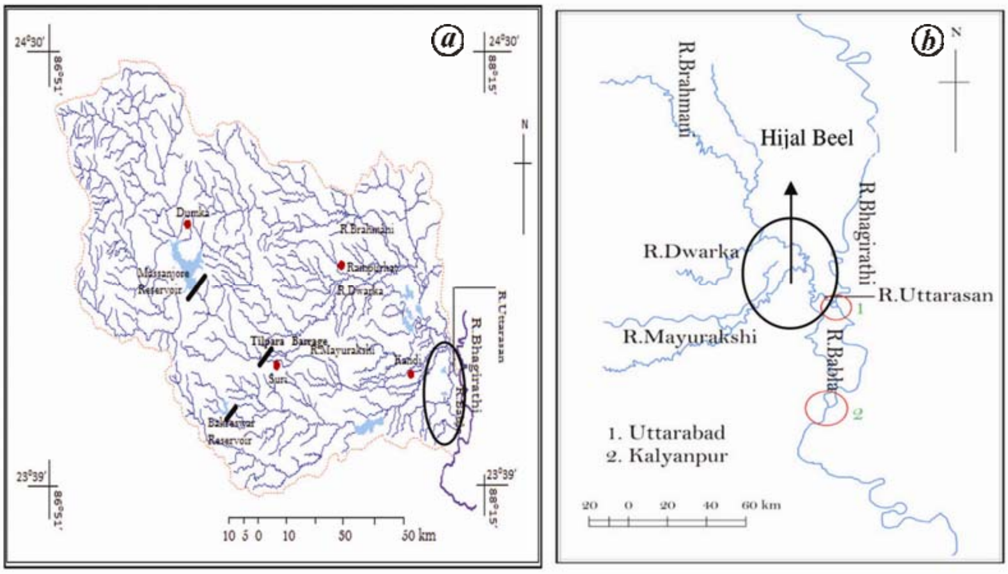

Figure 3. ***a***, Mayurakshi river basin. ***b***, Vulnerable points causing drainage congestion in Kandi block. (Source: Prepared from SRTM data, 2010 and IRS-P6 LISS-3 image, 1 October 2010.)

natural hazards, and can be viewed along a continuum from resilience to susceptibility[4]. Vulnerability is generally perceived to be a function of two components. The effect that an event may have on humans is referred to as capacity or social vulnerability and the risk that such an event may occur is often referred to as exposure[5]. Vulnerability not only depends on the sensitivity of a system, but also on its ability to adapt to new climatic conditions[6]. Vulnerability is the degree to which an exposure unit is susceptible to harm due to exposure to a perturbation or stress and the lack of the exposure unit to cope, recover or fundamentally adapt to become a new system or to become extinct[7]. The structure and health of the population may play a key role in determining vulnerability[8].

A close relationship exists between vulnerability and socio-economic structure of the society, which defines the resilience of populations to environmental shocks. Age is an important consideration, as the elderly and young people tend to be inherently more susceptible to environmental risk and hazard exposure. Generally populations with low dependency ratio and in good health are likely to have the widest coping ranges and thus be least vulnerable in the face of hazard exposure.

Factors like institutional stability and strength of public infrastructure are crucial in determining the vulnerability to climate change[9]. A well-connected population with appropriate public infrastructure will be able to deal with a hazard effectively and reduce the vulnerability. Such a society is said to have low social vulnerability. If there is an absence of institutional capacity in terms of knowledge about the event and ability to deal with it, then such high vulnerability is likely to ensure that biophysical risk turns into an impact on the human population.

The data used for capturing the risk to flood hazard at village level are from various reports of Census of India[10] and IWD[1].

Composite index is the aggregation of individual indicators into a single index or bottom line using a certain weighting scheme[11]. PCA and factor analysis (FA) help in the weighting of the composite indices as the different indicators have different levels of importance[12]. The weights derived from PCA are determined by the factor loadings on the components and are fixed across all groups. Therefore, an instrument is derived which compares the quality of life of different groups. It is a basic method to determine the weights and contributes to the selection of a limited number of indicator variables which represent the data.

PCA aims to extract the maximum variance from a dataset with each component[13].

In mathematical terms, PCA can be explained as follows:

From a set of variables X_1, $X_2 \ldots X_m$, the principal components PC_1 to PC_m are extracted:

$$\begin{array}{l} \mathrm{PC}_1 = a_{11}X_1 + a_{12}X_2 + \ldots\ a_{1n}X_n \\ . \qquad\qquad\qquad\qquad . \\ . \qquad\qquad\qquad\qquad . \\ . \qquad\qquad\qquad\qquad . \\ \mathrm{PC}_m = a_{m1}X_1 + a_{m2}X_2 + \ldots a_{mn}X_n, \end{array}$$

where a_{mn} represents the weight for the mth principal component and the nth variable. The weights of each principal component are given by the eigenvectors of the correlation matrix or the covariance matrix. The variance (λ) for each principal component is given by the eigenvalue of the corresponding eigenvector. The analysis conducted here relies on the eigenvalues and their corresponding eigenvectors, as they summarize the variance in a correlation or covariance matrix.

In the composite index, a total of 14 indicators have been selected. Though these indicators do not explain the vulnerability in total, unavailability of authentic data compels us to do the analysis with these data. General literacy, female literacy, dependent population, population below 6 years age and distance of the villages from the main centre of the region have been considered to express the degree of social status of the villages. Social development is one of the important indicators of vulnerability. Socially under-developed communities are more sensitive to any extreme condition in their environment compared to socially developed community. Literate population can collect information regarding the early warning and probability of occurrence of floods provided by different media and prioritize adaptation efforts to address the most threatening impacts and events. They can also take measures accordingly. Illiterate communities are not aware of the level of impact of different climate events on household and community. They lack skill in identifying current and possible uses of climate information also.

In the present economic system in the study area, agriculture does not bring high income. High dependence on agriculture results in less earning and consequently lack of money to cope with the extreme situation. Dependence on natural resources accelerates the sensitivity to flood hazard. Flood severely affects the production system as well. Thus this pattern of livelihoods is highly sensitive to flood hazard. Pressure of dependent population in terms of workforce and population below 6 years determines demographic vulnerability of the region. The minor population and old population need more assistance during the evacuation process and thus are more vulnerable. Accessibility reduces vulnerability. Highly accessible areas have the advantage of rapid evacuation process.

The KMO measure of sampling adequacy is 0.786, which indicates a high sampling adequacy for FA. The Bartlett test of sphericity-associated probability is less than 0.05, which is small enough to reject the null hypothesis of no correlation in the dataset. Therefore, both these tests indicate that there is sufficient correlation in the selected variables to perform PCA for calculation of composite index.

Table 1 shows that percentage of dependent population (0.902), percentage of population below 6 years of age (0.927), general illiteracy rate (0.899), female illiteracy rate (0.945) and distance from main town (0.722) have the highest factor loadings on the first component. This component was labelled 'social backwardness'. This dimension explains the most variance in the dataset, i.e. 33%.

In the second component, flood frequency (0.907), duration of flood (0.891), depth of flood (in m) (0.953), percentage of flood-prone area (0.896) and percentage of flood prone area (in ha) (0.852) loaded the highest on the component and this was labelled as 'exposure to flood'.

Table 1. Results of PCA analysis

KMO and Bartlett's test	
Kaiser–Meyer–Olkin measure of sampling adequacy	0.786
Bartlett's test of sphericity approx. chi-square	1.185E3
d*f*	78
Sig.	0.000

Indicator	Component 1	Component 2	Component 3	Component 4	Square loadings			
Frequency	–0.184	0.907	–0.038	–0.138	0.008	0.196	0.001	0.017
Duration	–0.234	0.891	–0.057	–0.13	0.013	0.189	0.003	0.015
Depth	–0.102	0.953	0.001	–0.038	0.002	0.216	0.000	0.001
% Area flood	–0.083	0.896	–0.007	0.117	0.002	0.191	0.000	0.012
% population flood	0.251	0.852	0.188	0.093	0.015	0.173	0.030	0.008
Density of population	0.225	–0.013	0.909	–0.026	0.012	0.000	0.693	0.001
% Minority population	0.256	–0.231	–0.204	0.797	0.015	0.013	0.035	0.561
% Dependent population	0.902	–0.067	0.263	0.033	0.188	0.001	0.058	0.001
% <6 years population	0.927	–0.066	0.151	–0.135	0.199	0.001	0.019	0.016
Gen illiteracy	0.899	0	0.025	0.034	0.187	0.000	0.001	0.001
Female illiteracy	0.945	–0.091	0.183	0.115	0.207	0.002	0.028	0.012
% Agri population	0.37	–0.223	–0.273	–0.636	0.032	0.012	0.063	0.357
Distance from town	0.722	–0.177	–0.29	0.33	0.121	0.007	0.071	0.097
Total variance	4.317	4.204	1.192	1.133				
	Social backwardness	Exposure	Population density	Economic backwardness				

This dimension explained the second most variance in the dataset (32%), and these variables also showed considerable variance between the indicators. The third and the fourth components – 'population density' and 'economic backwardness' explain about 17% of the dataset. These two components are less significant in terms of variance explained and thus have not been discussed much in the analysis.

The study shows that the villages with highest indices of physical exposure, i.e. 'exposure to flood' component are not the same in terms of their relative position as well as in terms of their absolute values with respect to their composite vulnerability indices combining the physical and socio-economic features. Regarding the degree of physical exposure to flood risk, H.T. Chak, Hijal, Jayarampore, Udaychandpur, Baze Gopalnagar, Durgapur, Gopalnagar, Belun, Benipur and Lakshmikantapur villages are highly vulnerable (Figure 4). The socio-economic index reveals that Ranipur, Bhabanandapur, Nabagram, D. Lakshminarayanpur, Munigram, Patenda, Gobarhati, Madarhati, Asua and Kumar Sanda (Figure 5) are exceedingly backward villages showing least adaptive capacity to cope with flood risk. With respect to overall vulnerability to flood risk, the most vulnerable villages are Kalyanpur, Sashpara, Bajedohalia, Parbbatipur, Udaychandpur, Ranipur, Bundai, Durgapur and Solepara (Figure 6). Thus, consideration of physical parameters alone does not provide the right direction to assess the overall risk pattern of the study area to flood risk.

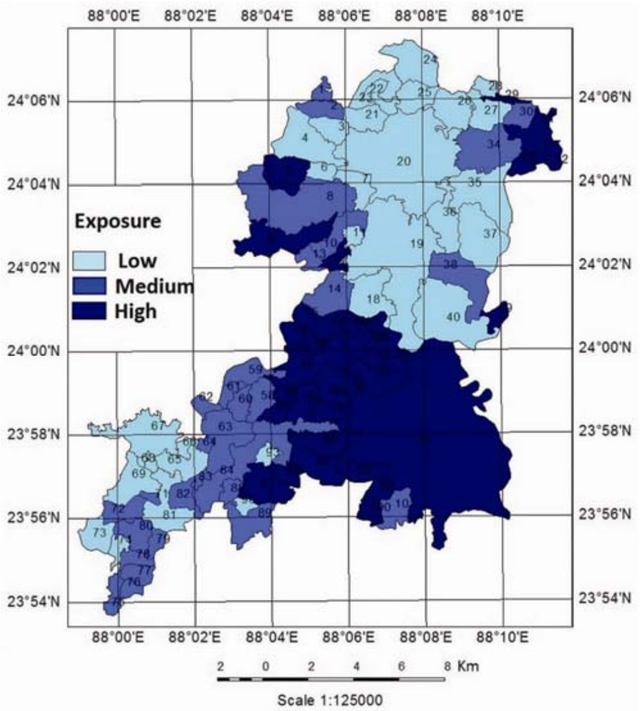

Figure 4. Village-wise exposure to flood in the study area.

With a view to controlling floods in Murshidabad district, efforts have been directed to the construction of embankment. People have heavily encroached upon these public structures, ignorant of the fatal consequences that

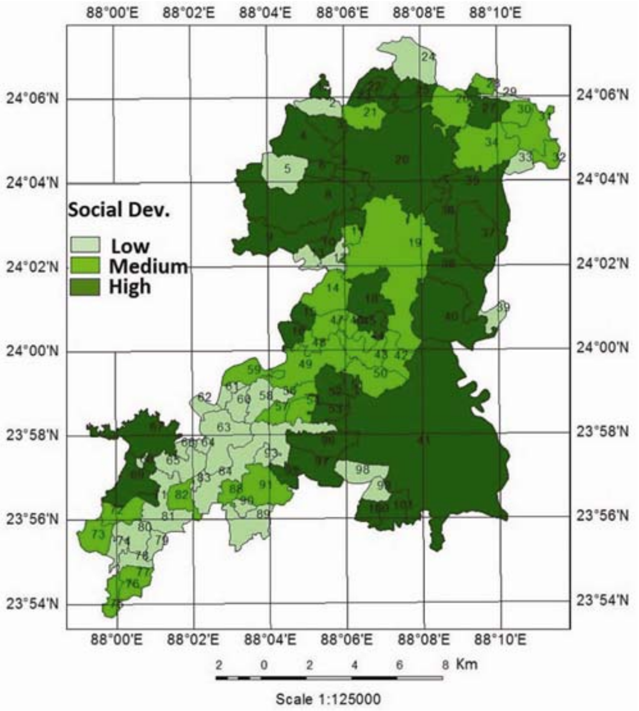

Figure 5. Village-wise social development pattern in the study area.

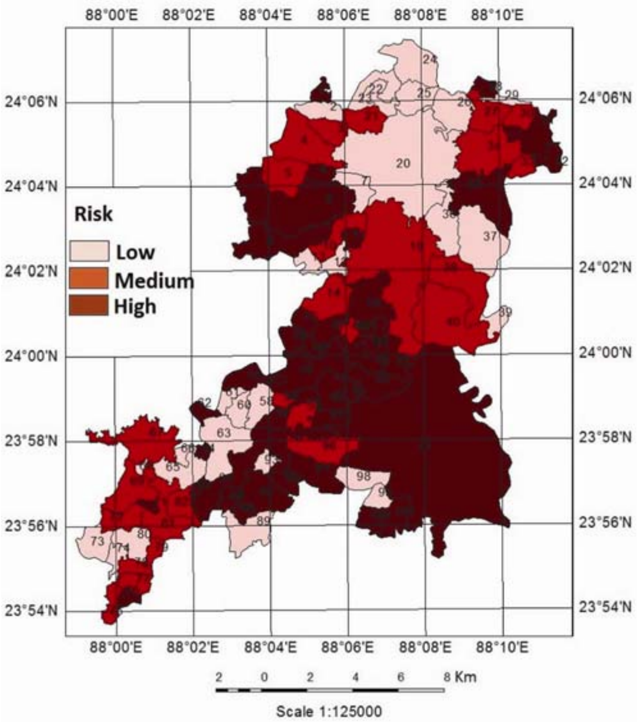

Figure 6. Village-wise vulnerability of floods in the study area.

could befall them. In the Mayurakshi basin alone, the length of embankment is 377 km. The efforts in this direction have interfered with the natural course of drainage across the region. At some places, IWD has undertaken construction of drainage channels to relieve certain areas from drainage congestion and waterlogging. However, these efforts have had a reverse effect exacerbating the flood condition.

Physiographic features of the study area favour natural generation of floods. By comparing the elevation pattern of the study area with that of inundation pattern of the year 2000, recorded as one of the biggest flood events ever to hit the block, it is found that topography plays the most important role in inundation. Outflows of a huge volume of extra water from Hijal Beel during rainfall and loss of carrying capacity of the Mayurakshi River are also responsible for flood severity in the Kandi block. So it is impossible to control the occurrence of floods in the region. We must adopt a preparedness-driven approach relating to flood and vulnerability analysis; improving the community's adaptive capacity, etc. are much more significant management options. In West Bengal all the flood control measures are structure-oriented in examining only the physical exposure. The socio-economic structure of that area is overlooked during formulation of any flood management plan at the district level. It is evident that the people involved in flood management conceived building structures like embankment, barrage, canals, etc. as the sole control. Non-structural approaches always remained obscure. We must develop proper flood management plans which will consider the social aspect along with biophysical aspect.

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Glossifungites ichnofabric signifying Crustacean colonization in early Permian Barakar Formation, Talchir Coal Basin, India

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Early Permian Barakar Formation (Gondwana Supergroup) in peninsular India was earlier interpreted as deposited in braided-meandering fluvial system. Intense burrowing by decapod crustaceans of marginal marine affinity led to *Thalassinoides–Ophiomorpha–Rhizocorallium* ichnoassemblage, belonging to *Glossifungites* ichnofacies, within the sandstone–mudstone heterolithic facies near the upper part of the Barakar sedimentary succession, Gouduni River, Talchir coal basin, Odisha, India. An early cementation of the sandstone–mudstone interbeds under changed salinity condition is attributed to mixing of fluvial channels with tide-wave influenced marine depositional systems. This resulted in a semi-consolidated firmground, favouring incipient crustacean colonization during prolonged phases of marine incursion within a fluvial–marine interactive estuarine system during the early Permian in eastern peninsular India.

Keywords: Crustacean trace fossils, coal basin, estuarine firmground, fluvial system, *Glossifungites* ichnofacies.

ICHNOFOSSIL assemblages in sedimentary successions provide convincing evidences of sediment–organism interactions under different substrate conditions and changing palaeoecological control parameters[1,2]. Ethological

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