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Determining the Degree of Flood Hazard Risks in the Baliapal Coastal Block, Odisha, India: A Quantitative Approach

Nilay Kanti Barman[1], Soumendu Chatterjee[2], Ansar Khan[3]* and Dipak Bisai[3]

[1] *Department of Geography, Hijli College, Kharagpur-721306.*
[2] *Department of Geography, Presidency University, Kolkata-700073.*
[3] *Department of Geography and Environment Management, Vidyasagar University, Midnapore-721102.*
***Corresponding author**: khanansar@gmail.com

Abstract:
With respect to the June 2008 flood event at Baliapal block of Balasore district, Odisha, the present paper gives light on the coastal flood hazard risk assessment through the appraising of flooding characteristic and also standardized value calculation of different measurable flooding parameters like intensity and impacts across the different gram Panchayats in Baliapal Gram-panchayat (GP). Consequently, according to extent of flooding intensity a Flood Magnitude Rank (FMR) has been assigned to each and every GPs. On the other hand Flood Impacts Rank (FIR) has also been quantifying using the flood damage database. Then the Flood Severity Score (FSS) has been derived from the product value of FMR and FIR of a GP. Subsequently this FSS of a GP can be multiplied by the probability of the concern flood event occurrence which yields Flood Hazard Score (FHS) for the GP. This study helps to divide the study area into five risk zones according to their sheer size of the flooding. The risk zones are a) Very Low (FHS Below 1.33); b) Low (FHS 1.33 – 2.07); c) Moderate (FHS 2.07 – 3.02); d) High (FHS 3.02 – 4.90) and e) Very high (FHS Above 4.90), respectively. Choumukh GP falls in very high flood hazard risk class while, Srirampurmahakumaremu, Kumbhirai, Nikhira and Debhoga tend to have very low risk from flood hazards. The rest 22 G.Ps of the area under study come under different risk classes in between above three extreme classes according to their flood hazard scores.

Keywords:
Flood Magnitude Rank; Flood Impact Rank; Flood Hazard Score; Flood Severity

1. INTRODUCTION

The coastal areas are more vulnerable in nature as they situated in transitional zone between marine and terrestrial environment as well as the zone of hazardous processes which originate from both oceanic and terrestrial environment. The complexity of coastal processes and the immense diversity of ecosystem, landform, land use etc. make the coastal zone as a sensitive one. The importance of coastal areas is growing day by day due to high productivity of the ecosystems, increasing concentration of population, industrial development, more intensive resource exploitation, expanding recreational activities etc. in this context the degree of coastal hazard concentration is also increasing in nature so there is a need of sustainable management of coastal zone to diminish the coastal hazard. The Swaminathan Committee [1] has recommended the coastal vulnerability as an important contemplation to manage the coastal zone. To assess the comprehensive coastal vulnerability it is needed to consider the physical sensitivity and also the exposure of coasts to the hazards. During the last few decades, a plethora of literatures on coastal risk assessment methods have been produced in connection with the global climate change and contemporary sea level rise which has considered as a real threat to coastal habitats.

To assess vulnerability of various coastal nations to predicted sea level rise, IPCC coastal zone management sub group (CZMS) developed a seven steps common methodology [2]. This common methodology considered the probable impacts of global sea level rise on population, economic sector, ethnicity and social assets and on agricultural production. Availability of adequate data of one or many parameters of common methodology is not so easy [3]. A four steps methodology has been developed by Kay and Waterman [4] to conquer the limitation associated with the common methodology. The four stages were - physical and biological environment study of the area under consideration; vulnerable and cultural system; links between different parts of the area and finally, formulation of management strategy. Hervey et al. [5] criticized this method. They said that the physical and biological environment is poorly determined and the man induced coastal hazards are not properly considered in Kay and Waterman's [4] methodology.

Hervey and his colleagues developed an eight-step methodology in which the above discrepancies were removed. Gronitz et al in 1994 gave an important contribution for coastal risk assessment in the form of Coastal Vulnerability Index (CVI) which considered a several parameters like relief, rock type, landform, tectonics and shoreline shift for calculating Coastal Vulnerability Index (CVI). United States Geological Survey (USGS) has developed the coastal vulnerability map throughout the coastal stretches of USA with the help of Gronitz et al. [6] method. But there is no consideration of socio-economic data in Gronitz et al [6] method which is logically criticized [7–9]. So coastal vulnerability analysis without consideration any socio-economic aspects, is not useful [3]. In these contexts the social vulnerability index [10] and CVI were combined to develop Coastal Social Vulnerability Index (CSoVI) where poverty, population, development, ethnicity, age and urbanization were emphasized along with the physical parameters [11]. Furthermore, exposure of a place to physical hazards has been measured in terms of Place Vulnerability Index (PVI) [12].

Odisha coast is experienced by different coastal hazards like flood, cyclone, storm surges etc. flood hazards are generally occurred in this area due to tropical cyclone and rarely by tsunamis. So the extent of flooding mostly depends on the character of storm, height of storm surges and also the tide level at the time of the event. Moreover global sea level rise is also an important criterion to assess the degree of flooding. River estuaries are the witness of estuarine flooding which is occurred by the combined effects of both storm surges and the river flood by rain storm in land. Coastal flooding is one of the most severe hazards in around the Bay of Bengal coast.

2. STUDY AREA

The present study area constitutes a part of the alluvium coast of Subarnarekha delta plain. It extends from Subarnarekha river mouth to Dugdugi river mouth along the Bay of Bengal coast of Odisha. The study area lies between 87°7′45″E to 87°23′3″E. and 21°28′25″N. to 21°43′55″N (**Figure 1**). The area is an unconsolidated alluvial coastal substrate with geomorphologically dynamic, rich in habitat diversity and ecologically sensitive. It is also locationally hazards prone mainly the tropical cycle induced tidal waves, storm surges and consequent coastal flooding. Geologically the area constructed by the ordinary alluvium deposits of the Holocene era along with the recent sediment brought down by Subarnarekha

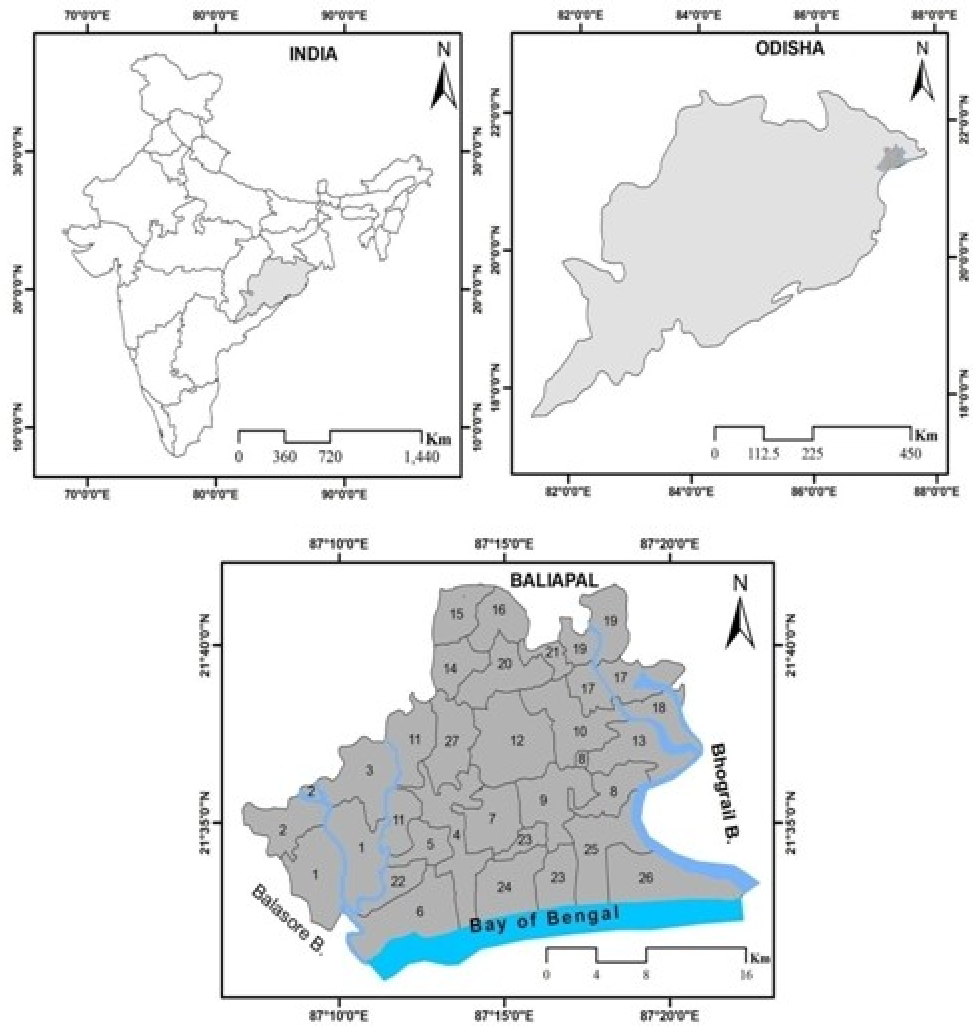

Figure 1. Situated between Subarnarekha River and Dugdugi river, Baliapal block, Odisha constitute a part of Subarnarekha strand plain; exposed to variety of hazards that originate from both land and sea.

river. It is a monotonously flat alluvium surface lying between 2.5 m to 3.5 m above MSL with a natural gradient to the east and south east direction which has been followed by the river Subarnarekha, Hanskara and Dugdugi. Soil type of the study area, under the brackish environment, is mainly sandy, clay and silty loam soils with a wide range of pH value (6.5 and 8.0 - pre monsoon and 6.2 and 8.2 - post monsoon) and also a high water retaining capacity. The climatic condition of the study area is generally Monsoonal in nature. Temperature varies from a minimum of 9°C in winter to a maximum of 38°C in summer. In most of the month relative humidity lays in between 90% – 96%. Low atmospheric pressure is frequent during summer and monsoon period. Wind dominantly blows from the offshore areas. Some typical coastal floral species like *Sesuvium portolacrustum*, *Ipomia bioloba*, *Lantena camera, Akanthesia*, and *Calatropis gigantia* are found at the study area. Some mangrove species are also found at the tidal crick and salt marshes. Coconut, Banana, Bamboo and Mango are indigenous floral species along with some planted species like *Casuarina*, *Eucalyptus* and *Acacia auriculiformis* are also present at the study area. .

3. METHODS

There are two important aspects to assess the flood hazard risk in a particular spatial location. Firstly the physical properties like depth, duration, inundation condition, extent and velocity of flooding and also the height of storm surges in low lying coastal tract. Another aspect is to quantify the damage database like damage of human life, properties, cattle died, crops damage, road damage etc. it is also very necessary to collect the concern flood damage data base through the proper data sheet. Considerable numerals of samples (50) within the concern spatial location have been considered each Gram Panchayat (GP), taken as sample unit depending upon the scale of study.

4. MATERIALS

The present study has been fulfilled with the help of some secondary data from Gram Panchayat office, Block Development Office, District Natural Hazard Management Office of Balasore district, Odisha and also some primary data, which have been collected from field through the questionnaire survey at randomly sampled house hold to represent the concerned GP. Each Gram Panchayat of study has been consider as the smallest spatial unit of studying for which the damage data base of concern flood is maintained and variations in flooding characteristics is not expected below this scale of geography when the natural setting of the terrain under study is considered. Furthermore the socioeconomic and the infrastructural futures of the study area reveal a satisfactory degree of homogeneity at the Gram Panchayat level.

5. DATA ANALYSIS

The four parameters namely I. depth of flood water, II. flood velocity, III. percentage of area under inundation and IV. distance from sea shore have been considered of a GP to estimate the Flood Magnitude Rank (FMR). Similarly to numerate the Flood Impact Rank (FIR), seven indices have been considered – these are I. percentage of fully damaged houses, II. percentage of partly damaged houses, III. number of people died per thousand, IV. number of cattle died per thousand of cattle population, V. monetary equivalent of crop damage per hector of net cropped area, VI. monetary equivalent of fishery damage as a percentage of total value of fish production, VII. length of road damaged as a percentage of the total length of roads in the GP these. Accordingly the Flood Hazard Score (FHS) of each GP has also been calculated using these physical and damage data base, which helps to give a numerical measure of flood risk associated with a GP.

Calculation of Flood Hazard Score (FHS) involves following steps:

Step-I: Computing flood magnitude and flood intensity score

With reverence of June 2008 flood, the Flood Magnitude has been quantifying with the help of above mentioned four physical parameters i.e. flood velocity, percentage of area under inundation and distance from sea shore. Which have been obtained from secondary sources supplemented by field survey. All the data of physical parameters of flood for all the 27 GPs have been standardized to make them dimension less and scale free and also to make them comparable. Then those standardized scores for the aforesaid parameters have been averaged to get GP wise Flood Magnitude Score (FMS)

$$FM_{GP} = \frac{\sum_{j=1}^{k} z_j}{k} \tag{1}$$

Table 1. Ranking of Flood Magnitude and Flood Impact in a 10 point scale according to corresponding Standard Score values.

Standardized Value	< -3	-3 to -2	-2 to -1	-1 to 0	0 to 1	1 to 2	2 to 3	>3
Flood Magnitude Rank and Flood Impact Rank (FMR and FIR)	1	2	3	4	5	6	8	10

where, j physical parameters of hazard; k number of physical parameters and z normalized physical parameter for the hazard considered GP wise damage data can similarly be combined into a Flood impact Score as follows

$$FI_{GP} = \frac{\sum_{i=1}^{n} z_i}{n} \tag{2}$$

where, i damaged parameters of hazard; n number of damage parameters of hazard considered. z, normalized physical parameter for the hazard considered.

Step-II: Obtaining Flood Severity Score

For the concern flood episode, GP wise standardized values of FMGP and FIGP can be ranked on a 10 point scale in **Table 1** to get the Flood Magnitude Rank and also the Flood Impact Rank (FIR).

Flood Severity Score of each and every GP has been obtained by the multiplying of FMR and FIR of every GP

$$FSS = FMR \times FIR \tag{3}$$

Step-III: Assessing Probability of flooding

Probability (p) of the occurrence of flood of a given magnitude is computed from recurrence interval (also called the return period). Flood recurrence interval has been computed on the basis of last 40 years worth of data. Recurrence interval (T) is defined as the average number of years between two successive floods of similar severity. Recurrence Interval (T) is given by

$$T = \frac{n+1}{m} \tag{4}$$

where, n number of years in record; m number of occurrences of floods of a given severity.

The probability (p) of occurrence of floods of a given severity is expressed by taking the inverse of recurrence interval (T)

$$P = \frac{1}{T} \tag{5}$$

Step-IV: Calculating Flood Hazard Score

Finally, the Flood Hazard Score (FHS) is calculated by multiplying the Flood Severity Score (FSS) in **Table 2** and the associated probability value is

$$FHS = FSS \times P \tag{6}$$

Table 2. Computation of Flood Magnitude Rank (FMR), Flood Impact Rank (FIR), Flood severity Score (FSS), Probability value (P) and Flood Hazard Score (FHS).

GP Code	GP Name	Avg. standard score of hazard magnitude	Flood Magnitude Rand(FMR)	Avg. standard score of hazard damage	Flood Impact Rank(FIR)	Flood Intensity Score(FIS)	probability	Flood Hazard Score
1	Bolonga	1.0629	6	-1.2573	3	18	0.1463	2.6341
2	Kunduli	0.5097	5	-1.2121	3	15	0.1219	1.8292
3	Baniadiha	-0.2216	4	-0.0139	4	16	0.0975	1.5609
4	Nuagaon	0.4937	5	-1.0456	3	15	0.1219	1.8292
5	Ratei	-0.4200	4	-0.3757	4	16	0.0975	1.5609
6	Jambhirai	0.9945	5	-1.1162	3	15	0.1219	1.8292
7	Jagajipur	-0.2701	4	-0.1195	4	16	0.0975	1.5609
8	Badas	0.4529	5	-1.2729	3	15	0.1219	1.8292
9	Pratappur	-0.3330	4	-0.1994	4	16	0.0975	1.5609
10	Madhupura	-0.7974	4	-0.5404	4	16	0.0975	1.5609
11	Balikuti	-0.7183	4	-0.3028	4	16	0.0975	1.5609
12	Deula	-0.6285	4	-0.0599	4	16	0.0975	1.5609
13	Jamkunda	0.68592	5	1.2546	6	30	0.1219	3.6585
14	Srirampur Mahakumaremu	-1.4058	3	-1.4267	3	9	0.0731	0.6585
15	Kumbhari	-1.3971	3	-1.3658	3	9	0.0731	0.6585
16	Nikhira	-1.1876	3	-1.1618	3	9	0.0731	0.6585
17	Baliapal	-0.3824	4	-0.2960	4	16	0.0975	1.5609
18	Bishnupur-mahakumanayabali	0.4162	5	0.3402	5	25	0.1219	3.0487
19	Asti	-0.2504	4	-0.0428	4	16	0.0975	1.5609
20	Debhoga	-1.1972	3	-1.1932	3	9	0.0731	0.6585
21	Ghantuai	-0.9936	4	-1.1152	3	12	0.0975	1.1707
22	Panchupali	0.2301	5	-0.0677	4	20	0.1219	2.4390
23	Betagadia	0.4586	5	0.2927	5	25	0.1219	3.0487
24	Anladiha	0.5810	5	0.4443	5	25	0.1219	3.0487
25	Dagra	0.8791	5	0.8217	5	25	0.1219	3.0487
26	Choumukha	1.4847	6	1.6147	6	36	0.1463	5.2682
27	Balarampur	-0.7944	4	-0.4818	4	16	0.0975	1.5609

6. RESULTS

Present study has been assigned the atrociousness of flood risk across the all 27 GPs under Baliapal C.D. Block, Odisha. According to the degree of flood hazard risk all 27 GPs have categorized into five flood hazard risk zone starting from Very Low through intermediate classes to Very High in **Table 3** . Accordingly a thematic map of these flood risk zones has been prepared for the spatial visualization of the flood hazard risk within the block (**Figure 2**). From the prepared thematic map it is very clear that Choumukh GP belong to very high flood risk zone which may be endorsed to their exposed geomorphic locations to the coastal hazards.

Srirampurmahakumaremu, Kumbhirai, Nikhira and Debhoga GPs lies in the very low flood hazard class. The 22 GPs have belonged into other intermediate classes according to their Flood Hazard Score. It is also very remarkable that in spite of being located far away from the sea Jamkunda and Bishnupurmahakumanayabali GPs received a high degree of flood hazard risk. Flood due to Spilling of river and rain water is very often among the GPs under low and very low flood hazard risk.

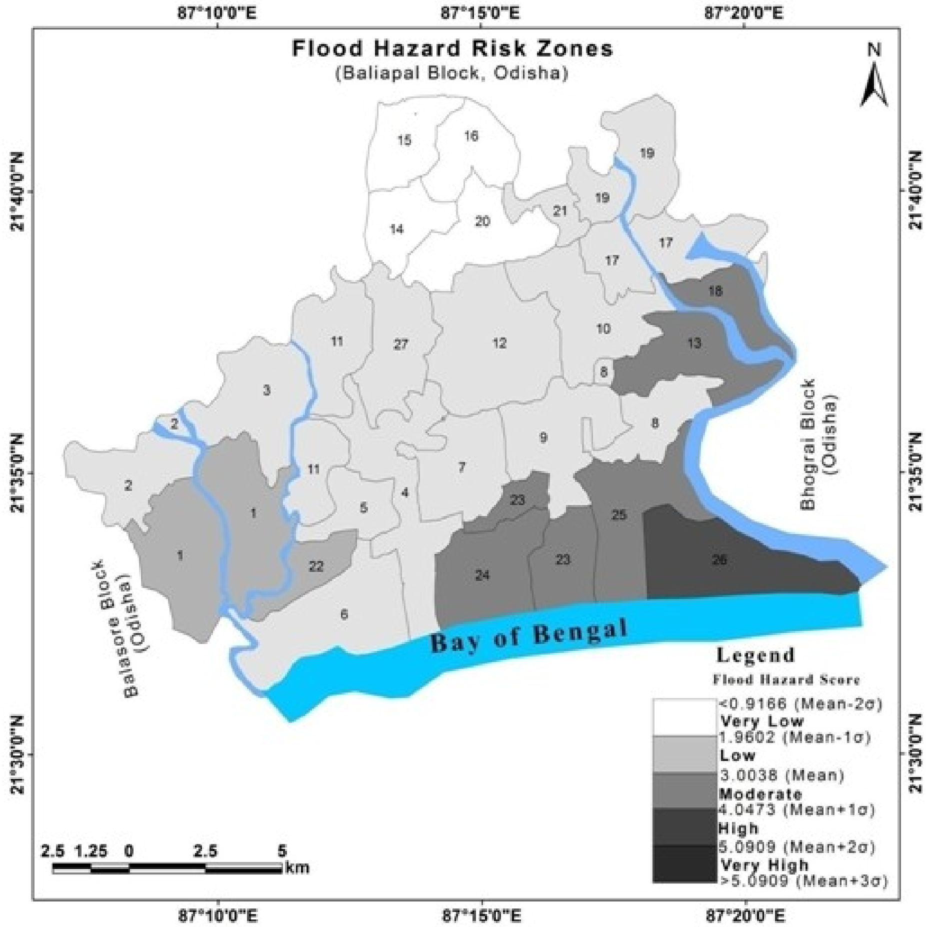

Figure 2. Gram Panchayats under different flood risk classes according to calculated flood hazard scores (FHS). Classes are taken on both sides around the mean of FHS values, standard deviation of which defines class width.

The squared value of average z-score for seven hazard impact parameters of every GP have been plotted in a graph (**Figure 3**) to visualize the parameters wise damage intensity. Out of these seven parameters fisheries, crop and road damage concentration is very high among the coastal facing GPs along with the GPs which located along the river bank due to high concentration of agriculture and aquaculture practice at the river flood plain and also the foreshore areas. On the other hand the GPs, located at landward side from the coast are mostly suffered from crop and road damage and in terms of number of population affected because this area is densely populated.

Flood Magnitude Rank (FMR) and Flood Impact Rank (FIR) of every GP have been represented by area graph (**Figure 4**) to compare these two aspects of flood. This is very fascinating to note that, in spite of being situated under the high magnitude of flood - the damage impacts of flooding is much less at Bolonga, Kunduli, Nuagaon, Jambhirai, Badas, Ghantuai and Panchupali GPs.

7. DISCUSSION

Being located along the active chenier plain of Subarnarekha delta the present study area is geomorphologically very dynamic in nature. The sea facing part of the studied coast is also composed of beach

Table 3. Gram Panchayats under different Flood risk classes according to flood hazard scores received.

Flood Hazard Score	Assigned Attribute	G.P Code	Identified G.P
<0.9166	Very Low	14, 15, 16 , 20	Srirampurmahakumaremu, KumbhariNikhira and Debhoga
1.9602 - 3.0038	Low	8, 9, 10, 11, 12, 17, 19, 21, 27	Kunduli, Baniadiha, Nuagaon, Ratei, Jambhirai, Jagajipur, Badas, Pratappur, Madhupura, Balikuti, Deula, Baliapal, Asti, Ghantuai and Balarampur
3.0038 - 4.0473	Moderate	1, 22	Bolonga, Panchupali
4.0473 - 5.0909	High	13, 18, 23, 24, 25	Bishnupur Mahakumanayabali, Betagadia, Anladiha and Dagra
>5.0909	Very High	26	Choumukha

barrier complex and wash over deposits. The alteration of regressive younger beach ridges, and mudflats and floodplains to the depressed zones are frequent in this geomorphorphic part. Recently these low lying chenier plain often altered into the agriculture and aquaculture field. Throughout the year mainly in monsoonal season a huge amount of sediment carried by the river Subarnarekha and thrown into the sea which when distributed at the near shore by the predominant wave tide dynamics and developed this barrier beach complex surrounded by the river Subarnarekha in the east, Dugdugi river in the west, young chenier complex to the north and beach barrier complex and wash over deposits to the south. Lower course of Subarnarekha, Hanskara and Burahbalam river is very much meandered and sedimented a huge amount of sediments in its flood plain. So the said coastal tract is situated at the flood plain of Subarnarekha, Hanskara and Dugdugi river which developed by the interaction among marine, fluvial and also the Aeolian processes.

Frequent tropical cyclone, storm surges, storm induced coastal flood and also the riverine and rain water logging flood have been found in this geomorphic part. The locational factor is very much responsible for intensity and severity of concern hazards. Recent climate change and environmental change has also accentuated the hazard vastness.

Being located at the sea front Choumukh GP is prone to coastal flooding. There are three river fell into this geomorphic part namely Subarnarekha, Hanskara and Dugdugi. At the time of monsoon a huge discharge along with sediment load carried by these river but strong south west monsoon wind and resultant cross shore current and high magnitude of wave tide inflow resists the natural flow of concern river so that accumulation of water taking place at the mouth of these river and flooding the Betagadia, Anladiha, Dagra and Choumukh GP. Then again at the land ward margin of this region, due to low lying condition (0.5m – 1m high above the sea level) along with substantial network of tidal inlets sea water can penetrate into the said region and cause flooding even in a low magnitude of storm surges or wave in a low magnitude. It is also a considerable factor that there is no sand dune to resist the coastal wave and storm surges at Betagadia, Anladiha, Dagra and Choumukh GP. This area was covered some mangrove species which protect the coastal hazards but now Mangrove coverage is also departed due to sedimentological properties of the shore deposits that constitute substrate for mangrove swamps.

Land use pattern of the area has undergone such changes that have increased probability of flooding.

Two types of flood are occurred in this area namely sweet water flood due to spilling of river another is saline flood which developed from the ocean due to high magnitude of storm surges or high magnitude of wave. Population density is very high at these coastal GPs because the accessibility of coastal resources is very easy.

Subarnarekha and Dugdugi river has a very much meandering course at the lower catchment. This roundabout channel produces a great obstacle to natural gradient flow of these two rivers which occurred the river spilling and the riverine flooding situation at the time of pick monsoon. Being located along the

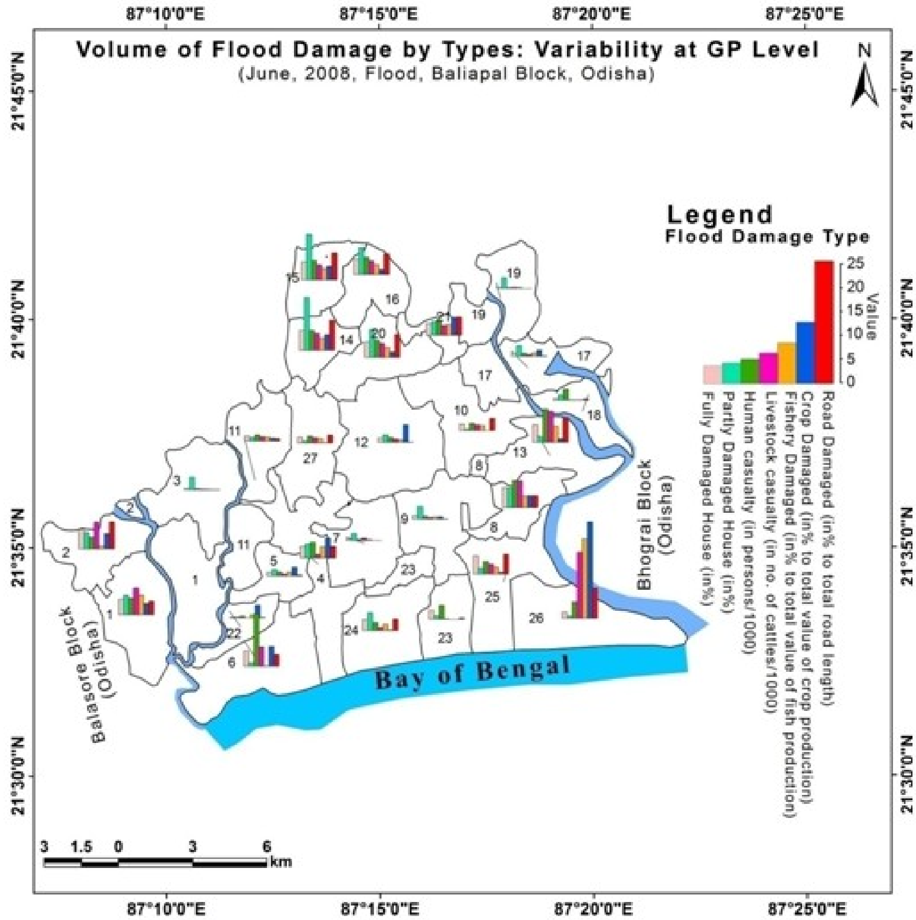

Figure 3. Landscape's response to flood hazards in terms of damage volume and type spatially varies according to terrain characteristics, geomorphological location, protective measures and flood type and magnitude.

sinuosity course of river Subarnarekha the Jamkunda, Bishnupurmahakumanayabali, and along the river Dugdugi the Bolonga and Panchupali GPs are under the high to moderate flood hazard risk. Similarly at the time of the high astronomical tide phase a considerable volume of ocean water enter into the funnel shaped river estuary which also restricts the natural river flow to the sea so the river unable to maintained the excess volume of water into its channel and spilling can be started which causing the flood condition. The width of these two river gradually decrease from their mouth and developed the funnelling effects which is a major flooding cause of Jamkunda, Bishnupurmahakumanayabali, Bolonga and Panchupali GPs as they situated at the narrowest points of these two river. The flood severity is accentuated by the sporadically discharge of excess water from Chandil Reservoir during the monsoon period.

Human alteration of indigenous land use land cover pattern is a major cause of flooding in this area. Last two decades all the flood plain, wet land and other coastal stretches have been transform into shrimp farming pond because aquaculture has emerged as a profitable economic activity currently. After converted into fish farming pond, all coastal stretches have been bounded by a high earthen embankment which restrict the flood water to spread over the flood plain and causing the flood situation to become more severe. To protect the riverine flood all the river of study area have been jacketing by the embankment construction without leaving the scope of sediment distribution over the flood plain for which the huge amount of sediments are not distributed into the flood plain and they sedimented in the river bed as well

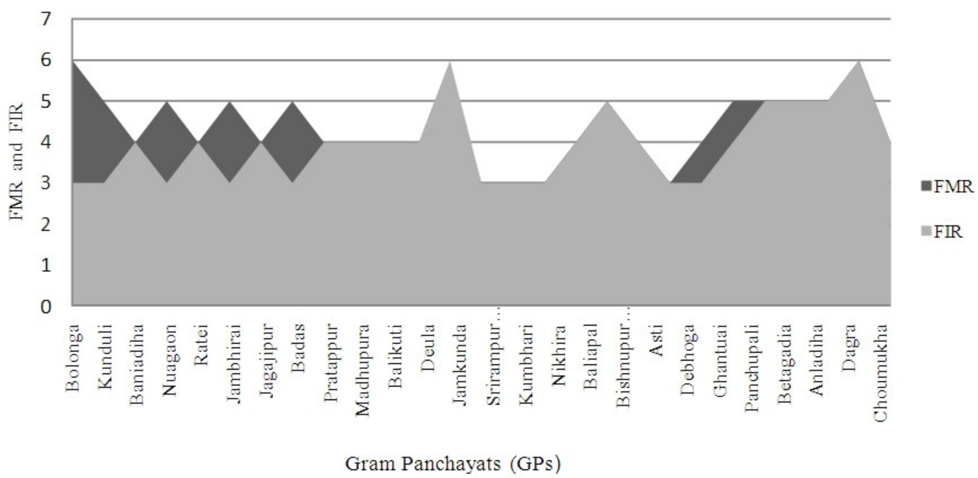

Figure 4. Area graph representing GP-wise comparison between FMR and FIR. Flood protective measures are capable of reducing flow impacts of even high magnitude floods.

as the river mouth. So the river mouth is gradually narrowing which increased the severity of flood.

In spite of the high magnitude of flood event, the damage impacts are much less at Bolonga, Kunduli, Nuagaon, Jambhirai, Badas, Ghantuai, Panchupali only due to protection measure undertaken for mitigation of flood impacts in those GPs. In this context the guard wall of Nuagaon, Jambhirai and the cyclone centre of Jambhirai, can be eminent here. By these initiatives flood impacts was remarkably reduced during and the after flood situation in those blocks. Several awareness camps have been organized among the coastal dwellers to aware them how to combat of flood situation. Except these at Bolonga, Panchupali, Kunduli and Badas riverine embankment are heightened under National Rural Employment Guarantee Act programme. Furthermore the specific hazards prediction with the help of modern technology and the preparedness has also been strengthened than ever before. All the above stated policies have contributed mostly in tumbling the impacts of high intensity flood in many of the GPs of Baliapal block.

8. CONCLUSION

The present study area is hazards prone due its river flood plain location of low lying coastal tract which is geomorphologically more vulnerable and prone to frequent flooding hazards that developed both land and ocean. Flood hazards risk has been quantifying at 27 Gram Panchayats of Baliapal block, Odisha, India through the considering the magnitude of flood represented by it physical characteristics and impact of flood measured from damage volume. The product of these two aspects of flood hazards along with its probability of occurrence yields a Flood Hazard Score for each of the Gram Panchayats by which the spatial variation of flood hazard risk throughout the study area has been assigned. The results clearly shows that the GPs being located along the meandering river channel and at the sea front without any natural protection are under the high flood hazard risk zone where as GPs of interior location are in zone of lower risk. Highly siltation along the river bed of Subarnarekha and Dugdugi river has also been declining the water holding capacity in time of high magnitude of rain storm phase which accentuated the river spilling as well as the riverine flood. In flow of tidal water along the river channel at the time of monsoonal discharge makes this situation critical. During the high astronomical tide ocean water reached the interior part of the block through the tidal inlets that floods many of the GPs of the study area. The earthen embankment which are surrounded the fish pond are also increased the intensity of flooding. It has also been found that the protective measure against the flood have effectively reduced the flood hazards impacts even in the high magnitude of flooding.

The present study immensely helps us to understand the causes, nature and types of coastal flooding along with the damage impacts variation at a reasonably lower scale (GP wise) of geography throughout the study area. Gram Panchayat wise flood nature variation can be easily understand through this work. The present study gives us a vivid picture of GP wise damage distinction which is not always linearly dependant on magnitude of physical severity. Last of all this study can be useful to make the spatial unit specific decision for flood management planning. The essence of present study can be carried out in any coastal region to assess the flooding characteristic and mapping the flood hazard risk zone along with other coastal hazards.

References

[1] *The M.S. Swaminathan Committee Report on Coastal Management Burnt*, p. 2. Kerala Independent Fish Workers Federation (KSMTF), 2006.

[2] IPCC-CZMS, "A common methodology for assessing vulnerability to sea level rise second revision," *Global Climate Change and the Rising Challenge of the Sea. Report of the Coastal Zone Management Sub-Group, IPCC Response Strategies Working Group, Ministry of Transport*, 1992.

[3] R. J. Klein and R. J. Nicholls, "Assessment of coastal vulnerability to climate change," *Ambio*, vol. 28, no. 2, pp. 182–187, 1999.

[4] R. Kay and P. Waterman, "Review of the applicability of the common methodology for assessment of the vulnerability to sea level rise to the australian coastal zone," in *Proceedings of the IPCC Eastern Hemisphere Workshop on vulnerability assessment to sea level rise and coastal zone management*, pp. 237–248, 1993.

[5] N. Harvey, E. Clouston, and P. Carvalho, "Improving coastal vulnerability assessment methodologies for integrated coastal zone management: an approach from south australia," *Australian Geographical Studies*, vol. 37, no. 1, pp. 50–69, 1999.

[6] V. Gornitz, S. Couch, and E. K. Hartig, "Impacts of sea level rise in the new york city metropolitan area," *Global and Planetary Change*, vol. 32, no. 1, pp. 61–88, 2001.

[7] J. Shaw, R. B. Taylor, D. L. Forbes, M. Ruz, and S. Solomon, *Sensitivity of the coasts of Canada to sea-level rise*, pp. 1–79. Geological Survey of Canada, 1998.

[8] P. A. Abuodha and C. D. Woodroffe, "Assessing vulnerability to sea-level rise using a coastal sensitivity index: a case study from southeast australia," *Journal of Coastal Conservation*, vol. 14, no. 3, pp. 189–205, 2010.

[9] T. S. Kumar, R. Mahendra, S. Nayak, K. Radhakrishnan, and K. Sahu, "Coastal vulnerability assessment for orissa state, east coast of india," *Journal of Coastal Research*, vol. 26, no. 3, pp. 523–534, 2010.

[10] S. L. Cutter, B. J. Boruff, and W. L. Shirley, "Social vulnerability to environmental hazards*," *Social science quarterly*, vol. 84, no. 2, pp. 242–261, 2003.

[11] B. J. Boruff, C. Emrich, and S. L. Cutter, "Erosion hazard vulnerability of us coastal counties," *Journal of Coastal Research*, pp. 932–942, 2005.

[12] S. L. Cutter, "Vulnerability to environmental hazards," *Progress in human geography*, vol. 20, no. 4, pp. 529–539, 1996.

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