Flash Flood Hazard Mapping using AHP model with Arc GIS

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Abstract. Flood is the most dangerous natural occurring disaster in the worldwide. By it, there is a loss of lives, property, soil erosion and cost effective infrastructure. In this paper, I take Balasore as my study area, which is highly flood prone area due to the coastal region and nearby channel of the river. In this study, I take the factors which are highly influenced factors of this city are slope, land use/land cover, drainage density, distance from the main channel and rainfall. These factors are taken by expert's opinion giving the weightage to the factors included by using the Analytical Hierarchical Process (AHP). DEM file will be used which is downloaded by USGS and using a software of Arc GIS 10.2.

1. Introduction

Surge is a flood of water that submerges arrive, harm to agrarian land, urban territories and can cause loss of lives. Rapid population growth, industrialization, vacationer exercises and monstrous weight on existing offices, the infrastructure such as roads, buildings, and transports are extending into hazard prone areas. The effect is that the magnitude of stroke of disaster increases due to dependency on land and vulnerable of society. These natural disasters take place frequently and their effect on earth greatly increased due to land degradation, erosion, build up land use and increased community. From today's complication of society, feedback and satisfaction from floods is a basic concern. Therefore, there is an urgency to move from hazard prone areas to the less prone area and before the disaster happen.
Flash floods and floods are the most disastrous natural hazard in the nature because it causes largest amount of mortality and loss of land.Heavy rain, land-use change in pan areas and various engineering applications commit to the consequence and repetition of flood events. Flood hazard maps are fruitful tools for outlining the future forecasting of city growth, and used to classify flood-affected areas.Risk of flash floods are vital in terms of human lives loss and cost-effective destruction. Due to the increasing interest in flood impacts over the last couple of decades, large-scale flood assessment studies have been carried out in different countries, such as USA [13], Egypt [7,8], Nigeria [12], South Korea [9], China [14], and Saudi Arabia [6,4].

For multi-criteria decision-making,Analytical Hierarchical Process (AHP) is a mathematical modeling technique [10,2].In the early 70s,Saaty a mathematician had developed it. The AHP as certain to define numerical weights signifying the relative value of factors,elements,norm for flood susceptible models [2,5]. AHP allows both quantitative and qualitative access to figure-out complex decision problems.In quantitative prospects, the AHP method can compute as set of attributes and differentiate in general, the more important factors from the less important factors. The pair-wise co-relation analysis were made with respect to the attribute so for level of ranking given to the attribute for the next higher level of ranking (from the main criteria to the sub-criteria). The most of the work and literature available on the utilization of AHP methods eco-engineering is committed to the generation of relative weights of significant factors and as simulation of the weights into a GIS environment.

2. Literature Review

- Yang et al. (2006) integrated the hydraulic model of the choice of geographic information system (GIS). Generate water surface profiles throughout the system for six different designs storm events. Build a triangular irregular network (TIN) terrain model.

- Youssef et al. (2010) described about the utilization of remote sensing data such as Enhanced Thematic Mapper Plus (ETM+), Shuttle Radar Topography Mission (SRTM), coupled with geological, geomorphological and field data for estimation of flash flood risk in Egypt.

- Gomaa et al. (2011) found that the curve number method for flood modelling is taken for ungauged arid catchments. This research develops a GIS based approach for mapping and quantifying flood assessment measures. It conclude that higher the CN value, the higher runoff and flood hazards.

- Siddayo et al. (2014) combined AHP with GIS tool for evaluating flood risks in Tuguegarao city, which is located in northern Philippines. Their techniques can be extended in other areas for consulting, planning agencies, land use zoning, damage estimates to mitigate risks.

- Matori et al. (2014) concluded that a GIS based AHP effectively connected in reproducing the surge zones. The social and prudent misfortunes comes about surge fiascos, mechanical emergency and worldwide scourges.

3. Study Area

Balasore or Baleshwar is a city in the state of Odisha, in eastern Indiaabout 194 kilometers (121 mi) north of the State capital of Bhubaneswar. Balasore district is themanagerial headquarters. It is likewise the site of the Indian Ballistic Missile Defense Program's Integrated Test Range, found 18 km. south of Balasore. It is the biggest city of North Odisha. It is bounded by longitude 86°92'46" E and latitude 21°48'69" N respectively. The city has Bay of Bengal in the east and West Bengal in the north. Balasore has a field of 3076 km2.It is the coastal district of Odisha with perennial and estuarine rivers because of its closeness to the sea. Two important rivers of Odisha, Subarnarekha and Budhabalanga, pass through the district from west to east before streaming into the Bay of Bengal. There is a broad irrigation in Balasore district. The highest recorded rainfall in the studied area is 484.4 mm. The maximum and minimum temperature in Balasore is 32° C and 10° C respectively. Every year relative humidity of Balasore differ between 53% to 61%.The district comes in Balasore are Jaleswar, Bhogral, Basta, Baliapal, Remuna, Nilgiri, Bahanaga, Soro, Oupada, Khaira, Simulia. Here the table shows the rainfall, land use pattern and major soils in Balasore. The following figure 1 picturizes my study area.

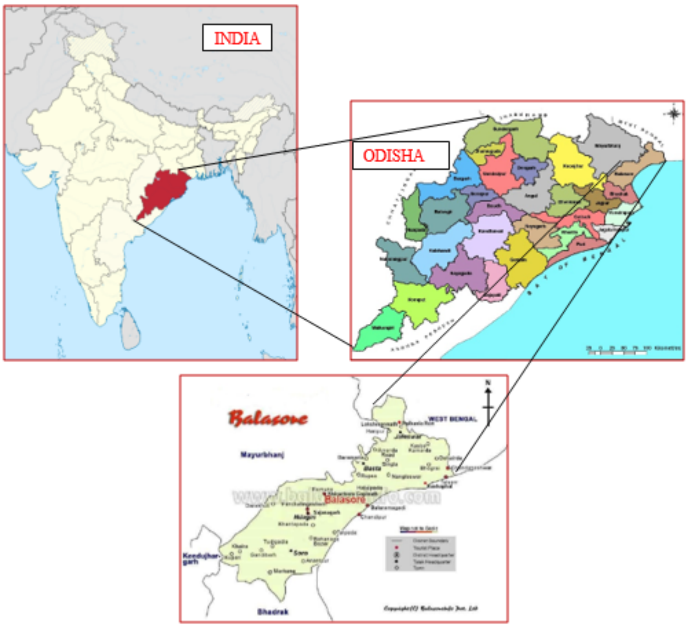

Figure 1. Pictorial presentation of the Study Area

4. Data Collection

The following data of the study area were collected precisely from online sources those are freely available. The Table 1 below summarizes the rainfall distribution of the study area for the whole year, which includes the normal rainfall in mm and normal rainy days in number for each class of rainfall.

Table I. Rainfall Classification

Rainfall	Normal RF(mm)	Normal Rainy days (numbers)
SW monsoon (June-Sep)	1481	50
NE Monsoon (Oct-Dec)	10	10
Winter (Jan- March)	89	5
Summer (Apr-May)	121	9
Annual	1701	74

Table II. Land Use Pattern

Land use pattern of the district (latest statistics)	Geo-graphical area	Cultivable area	Forest area	Land under non agricultural use	Permanent pastures	Cultivable wasteland	Land under Misc. tree crops and groves	Barren and un cultivable land
Area (ha)	381	234	33	33	16	9	25	10

Table III. Major soils

Major Soils (common names like red sandy loam deep soils (etc.,)	Area (ha)	Percent (%) of geo- graphical area of the zone.
Saline	75.4	19.8
Alluvial soils (Rain fed)	98.1	26.0
(Canal irrigated)	22.6	5.9
(Flood Prone)	90.5	23.9
Red Laterite Soil (Rain fed)	49.0	12.9
(Canal irrigated)	41.5	11.0

5. Methodology

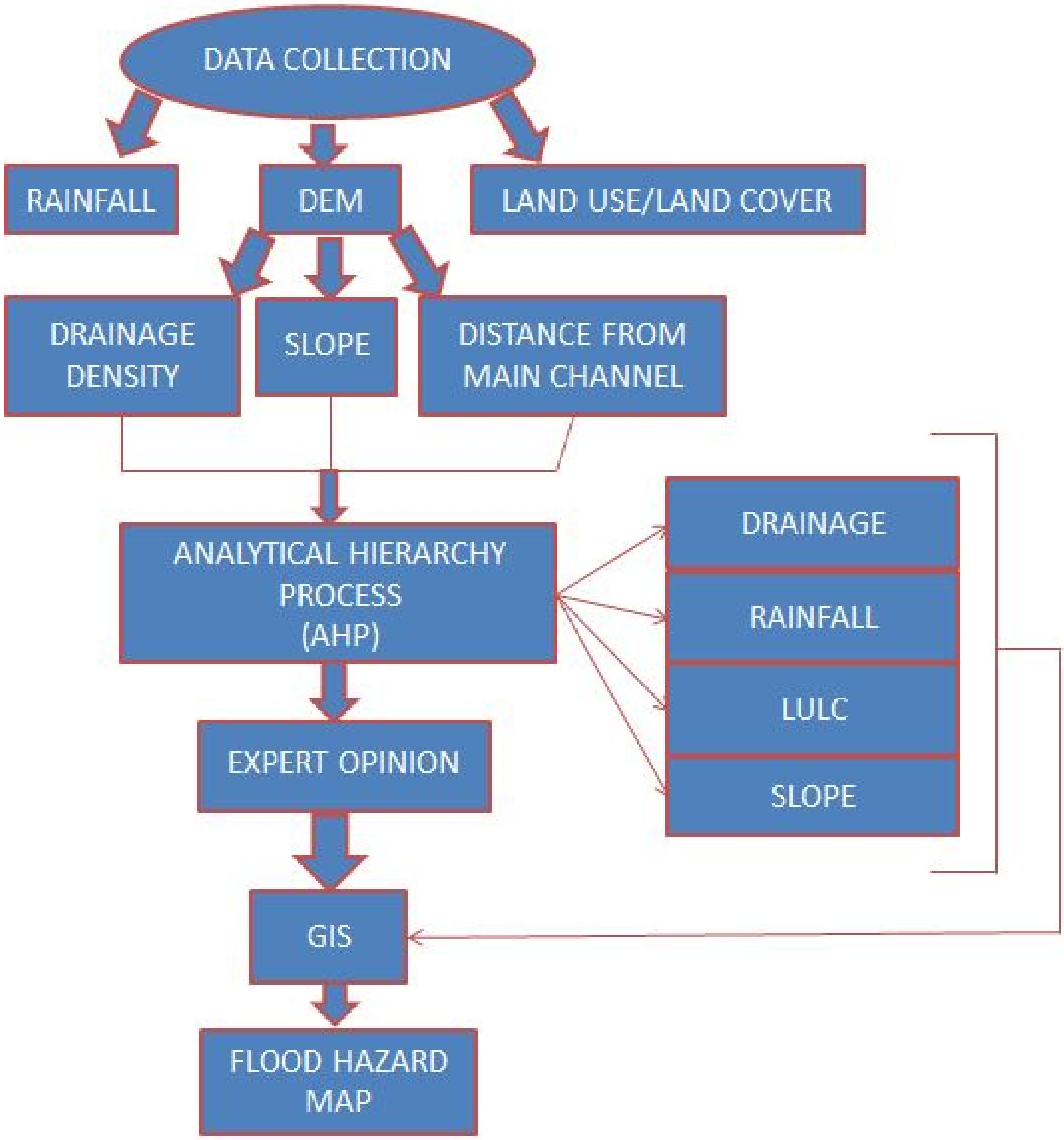

Figure 2. Flowchart of Methodology Adopted

SLOPE

Physiography of town shows it does not have any derived drainage pattern due to plain land and gentle slopes. The general slope of the area is towards the Budhabalanga River, which is merged into the Bay of Bengal. The slope has a control in the flood bearing of water in the profundity of overwhelmed zone. The slant territory created from USGS DEM picture of the region utilizing Arc GIS 10.2 programming. The map is classified into five classes as follows: 0-2%, 2-5%, 5-10% and 10-20% and >20%.

DRAINAGE DENSITY

Before bore wells, ponds and lakes are the only source of water. Currently, the area does not have 100% piping water connectivity. The water is available at 25-30 foot below ground level. Piped water supply is costlier to ground water supply. Sewerage network facility is absent in the planning area including the Municipal area. All throughout household level septic tanks are provided and maintained by residents. In rural parts, residents also prominently use wet pit system. Due to absence of sewerage system mixing of storm water and wastewater, takes place resulting unhygienic conditions. Budhabalanga River untreated or through the natural drains meeting the river, which is polluting the river. Open defecation in slum areas are normal phenomenon in the city and takes place in the rural areas.

DISTANCE FROM MAIN CHANNEL

The separation from streams assumes an imperative part to decide the overwhelmed zone. The most influenced zones amid surges are those zones, which are near to the river, because of overflow. The map produces a buffer zone of nearby flooded areas and 100m buffer is made with the stream flow.

LAND USE/LAND COVER

The Balasore locale is separated into three geological districts i.e. beach front belt, inward alluvial plain and North Eastern slopes. Land utilize/arrive cover is a vital factor to distinguish those zones, which are profoundly defenseless to flooding. Vegetated zones have low potential flooding because of negative connection amongst vegetation and surge thickness. Local locations and streets, which are made on impenetrable surfaces and exposed grounds, increment the tempest spillover. In LULC map, four classifications have been identified: water bodies, open land, vegetation and built-up areas (fig. 4).Here the table indicates the category of land use data.

Table IV. Land division

Land use category	Area(in Ha)	% of Developed area	% of Planning area
Residential	3974.38	68.88	16.24
Commercial	122.97	2.13	0.50
Industrial	331.72	5.75	1.36
Transport and Communication	450.35	7.80	1.84
Agricultural	14094.39		57.58
Forest	144.38		0.59
Water Bodies	2260.41		9.24
Waste land	704.80		2.88
Wet land	303.69		1.24
Vacant land	1188.37		4.86

RAINFALL

Climatic condition of Balasore is mainly hot and humid in nature. In summer, during April to July the temperature goes to round 37°C. In winter season, during December and January temperature will be goes around 13°C. The region gets most its precipitation from the South-West monsoons during the months of July to October. Average rainfall of the area is high due to the proximity to the sea. The below table is represented the rainfall data of 2012-16 on monthly basis.

Table V. Monthly Rainfall data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F	R/F
2012	70.7	26.1	0.0	105.2	20.8	140.1	171.0	266.1	228.0	39.4	39.3	22.9
2013	0.3	6.6	2.9	87.6	176.9	233.3	238.9	340.8	356.6	746.0	0.0	0.0
2014	0.0	58.7	23.4	22.5	200.4	156.8	445.3	484.4	285.7	125.7	0.0	0.1
2015	32.8	11.3	28.2	91.7	22.9	255.6	457.9	176.3	137.9	26.4	0.2	19.4
2016	6.9	49.5	6.7	23.2	182.7	168.7	270.0	307.1	303.2	190.7	56.9	0.0

6. Result

SLOPE MAP

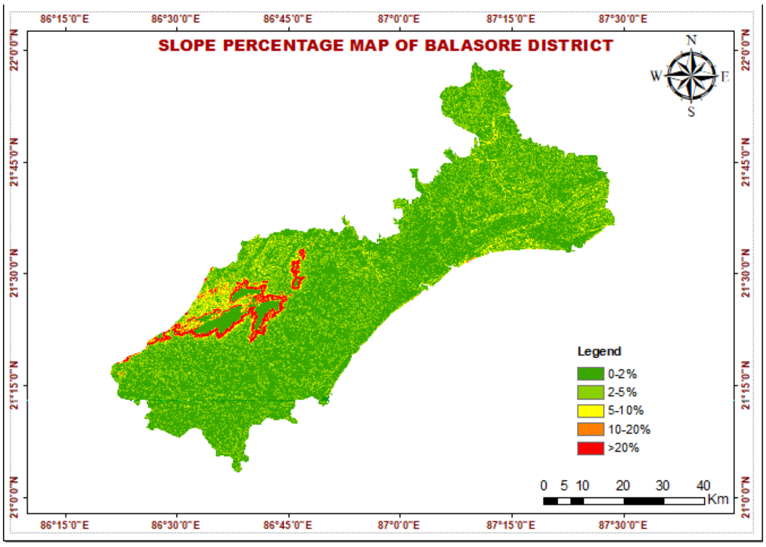

Figure 3. Slope map of Balasore district

DRAINAGE DENSITY

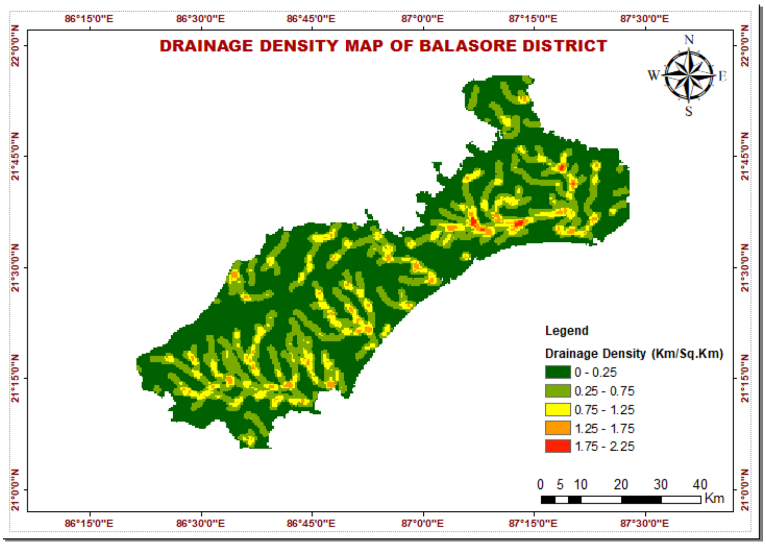

Figure 4. Drainage density map of Balasore district

DISTANCE FROM MAIN CHANNEL

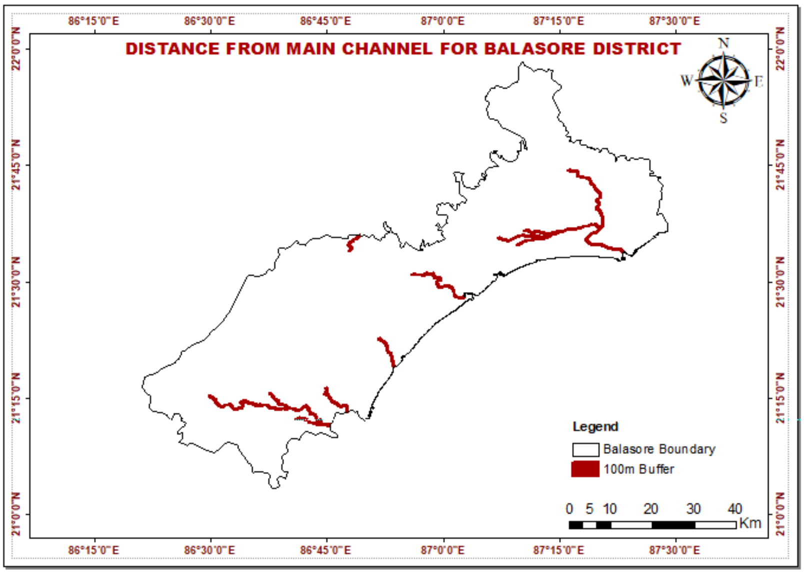

Figure 5. Distance from main channel map of Balasore district

LAND USE/LAND COVER

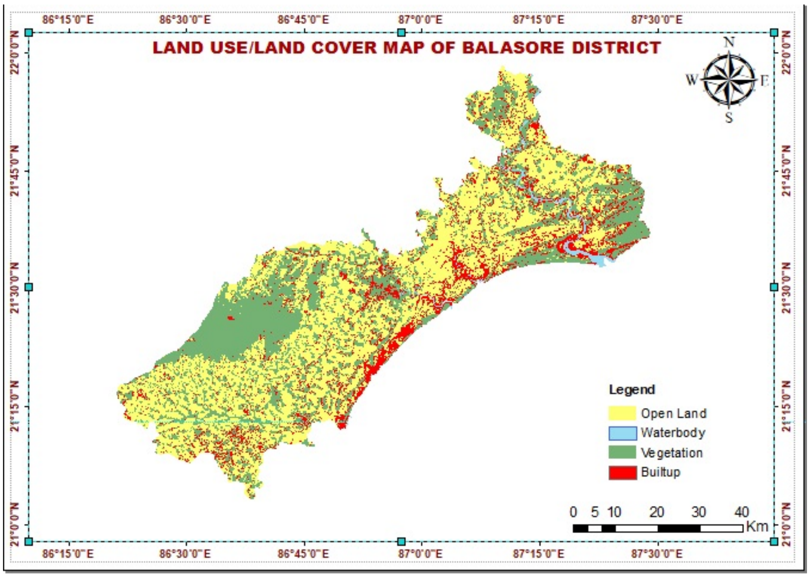

Figure 6. Land use/land cover map of Balasore district

7. Conclusion

In this study, flash flood hazard maps was produced using a knowledge-driven expert-based GIS model.Four parameters, including distance from main channel, land use/land cover, slope and drainage density was exhibited to specialists to matched a correlation and doling out a weight as the principle criteria/factor for streak surge danger mapping in the structure of GIS. AHP is joined with GIS to think of a device for assessing surge chance regions in Balasore area. The created apparatus is exceptionally profitable for counseling, arranging offices, arrive utilize zoning, great administration, and help crisis administrations and remediation endeavors to alleviate dangers. This method can be reached out in different zones, where different components might be thought about relying upon the accessibility of information.

References

[1] Cheng, E.W.L., and Li, H.(2001),"Analytic Hierarchy Process: An Approach to Determine Measures for Business Performance", Measuring Business Excellence, 5(3),30-37.

[2] Chen, D.C., Chen, P.C., Lee, Y.C., You, S.U. andJao, H.C.(2011),"Using an Analytic Hierarchy Process to Develop Competencies on Mould Product Creativity for Vocational College Students", World Transactions on Engineering and Technology Education (WIETE) .9(1), 54-59.

[3] Emmanou loudis D ,Myron idis D,and IoannouK.(2008),"Assessment of Flood Risk in Thasos Island with the Combined Use of Multi-criteria Analysis ÎŚHP and Geographical Information System", Innovative Applications of Informatics in Agriculture and Environment.2,103-115 ESRI.

[4] E. Fred and B. Mostafa, "Flood Risk Modeling for Holy Sites in Makkah," Proceedings of the Symposium on National GIS application in Saudi Arabia, Al-Kober City, 2008, pp. 1-12.

[5] Meyer V, Scheuer S,and Haase D.(2009),"A Multi-criteria Approach for Flood Risk Mapping Exemplified at the Mulde River, Germany", Natural Hazards .48, 17-39.

[6] M. Al Saud, "Assessment of Flood Hazard of Jeddah Area 2009, Saudi Arabia," Journal of Water Resource and Protection, Vol. 2, No. 9, 2010, pp. 839-847. doi:10.4236/jwarp.2010.29099

[7] M. Azab, "Assessment and Management of Natural Hazards and Disasters along Qena-Safaga Road, Central Eastern Desert, Egypt," Egyptian Journal of Remote Sensing and Space Science, Vol. 12, 2009, pp. 55-70.

[8] M. El-Bastawesy, K. White and A. Nasr, "Integration of Remote Sensing and GIS for Modelling Flash Floods in WadiHudain Catchment, Egypt," Hydrological Process, Vol. 23, No. 9, 2009, pp. 1359-1368. doi:10.1002/hyp.7259

[9] N. Kim, J.W. Lee, J., Lee and J. E. Lee, "SWAT Application to Estimate Design Runoff Curve Number for South Korean Conditions," Hydrological Process, Vol. 24, No. 15, 2010, pp. 2156-2170.

[10] Saaty, T. L.,(1980)," The Analytic Hierarchy Process: Planning, Priority Setting, Resource Allocation",McGraw-Hill, New York.

[11] Sinha R, Bapalu G, Singh L, and Rath B.(2008),"Flood risk Analysis in the Kosi River Basin, North Bihar Using Multi-Parametric Approach of Analytical Hierarchy Process(AHP)", Journal of Indian Society of Remote Sensing.36, 335-349.

[12] S. Yahaya, N. Ahmad and R. Abdalla, "Multi criteria Analysis for Flood Vulnerable Areas In Hadejia- Jama' are River Basin, Nigeria," European Journal of Scientific Research, Vol. 42, No. 1, 2010, pp. 71-83.

[13] USGS (U.S. Geological Survey), "Watershed Models for Decision Support for In flows to Potholes Reservoir," Washington Scientific Investigations Report 2009-5081, 2009.

[14] W. Liang, C. Yongli, C. Hongquan, D. Daler, Z. Jingmin, and Y. Juan, "Flood Disaster in Taihu Basin, China: Causal Chain and Policy Option Analyses," Environmental Earth Science, Vol. 63, No. 5, 2010, pp. 1119-1124. doi:10.1007/s12665-010-0786-x