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Watershed analysis and Landuse Management to Protect from Flash Flood in the Semi-Arid Region Udaipur, Northwestern India using Geospatial Techniques

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ABSTRACT

Flood is one of the most dangerous natural disaster destruct socioeconomic structure around Udaipur during monsoon. To assess hydrological character and flood potential an exhaustive morphometric and landuse/landcover analysis of Ahar watershed has been done. Delineation of highly structural controlled drainage network and computation of linear, areal and relief aspects has been done under GIS environment. Elevation, slope and aspect map has prepared by using SRTM DEM (1 arc) to understand about terrain characteristics. The analysis reveals that the high slope area covering with impermeable heavy clay and less permeable clay loam is responsible for more runoff leads to develop peak flow within short period of time. To reduce flood susceptibility a proper landuse management by increasing depth of reservoir particularly Badi and Madar lake situated upstream side in high drainage density area. Some anthropogenic activity blockage drainage system should be stopped to control the flood hazard in the area.

Keywords: Flood behavior, drainage morphometry, Land use, Mitigation, GIS.

I. INTRODUCTION

The extreme form of hydrological phenomena such as the flood is naturally generated by heavy rainfall and excess runoff removed from channel as it overflows (Ghosh, 2013). Flash floods occur as a result of high-intensity rainy storms over catchment areas which have steep slopes and poor vegetation cover, producing sudden and high velocity flows (Xiao, 1999). Flooding is one of the most costly disasters in terms of both property damage and human casualties and it has a serious impact on economy, agriculture, and others (Alexander, 1993). From last two decade, the intensity of flash flood around Udaipur city has increased. In the year 2006, 2009, 2011 and 2014 are the witness of flash flood in Udaipur city. In 2016 six members of a family has died in flash flood at Jhalara village situated southeast 70 km from Udaipur city.

The morphometry of the river basins relates to the hydrological and geomorphic response of processes like runoff, soil erosion, floods and droughts, river sedimentation, changing river flows and branching habit of the streams, flow characteristics of the drainage lines, and on the performance and sustainability of the associated dams and reservoirs if available within the basin (Garde, 2005; Mohd *et al.*, 2013). The study of drainage basin morphometry involves analyzing areal, linear and relief parameters which help us to understand the natural environment of the basin, and they also summarize spatial characteristics of the basin (Samson *et al.*, 2016). Geology (lithology and tectonics), morphology (topography and slopes), and climate are considered the major attributes which determine the characteristics and evolution of drainage basins and drainage networks (Farhan *et al.*, 2016) and with above territorial data, historical document also showed that geomorphological hazard has been accentuated by the intense human activity (Youssef *et al.*, 2009).

Geospatial analytical techniques (GIS and remote sensing) are powerful tools for computation, quantitative description and assessment of morphometric parameters, thematic mapping of morphometric variables, and the application of morphometric analysis in different fields of research such as: hydrology and appraisal of environmental hazard (Angillieri *et al.*, 2008; Arnous *et al.*, 2011; Patel *et al.*, 2012; Rahman *et al.*, 2015). Morphometric analysis also helps to infer the hydrological characteristics of drainage basins; therefore, it facilitates hydrological prospecting, assessment of the potential of groundwater recharge, and mapping of flood prone areas (Farhan *et al.*, 2016). Demarcation of flood prone areas in Sukhang- firozpur catchment of Kashmir basin was carried out by by drainage analysis (Ali et al., 2017). Characteristics of watershed geometry in and around Udaipur city was carried out earlier in respect of prioritization and neo-tectonic implication (Ali et al., 2017; Ikbal et al., 2017; Ikbal and Ali, 2017, Ali and Ikbal, 2018). Sub-dendritic-sub-parallel and in some places trellis pattern of drainage network with highest 6th order stream of Ahar watershed falls under moderate flood vulnerable zone (Ikbal et al., 2017). The present work describes the watershed behavior with respect to flash flood by the analysis of linear, areal and relief morphomeric parameter using SRTM DEM under GIS environment.

II. STUDY AREA

The main Ahar river crosses the Udaipur city trending in NW-SE direction, therefore the Ahar watershed is considered for flash flood analysis. It covers an area of 438 km^2 and is located between 24°29.23'N to 24°47.21'N and 73°32.10'E to 73°44.57'E (Figure 1). Topographically Ahar watershed can be divided into western rugged hilly area with elevation >1000 meters and eastern plain area. The main Udaipur city is located in this plain area surrounded by hill.

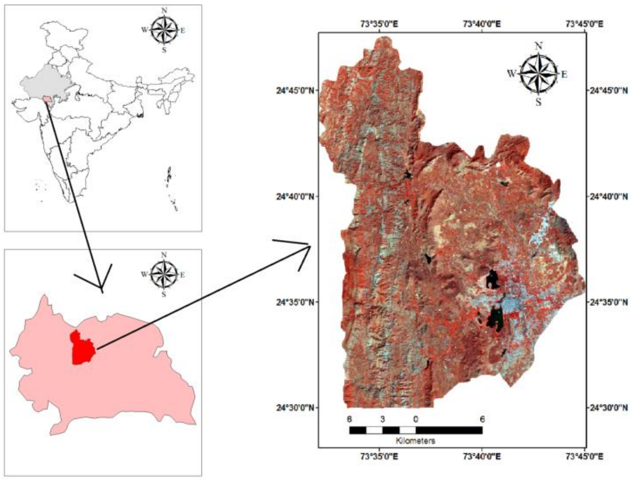

Figure 1. Location map of Ahar Watershed in Rajasthan

Table 1. Soil distribution in Udaipur district (Source: Central Ground Water Board, Ministry of Water resources)

Soil type	Tehsil
Clay loam	Mavli, **Girwa** and Vallabhnagar
Red clay	Salumbar, Kotra, Sarada, Kherwara and Rishabdev
Heavy clay	Gogunda, Jharol and **Girwa**

The area falls in Tehsil Girwa (Udaipur) which is covered by less permeable clay loam and heavy clay (Table 1). The area is covered by meta sedimentary rocks of Aravalli Supergroup and the Archean basement of Ahar river granite (Roy and Jakhar, 2002). North-south trending Rakhabdev lineament here divide Aravalli supergroup into two lithofacies such as the eastern side shale-sand-carbonate assemblage representing near shore self-facies and the western side a thick sequence of carbonate free shale inter bedded with thin beds of arenites representing deep-sea facies (Roy and Paliwal, 1981). Rocks of Aravalli Supergroup in this area represented by Debari

Udaipur, Bari lake and Jharol group (Figure 2) and lithologically early Proterozoic rocks such as conglomerate, phyllite, schist, quartzite, metavolcanic are found here (GSI memoir, 1997).

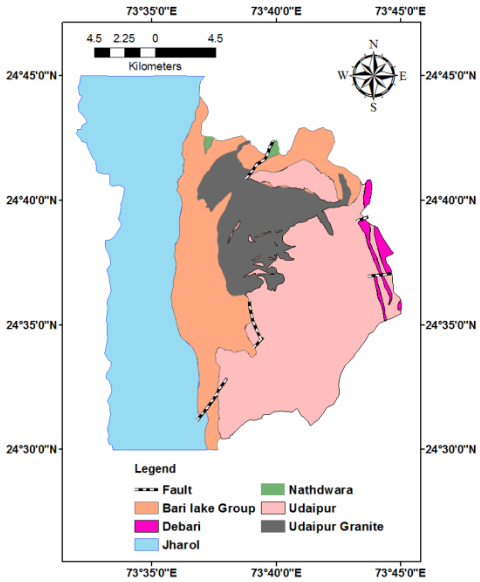

Figure 2. Geological map of the study area (Source: Geological Survey of india)

III. METHODOLOGY

Topographic map of 1:50,000 scale and SRTM DEM of 1-arc second or 30-meter resolution have been used to delineate drainage network and watershed boundary (Figure 3a). Linear, areal and relief parameter were computed using ArcGIS 10.2 software. Basic parameters such as area (A), basin length (Lb), perimeter (P), stream order (u), stream number (Nu), and stream length (Lu) were measured directly from the DEM using GIS software. Parameters including bifurcation ratio (Rb), drainage density (Dd), drainage frequency (Fs), length of overland flow (Lo), circularity ratio (Rc), elongation ratio (Re), basin relief (Bh), relief ratio (Rr), form factor (Rf), and shape factor (Bs) were calculated based on mathematical equations. Different terrain maps like elevation map (Figure 3b), slope map (Figure 3c), aspect map (Figure 3d) and drainage density map (Figure 3e) were generated using spatial analyst tools by SRTM DEM. Udaipur city growth map (Figure 7) was prepared from GSI toposheet (1:50,000) of the year 1970, google earth image of the year 2007 and 2017. Two different approaches, one is the relationship between bifurcation ratio (Rb) and drainage density (Dd) and other between bifurcation ratio (Rb) and stream frequency (Fs) have been considered for flash flood analysis of Ahar watershed (El-Shamy, 1992). Rainfall data has also been compared with flood history in Udaipur.

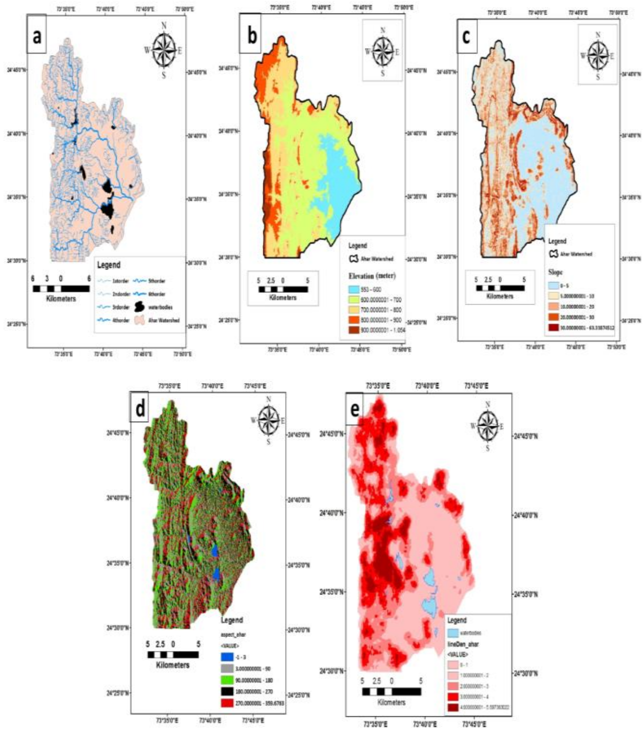

Figure 3 (a) Drainage, (b) Elevation, (c) Slope, (d) Aspect, (e) Drainage density, (f) Land use map

IV. RESULT AND DISCUSSION

Drainage network of Ahar watershed exhibits sub-dendritic, sub-trellis and sub-parallel nature with highest 6th order stream. In hilly region, lower order stream shows perfect trellis pattern whereas in plainer side channel network shows dendritic pattern.

Linear aspect

Computation of stream order and stream number is an initial step for watershed analysis (Horton, 1945). Watershed with higher stream order is responsible for greater discharge with higher velocity of water flow, accumulate more water to the mouth making higher order stream susceptible to flood during monsoon (Shankar and Dharaniranjan, 2014). In Ahar watershed, the area has a total of 1425 stream in which 1098 of 1st, 251 of 2nd, 56 of 3rd, 16 of 4th, 3 of 5th and 1 of 6th order stream (Table. 2), and the higher stream number is also associated with greater discharge. Stream length is an important parameter for determining surface run-off. The total length of streams decreases with increasing stream order satisfying the law of stream length (Table. 2) (Strahler, 1950). The stream length ratio can be defined as the ratio of the total stream length of a given order to the total stream length of next lower order and having an important relationship with surface flow and discharge (Ali & Ikbal, 2015). Table 3 shows the change of stream length ratio from one order to another indicating their late youth stage of geomorphic development (Singh & Singh, 1997) and the variation may be due to changes in slope and topography (Sreedevi et al., 2005). The mean bifurcation ratio of the area is 4.14 indicates the watershed has strong structural controlled drainage pattern and the irregularities of the value of the bifurcation ratio between different order are due to geological and lithological development of the drainage basin (Muthamilselvan and Dhivya, 2017). Bifurcation ratio is the important parameter to link the hydrological regime of a watershed under topological and climatic conditions (Raj et. al., 1999).

Table 2. Linear aspect of Ahar watershed

Stream Order	I	II	III	IV	V	VI	**Total**
Number of Streams (Nu)	1098	251	56	16	3	1	1425
Stream Length in Km (Lu)	579.85	195.89	97.12	82.41	24.03	20.67	999.97
Mean stream length in Km (Lsm)	0.53	0.78	1.73	5.15	8.01	20.67	0.70

Table 3 Linear aspect of Ahar watershed

Stream length ratio	**2nd/1st**	**3rd/2nd**	**4th/3rd**	**5th/4th**	**6th/5th**	**Mean stream length ratio**
	0.34	0.49	0.85	0.29	0.86	0.57
Bifurcation ratio	**1st /2nd**	**2nd /3rd**	**3rd /4th**	**4th /5th**	**5th /6th**	**Mean Bifurcation ratio**
	4.37	4.48	3.5	5.33	3	4.14

Areal aspect

Drainage density describes the spacing of channels and it is a key detrimental factor for water to travel from source to sink (Horton, 1945). Low value of drainage density revealed permeable subsoil material under vegetative cover and low relief, where as high Dd is favored in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief (Nag, 1998). Drainage density is very high (2.28) which induce a rapid storm response giving rise to a higher runoff resulting in downstream (Lingadevaru et al., 2015). A higher value of stream frequency (3.25) reflects greater surface runoff, resistance sub surface material, sparse vegetation and a steeper ground surface (Reddy et al., 2002; Reddy et al., 2004) making the watershed vulnerable to floods. Drainage texture (T) describes relative spacing of drainage lines and it depends on natural factors such as climate, rainfall, vegetation, lithology, soil type, infiltration capacity, relief and stage of development (Smith, 1954). Fivefold classification of drainage texture are very coarse (<2), coarse (2 to 4), moderate (4 to 6), fine (6 to 8) and very fine (>8) (Smith, 1954). The study area falls under very high drainage texture (12.93). Form factor, elongation ratio and circulatory ratio signify the shape of the watersheds. In a circular watershed, more water accumulates downstream in very short period of time whereas more elongated watershed is less vulnerable to flood. Flood flows of elongated basin are easier to manage than those of circular basin (Nautiyal, 1994). For a perfectly circular basin, the form factor would always be near about 0.7854. Values of elongation ratio from 0.6-0.8 usually occur in areas of high relief and steep ground slope. Circularity ratio is useful for assessment of flood hazards which is mainly concerned with the length and frequency of streams, geological structure, land use/land cover, climate, relief and slope of the watershed (Rudraiah et al., 2008). The value of form factor, elongation ratio and circularity ratio is 0.41, 0.73 and 0.45 respectively indicates the watershed is moderate to less elongate in nature. Analysis of shape factor reveals that though the area is vulnerable to flood but it can be easier to manage. Bifurcation ratio vs. drainage density and bifurcation ratio vs. stream frequency graph shows that the area falls under intermediate flood zone (Figure 4) (El Shamy, 1992).

Table 4. Areal aspect of Ahar watershed

Area (A) in Km2	Perimeter (P) in Km	Length of Basin (L) in Km	Drainage Density (Dd)	Drainage Texture (T)	Stream Frequency (Fs)	Form Factor (Ff)	Shape factor (Sb)	Elongation Ratio (Re)	Circularity Ratio (Rc)	Length of overland flow (Lg)	Constant of channel maintenance (C)	Compactness coefficient (Cc)
437.92	110.24	31.85	2.28	12.93	3.25	0.41	2.41	0.73	0.45	0.22	0.44	1.49

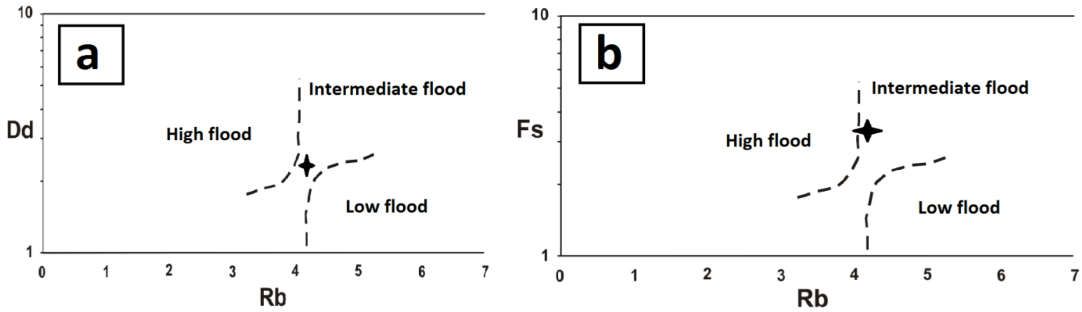

Figure 4 .Flood susceptibility graph, (a) Rb vs. Dd and (b) Rb vs. Fs

Relief aspect

Relief aspect refers to three-dimensional feature involving area, volume and altitude. The highest and lowest elevation of the watershed is 1054 m and 553 m respectively. Relative relief (R) of the watershed is 501. This high value indicates more gravity of water flow, low infiltration and high runoff conditions. Slope average is the ratio of the length of the watershed to the relative relief. Slope average is 63.57 and this is relatively high due to the magnitude of relief of the watershed. As the velocity of water increases with increasing slope, thus steep slope could lead to severe flash flood. The relief ratio (Rr) is the ratio between the basin relief and the length of the basin and is low as 0.016. It is an indicator of the intensity of erosion processes and sediment delivery rate of the basin. Relief ratio is inversely proportional to slope average. Ruggedness number is the product of maximum basin relief and drainage density. It can describe the slope steepness and length of the basin. Ruggedness number is 1.14 indicates that the area is rugged with high relief and high stream density, making the area vulnerable to flood.

Table 5. Relief aspect of Ahar watershed

Maximum elevation (meter)	Minimum elevation (meter)	Relative relief (R) in meter	Relief ratio (Rr)	Slope ratio (S)	Ruggedness number (Rn)
1054	553	501	0.016	63.57	1.14

Flood history

Though Ahar and its tributaries are seasonal but during monsoon with intense rainfall, these rivers become vulnerable to flood. From the last two decades flood in this area happens in regular manner (Table 6). The degree of effectiveness of flood can be categorized as moderate or severe flood based on the amount of excess of rainfall. A moderate flood occurs when the amount of rainfall is up to 50 percent excess than average rainfall and a severe flood occurs if the rainfall is more than 50 percent of average rainfall in a particular region. The study area falls in the central part of Udaipur district under Girwa Tehsil which has also moderate and severe flood history.

Table 6. Flood history of Udaipur district

Year	Average annual rainfall	Departure from average rainfall	Percentage of departure	Category of flood
1980	585.02	143.53	32.51	Moderate flood
1981	633.12	191.64	43.41	Moderate flood
1982	797.91	356.43	80.73	Severe flood
1984	655.59	214.10	48.50	Moderate flood
2004	591.66	150.18	34.02	Moderate flood
2005	631.92	190.43	43.14	Moderate flood
2006	119.79	678.31	153.64	Severe folood
2007	598.76	157.28	35.62	Moderate flood
2008	571.55	130.06	29.46	Moderate flood
2009	579.73	138.25	31.31	Moderate flood

(Source:shodhganga.inflibnet.ac.in/bitstream/10603/24677/11/11_chapter%205.pdf)

Rainfall

The whole Udaipur district annually receives around 587 mm of rainfall in which monsoon season contributes 555 mm (94.5%) (Figure 5). July (normal rainfall 199 mm) and August (normal rainfall 198 mm) are the rainiest months (Figure 5a). In monsoon, only July and August months receive about 71% rainfall of the season.

In the study area, highest rainfall month observed is August 2006 (578 mm) followed by July 2010 (430 mm) (Table. 7). The 104 mm, 130 mm, 115 mm and 124 mm rainfall received in one day of 2005, 2006, 2010 and

2015 respectively (Table. 7) can be termed as cloud burst. This high amount of rainfall during the month or cloudburst is more enough reason for flooding.

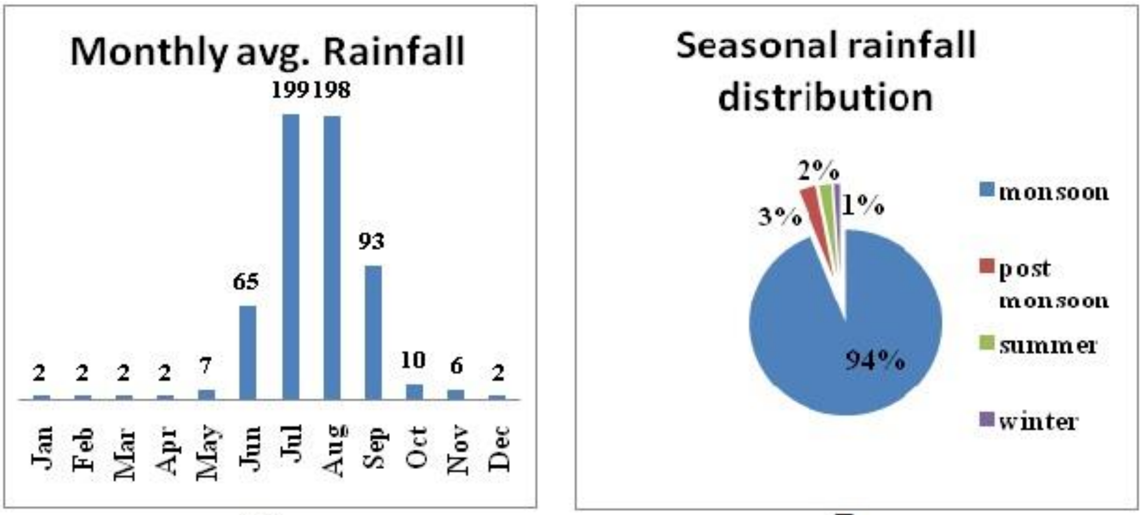

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Figure 5. (a) Monthly average rainfall and (b) Seasonal rainfall distribution in percentage of Udaipur district (Source: Meteorological department, ministry of Earth Science (2013)

Table 7. Rainfall data of Udaipur (Girwa) tehsil of Udaipur district (Source: water resource department, Govt. of Rajasthan)

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	One day Highest Rainfall	date	Annual rainfall
2000	0	0	0	0	56	83	186	86	54	0	0	0	76	9/06	465
2001	0	0	0	0	0	131	239	129	10	37	0	0	76	11/07	546
2002	0	0	0	13	0	98	0	179	62	0	0	0	51	29/06	352
2003	0	16	0	0	0	65	299	128	102	8	0	0	79	24/07	618
2004	0	0	0	0	0	24	162	204	128	49	0	0	64	30/09	567
2005	0	0	0	43	10	43	132	138	307	0	0	0	104	28/07	773
2006	0	0	8	0	0	106	201	578	33	0	0	0	130	1/08	926
2007	0	2	0	0	2	25	200	221	49	0	0	0	47	8/08	499
2008	0	0	0	0	28	94	162	171	222	80	0	0	84	16/09	757
2009	0	0	5	0	0	97	241	109	37	3	4	0	63	23/07	496
2010	2	0	0	0	0	43	430	244	92	0	88	3	72	5/07	902
2012	0	0	0	4	23	47	180	226	259	0	0	0	115	11/07	739
2013	0	4	3	13	0	76	299	222	167	78	0	0	70	10/08	862
2014	22	7	0	24	38	0	229	150	282	1	15	0	84	9/09	768
2015	7	0	28	13	0	73	295	106	37	0	0	0	124	29/07	559

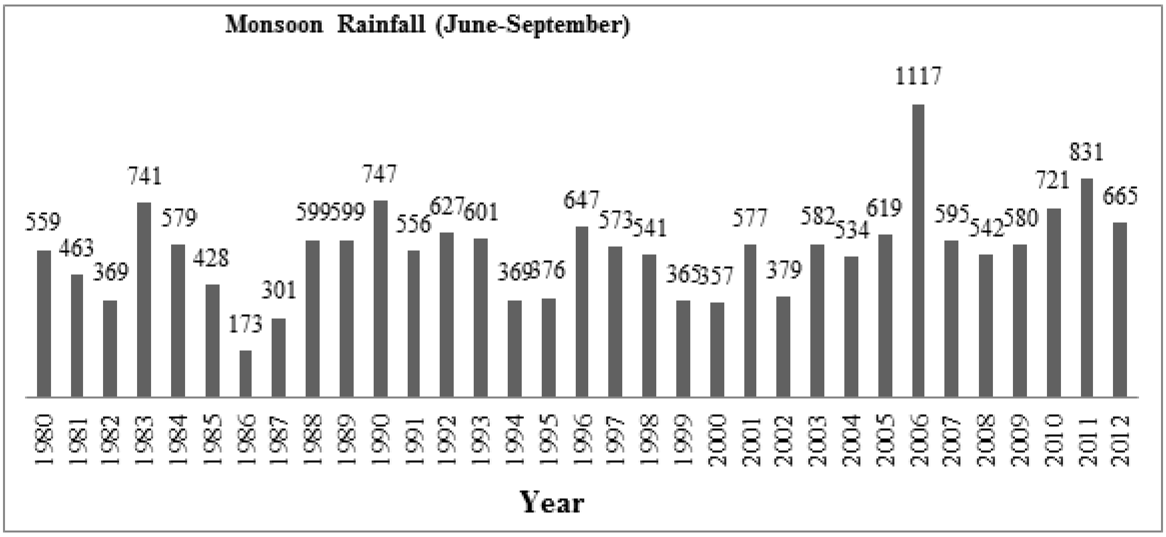

Figure 6 Amount of monsoon rainfall received in different year in Udaipur district (Source: Meteorological department, ministry of Earth Science (2013)

Urbanization

Urbanization is responsible for the loss of existing drainage capacity and flooding in urban areas (Zope et al., 2016). It increases the total runoff volume and peak discharge of storm runoff events (Dewan and Yamaguchi, 2009; Ali et al., 2011; Sanyal et al., 2014). Of all the land use changes affecting the hydrology of a drainage basin, urbanization is by far the most forceful (Wong and Chen, 1993).

The area of Udaipur city is growing rapidly from last decade (Figure 7). From the year 1970 to 2007, Udaipur city increased its area from 4.93% to 13.75%, whereas from 2007 to 2017 the city increased its area to 19.06% with respect to the study area (Table. 8). Due to urbanization, more permeable land surface with grass and vegetation is replaced by more impermeable land such as concrete, natural canals are replaced by concrete sewers. The replacement of natural water courses with more efficient man-made drains reduces the lag-time of the runoff response (Miller et al., 2014). Urbanization increases population (Figure 8) which is responsible for increasing solid waste. Udaipur Municipal Corporation reported that only Udaipur city generates 160 metric tons solid waste daily at present, out of which only 120 metric tons were collected and disposed of by Municipal Corporation. This amount of solid waste is enough to block sewer system in the city and increasing flood vulnerability. According to Udaipur Municipal Corporation due to deforestation heavy siltation has reduced the depth of the lakes to a quarter of which it used to be 40 years ago.

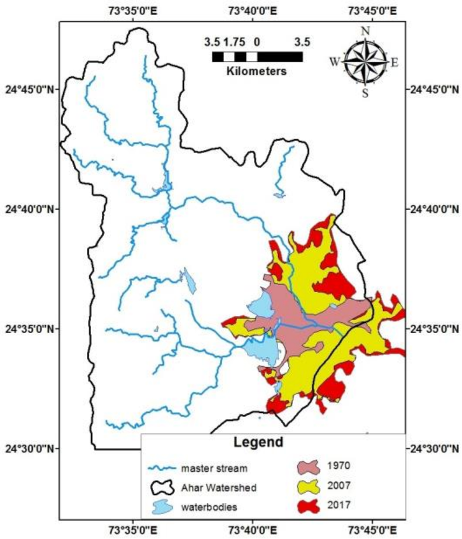

Figure 7 Urbanization growth map of the study area

Table 8 growth of Udaipur city

Year	Urban area (in Km^2)	Urban area in % with respect to the study area
1970	21.54	4.93
2007	60.09	13.75
2017	83.21	19.06

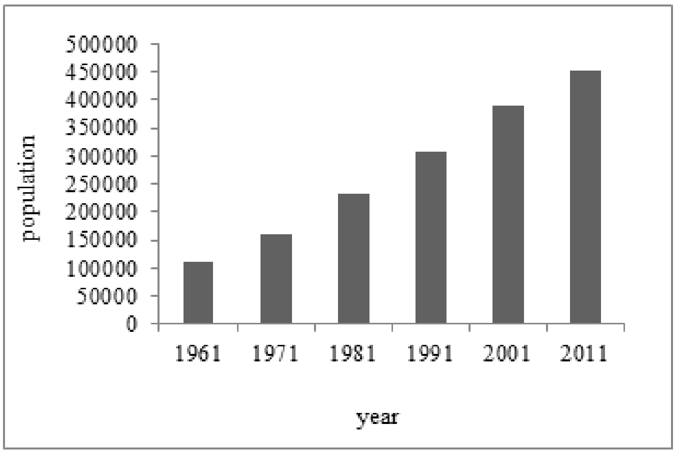

Figure 8. population growth in Udaipur city (Source: Udaipur Municipal Corporation, Govt. of Rajasthan)

Mitigation

To reduce the risk from flash flood, a requirement of natural conservation and land use management should be taken into account. There are so many lakes in which water is reserved. Increasing depth of the reservoir or lake can conserve more water which can reduce flood vulnerability. Encroachment from both side of the river bank, silt from the stream as well as lake should be removed. Construction of new small scale dam at high drainage density area can divert the flow. Badi ka Talab, Choti Madar and Badi Madar are considered as upper lake system (Mehta, 2007) located at high drainage density area on the western side of Ahar watershed. These water bodies of upper lake system should be taken into account for increasing water quantity by increasing reservoir capacity to reduce flood vulnerability. The implication of this project can be done by Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) scheme. Canal and sewer network should be increased in and around the city or plain area so that the excess flow of water at the time of monsoon can be easily drained out. Udaipur Municipal Corporation should take a positive step towards proper solid waste management. The plot between Rb vs. Dd and Rb vs. Fs showed that the area falls under moderate flood prone zone.

V. CONCLUSION

To study watershed characteristics quantitative, morphometric analysis under GIS environment is convenient and effective methodology. The drainage pattern with highest 6th order stream and high Rb value indicate that the area is structurally controlled. High drainage density and soil type revealed that the area is with impermeable subsurface. Shape factors such as form factor, elongation ratio and circularity ratio indicate the watershed is moderate to less elongated which is responsible peak discharge in short duration. High value of Fs confirms greater surface runoff. High value of relative relief is responsible for increasing the velocity of water flow. Relatively high value of slope average, low value of relief ratio and the value of ruggedness number indicate the area is vulnerable to flood. Analysis of all the morphometric parameters in conjunction with landcover mapping highlights that the area comes under the moderate flood prone zone, enhanced by high rainfall in short period of time during monsoon which causes the flash flood. Modification of lake system by increasing reservoir capacity, removing silt and encroachment along the river side, development of sewer network, proper solid waste management and public awareness is necessary to reduce flood hazard.

VI. REFERENCES

[1]. Abdul Rahman, S.S., Abdul Ajeez, S.A. and Jegankumar, R. (2015) Prioritization of Sub Watershed Based on Morphometric Characteristics Using Fuzzy Analytical Hierarchy Process and Geographical Information System—A Study of Kalla Watershed, Tamil Nadu. Aquatic Procedia, 4, 1322-1330.

[2]. Alexander, D. (1993) Natural disasters, London; UCL Press.

[3]. Ali, S. A. and Ikbal, J. (2015). Prioritization based on geomorphic characteristics of Ahar watershed, Udaipur district, Rajasthan, India using Remote sensing and GIS. Journal of environmental research and development (JERAD). 10, 1.

[4]. Ali, S. A., Ikbal, J., Ali, U., and Aldharab, H. (2017) Measurment of watershed geometry in the central part of Udaipur sector, Rajasthan using remote sensing and GIS. International

Journal of Recent Scientific Research, 8 (11), 21786-21791
[5]. Ali, M., Khan, S. J., Aslam, I., and Khan, Z. (2011) Simulation of the impacts of land-use change on surface runoff of Lai Nullah Basin in Islamabad, Pakistan Landsc. Urban Plan., 102, 271–279.
[6]. Ali, U., Al, S.A. and Ikbal, J. (2017). Flood and landslide prone areas based on drainage analysis and other causative factors in Sukhang-Firozpur catchment, Kashmir basin, Himalaya. International Journal of Emerging Technology and Advanced Engineering, Vol-7, Issue-12, pp-290-301
[7]. Angillieri, M.Y.E. (2008) Morphometric Analysis of Colanguil River Basin and Flash Flood Hazard, San Juan, Argentina. Environmental Geology, 55, 107-111.
[8]. Arnous, M., Aboulela, H. and Green, D. (2011) Geo-Environmental Hazard Assessment of the North Western Gulf of Suez, Egypt. Journal of Coastal Conservation, 15, 37-50.
[9]. Dewan, A.M. and Yamaguchi, Y. (2009) Land Use and Land Cover Change in Greater Dhaka, Bangladesh: Using Remote Sensing to Promote Sustainable Urbanization. Applied Geography. Vol. 29, issue 3, pp. 390-401.
[10]. El-Shamey, I. (1992) Recent Recharge and Flash Flooding Opportunities in the Eastern Desert, Egypt. Annals of the Geological Survey of Egypt, 18, 323-334.
[11]. Farhan, Y., Anaba, O., Salim, A., (2016). Morphometric Analysis and Flash Floods Assessment for Drainage Basins of the Ras En Naqb Area, South Jordan Using GIS. Journal of Geoscience and Environment Protection,n 4, 9-33
[12]. Garde, R.J. (2005). River Morphology, New Age International (Pvt) Ltd. Publishers, New Delhi.
[13]. Ghosh, S. (2013). Estimation of flash flood magnitude and flood risk in the lower segment of Damodar river basin, India. International journal of Geology, Earth and Environmental Science, 3, pp. 97-114.
[14]. Horton, R.E., (1945). Erosional development of streams and their drainage basins: hydro physical approach to quantitative morphology, Bull. Geol. Soc. Amer., 5, 275-370.
[15]. Ikbal, J. and Ali, S.A., (2017). Site selection for soil conservation by geometric analysis of watershed in the southern part of Aravalli mountain range using remote sensing and GIS. International Journal of Scientific Research in Science and Technology, 3 (8), 369-378
[16]. Ikbal, J., Ali, S.A. and Aldharab, H. (2017) Morphological character of a micro watershed of Katla river in Udaipur district, Rajasthan. International Journal of Current Research, 9 (9), 57708-57715
[17]. Ikbal, J., Ali, S.A. and Ali, U., (2017) Assessment of flash flood in and around Udaipur city of Rajasthan based on remote sensing and GIS techniques. Proceeding International conference on Environment, Health and Policy nexus, Mysuru (India), 27-28th july, 2017, pp. 92-93
[18]. Lingadevaru, D. C., Govindaraju and Jayakumar, P. D. (2015). Flood hazard zonation based on basin morphometry using Remote Sensing and GIS techniques: A case study of Tungabhadra and Hagari river subcatchments in north-east Karnataka, India. Journal of Geomatics. Vol. 9, No. 1, pp. 122-128.
[19]. Mehta, A. (2008). Citizens role in Ecological, Limnological, Hydrological conservation of Udaipur lake system. Proceeding on Taal 2007: The 12th world lake conference: 1810-1870.
[20]. Miller, J. D., H. Kim, T. R. Kjeldsen, J. Packman, S. Grebby, and R. Dearden (2014), Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover, J. Hydrol., 515, 59–70.
[21]. Mohd, I., Haroon, S. and Bhat, F.A. (2013). Morphometric Analysis of Shaliganga Sub Catchment, Kashmir Valley, India Using

Geographical Information System, International Journal of Engineering Trends and Technology, 4 (1).
[22]. Muthamilselvan A., Dhivya Sri M. (2017). “Morphometric analysis of Sweta Watershed, Perambalur District of Tamil Nadu, India: A Remote Sensing and GIS approach” , Int. Journal of Advances in Remote Sensing and GIS, Vol. 5, No. 1.
[23]. Nag, S. K. (1998). Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal. J Indian Soc. Remote Sensing, 26(1&2), 69–76.
[24]. Nautiyal, M. D (1994), Morphometric Analysis of a Drainage Basin using Aerial photographs: A case study of Khairakulli Basin, District Dehradun, Uttar Pradesh. Journal of the Indian Society of Remote Sensing, 22(4), pp 251¬261.
[25]. Patel, D., Dholakia, M., Naresh, N. and Srivastava, P. (2012) Water Harvesting Structure Positioning by Using Geo- Visualization Concept and Prioritization of Mini Watersheds through Morphometric Analysis in the Lower Tapi Basin. Journal of the Indian Society of Remote Sensing, 40, 299-312.
[26]. Raj R, Maurya DM, Chamyal LS (1999) Tectonic geomorphology of the Mahi river basin, Western India. J Geol Soc India 54:387–398
[27]. Reddy, O. G. E., Maji, A. K. And Gajbhiye, K. S. (2002). GIS for morphometric analysis of drainage basins. GIS India, 4: 9-14.
[28]. Reddy, G.P.O., Maji, A.K., and Gajbhiye, K.S. (2004). Drainage morphometry and its influence on landform characteristics in a basaltic terrain, Central India – a remote sensing and GIS approach, Inter J Applied Earth Obs Geoinfor, 6, 1–16.
[29]. Roy, A. B. and Jakhar, S. R., Geology of Rajasthan (Northwest India) – Precambrian to Recent, Scientific Publishers, Jodhpur, 2002
[30]. Roy, A. B. and Paliwal, B. S., (1981). Evolution of lower Proterozoic epicontinental deposits: Stromatolite bearing Aravalli rock of Udaipur, Rajasthan, India. Precamb. Res. 14, 49-74
[31]. Rudraiah, M., Govindaiah, S. and Vittala, S. S., (2008). Morphometry using Remote Sensing and GIS techniques in the subbasins of Kagna river basin, Gulburga district, Karnataka. Journal of Indian society Remote Sensing. 36(4), 351-360.
[32]. Samson, S. A., Eludoyin, A. O., Ogbole, J., Alaga, A. T., Oloko-Oba, M., Okeke, U. H., Popoola, O. S., (2016). Drainage Basin Morphometric Analysis for Flood Potential Mapping in Owu Using Geospatial Techniques. Journal of Geography, Environment and Earth Science International. 4(3): 1-8, 2016.
[33]. Sanyal, J., Densmore, A. L., and Carbonneau, P. (2014). Analysing the effect of land-use/cover changes a sub-catchment levels on downstream flood peaks: A semi-distributed modelling approach with sparse data, Catena, 118, 28–40.
[34]. Shankar, S. and Dharaniranjan, (2014). Drainage morphometry of flood prone Rangat watershed, middle Andaman, India – A geospatial approach. International journal of innovative technology and exploring Engineering, 3, 11.
[35]. Singh, S. & Singh, M.C., (1997). Morphometric Analysis of Kanhar River Basin. National Geographical Journal of India, 43, 31-43.
[36]. Smith, K. G., (1954). Standards for Grading Texture of Erosional Topography, American Journal of Science, 248, 655-668.
[37]. Sreedevi, P.D., Subrahmanyam, K. and Ahmed, S., (2005). The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. Environmental Geology, 47(3), 412-420.
[38]. Strahler, A. N., (1950). Equilibrium theory of erosional slopes, approached by frequency distribution analysis. American journal of sciences. 248, 800-814.
[39]. Wong, T. S. W. and Chen, C. N. (1993). Pattern of flood peak increase in urbanizing basins with

constant and variable slope. Journal of hydrology. Vol. 143, pp. 339-354.

[40]. Xiao, L., (1999). Flash Floods in Arid and Semi-Arid Zones. International Hydrological Program, Technical Documents in Hydrology, No. 23, UNESCO, Paris.

[41]. Youssef, A. M., Pradhan, B., Gaber, A. F. D. and Buchroithner, M. F. (2009). Geomorphological hazard analysis along the Egyptian Red Sea coast between Safaga and Quseir. Natural Hazards and Earth System Sciences. 9, 751-766.

[42]. Zope, P. E., Eldho, T. I. and Jothiprakash, V. (2016). Impacts on landuse-landcover change and urbanization on flooding: A case study of Oshiwara river basin in Mumbai, India. Catena. Vol. 145, pp. 142-154.