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A Multi Criterion Decision Approach for Identification of Potential Flood Risk Zones in Hussainsagar Watershed using Geomatics– A Case Study

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ABSTRACT

Urban flooding is becoming a major threat in the recent times due to changes in the land use land cover leading to chaos, loss of livelihood, damage to property, infrastructure and utilities. The main objective of the present study is to assess the current state of land use, assess the impact of these temporal changes on the basin hydrology over the past few years. The study was initiated to identify how increase in impervious layer due to construction activities over a decade have significantly increased the potential flood risk zones in and around the Hussainsagar catchment using multi criterion decision support system using GIS and RS techniques. From the analysis it was observed that there is an increase of almost 32.6% in the built-up area from 104.05 km^2 to 154.39 km^2,38.20% reduction in open space, 51.75% in agricultural and, 14.10% decrease in vegetation cover, of the total catchment area between the years 2005 and 2019. These changes in the land use have not only altered the basin hydrology but also augmented the extent of potentially high flood risk zones in the proposed study leading to frequent flooding over the past few years.

Key words : *MultiCriterion Decision Making (MCDM), LULC, Weighted Overlay Analysis, Flood risk zones*

Introduction

A Watershed is a natural hydrogeological unit and any change in the land use land cover pattern would significantly influence the water balance and hydrological processes in the entire watershed. Due to unprecedented growth in terms of population and surge in numerous developmental projects there is a continuous change in the land use land cover pattern particularly in the urban areas over the past few decades. Proper management of the existing natural resources specially land and water along with efficient planning is an effective means to attain the sustainable development goals wherein we can make sure the availability of these resources to our future generations.

Expansion of cities as part of various developmental projects has changed the pervious surfaces into impervious ones leading to frequent flooding in most parts of the region. One of the major contributing factors for increasing number of flood risk zones is due to increased high intensity rainfall events and rising sea levels near the coastal areas but another important factor that has greatly influenced flood risk zones is changes in the land pattern from pervious to impervious (Buurman and Babovic, 2016; Hallegatte *et al*., 2013; Hansen *et al*., 2014). Nowadays the total number of flood events are increasing at an alarming rate in areas having high population density creating lot of chaos, damage to infrastructure and property. Presently the temporal changes in land use have seriously distressed the natural

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environment there by increasing the incidences of urban floods which is considered as one of major disasters. The menace due to floods is increasing at an alarming rate due to rapid urbanization and increased developmental activities leading to severe losses over the past decade (Jha *et al.*, 2012).

Remote sensing and GIS techniques are effective technologies used in hydro-geological applications to prepare various thematic maps such as Land use land cover, DEM, slope, drainage density, rainfall-runoff etc. which could be further used for multi-criterion analysis. (A Rahul, *et al.*, 2018). The problems associated with floods due to developmental activities needs to be identified and measures should be taken as part of the urban flood management programs (Yýldýrým Bayazýt, *et al.*, 2020). Hydrological modeling and hydrological behavior with respect to changes in land use land cover due to human interventions have gained lot of importance and enormous research interest over the past few decades (Sunitha Koneti, *et al.*, 2018). As part of urban flood management strategies, assessment of the extent of potential flood risk zones in a particular area is an important phase that helps to reduce the possible losses due to flooding. In the present study, Multiple Criteria Decision Making (MCDM) approach was preferred to study the catchments behavior owing to significant changes that occurred in land use land cover pattern over the years which led to upsurge in areas more vulnerable to floods.

Materials and Methods

Study Area and Data Input

Hussainsagar catchment area is around 287 sq. km and falls under six sub-watersheds viz. Dhulapally, Bowenpally, Banjara hills, Kukatpally, Yousufguda, and Hussainsagar Downstream catchments. The highest peak in the catchment is at 642 m which lies north of Nizampet while the lowest is about 500 m at the confluence of the stream outlet adjoining with the Musi river downstream. The lake is located in the central part of Hyderabad spreading 540 hectares but due to unprecedented growth and infringements the area has shrunk to 450 hectares. The majority of the water that enters into the Hussainsagar

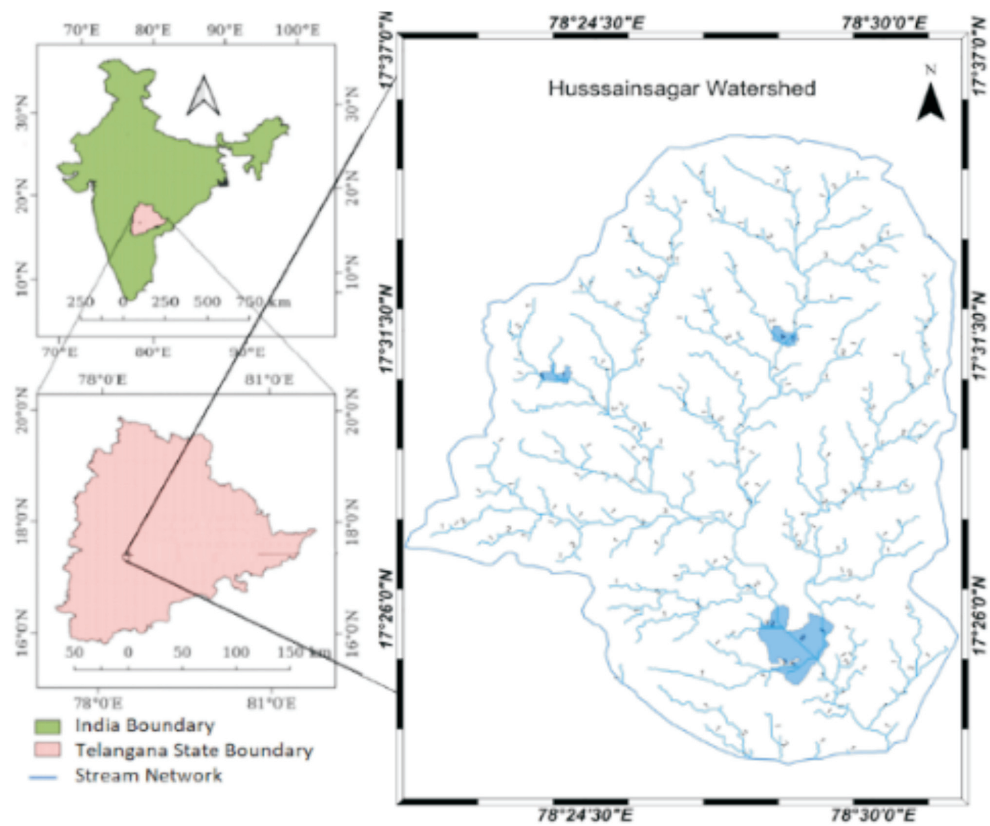


Fig. 1. Location of Study Area

watershed is from the Kukatpally Nala, but during monsoon season most of the water that enters into the lake is due to domestic sewage and industrial effluents (Sridhar Kumar *et al*., 2015).

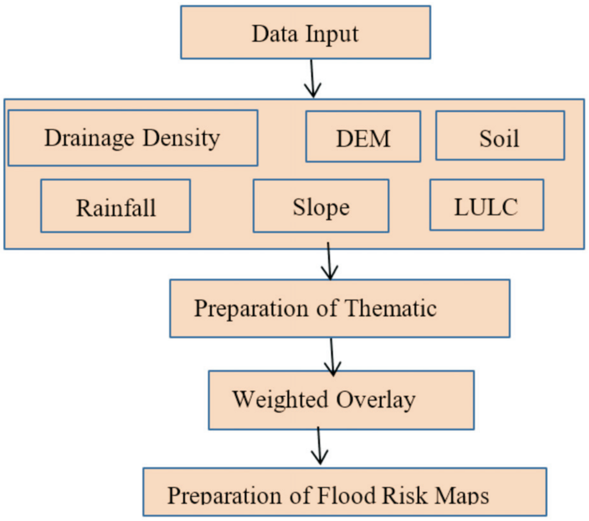


Fig. 2. Methodology Flow chart

Methodology

The present study is divided into two parts based on its objectives: (i) a detailed study on changes in land use land cover in the study area from 2005 to 2019 and (ii) Multi criterion decision support system for identifying the influence of changes in land use land cover on the hydrology and its impact.

Data Input

In the present study, time series satellite data freely acquired from USGS Earth explorer for the years 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019 and Aster DEM with 30m resolution were used to study changes in the hydrologic responses of the watershed with respect to changes occurred in the land use pattern over the years.

Interpolated Rainfall Maps

Rainfall is another important input parameter required for multi criterion decision-making. Interpolation is a technique used in GIS for creating a continuous surface from discrete points. There are several spatial interpolation techniques available and in the present study IDW was used for interpolating the rainfall data obtained from CRU time series data sets having monthly precipitation data gridded to 0.5x0.5 degree resolution to produce the time series rainfall maps.

Land Use /Land Cover Maps

Change detection is the process of identification of temporal changes that have occurred in a particular

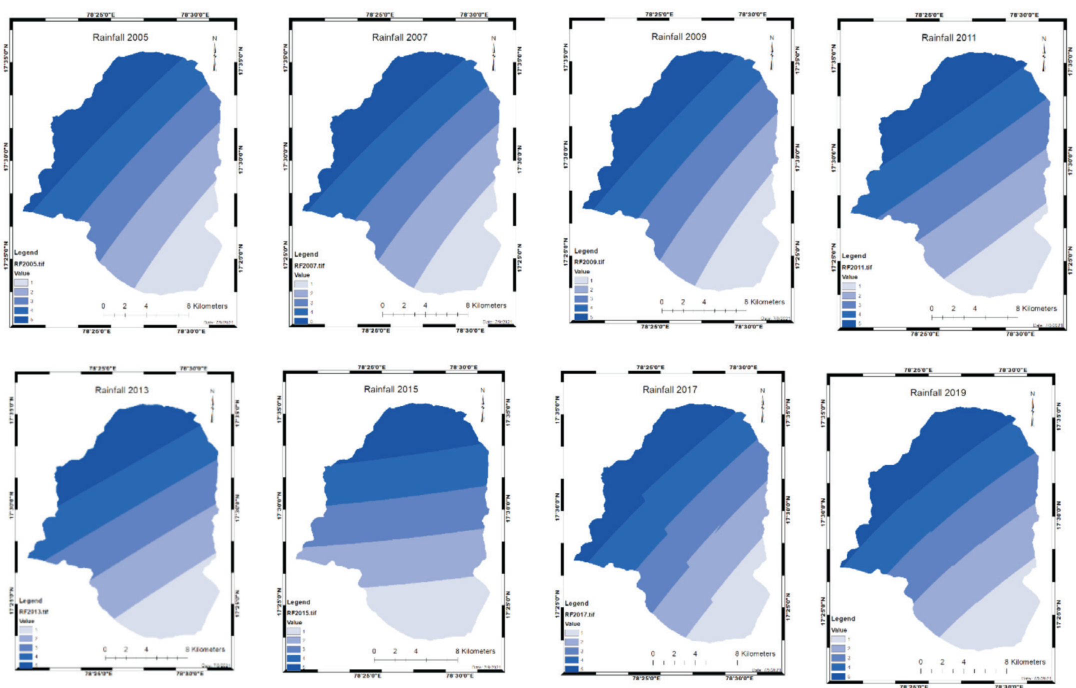


Fig. 3. Showing Interpolated Rainfall Maps during 2005, 2007,2009, 2011, 2013, 2015, 2017, and 2019

area with time and this information is extremely useful for taking right decisions in infrastructure design. The alterations in the land use land cover pattern shows substantial influence on the hydrological behavior of the watershed more so with the rainfall and runoff patterns. To assess the changes that have occurred in the land use and land cover with time, LULC maps were developed by using satellites images acquired during 2005, 2007, 2009, 2011, 2013, 2015, 2017, and 2019. For the current analysis five major classes, i.e. Waterbodies, Urban settlements, Vegetation, Low vegetation, and Barren land were considered which are represented in Fig. 4.

Other Data Sets

Digital Elevation Model (DEM) that was acquired was clipped to get the AOI. Other hydrological parameters required for the analysis such as slope, flow direction, drainage density maps were derived using the DEM. The soil map was freely acquired from https://swat.tamu.edu/data/website and in

Table 1. Details of LULC during 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019

Class Year	Water bodies	Urban Settlements	Vegetation Area (Km^2)	Agriculture	Barren Land
2005	7.8	104.1	78.2	8.1	88.9
2007	7.5	106.5	72.1	9.4	91.6
2009	7.5	110.2	92.4	4.3	72.6
2011	7.5	114.5	90.7	4.1	70.2
2013	6.9	124.5	74.7	3.7	77.3
2015	6.7	125.4	77.1	4.4	73.4
2017	6.9	143.4	73.2	3.1	60.4
2019	6.6	154.4	67.2	3.9	54.9

Table 2. Weights assigned to the Parameters used in the analysis

Sl.No	Factors affecting flood	Classes	Rank	Weightage
1	Drainage Density	0 – 0.44	1	20
		0.44- 0.99	2	
		0.99 – 1.57	3	
		1.57 – 2.18	4	
		2.18 – 3.74	5	
2	Rainfall (mm)	600-750	1	20
		750-900	2	
		900-1050	3	
		1050-1200	4	
		1200-1350	5	
3	Slope (°)	0 - 2.20	5	10
		2.20 - 4.54	4	
		4.54 -7.85	3	
		7.85 -13.09	2	
		13.09 -35.15	1	
4	DEM (m)	356 - 447	5	18
		447 - 471	4	
		471- 493	3	
		493 - 516	2	
		516-564	1	
5	Soil (type)	Clay-Loamy (Lc76-2b-3782)	1-1	8
6	LULC (Class)	1.Waterbodies	3	24
		2. Urban Settlements	5	
		3. Vegetation	2	
		4. Low Vegetation	4	
		5. Barren Land	1	

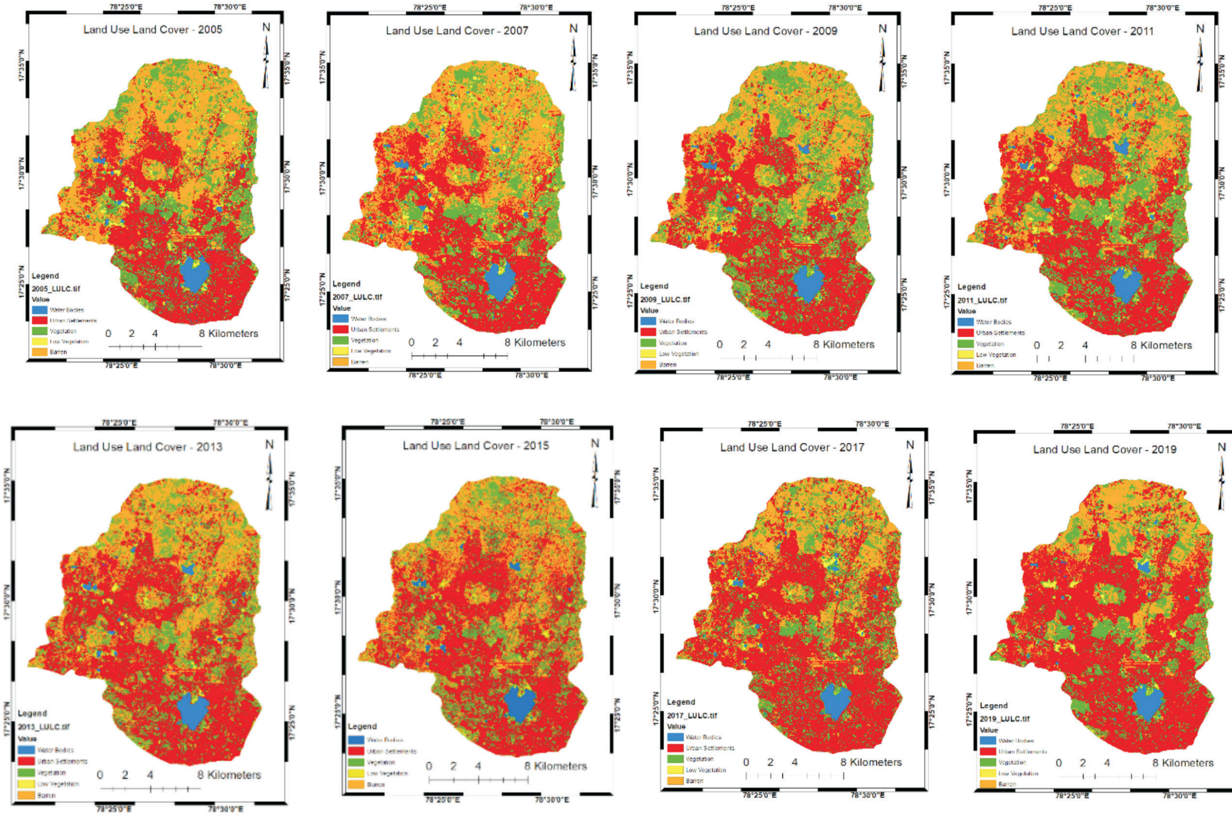


Fig. 4. Showing LULC classification maps generated for 2005, 2007, 2009, 2011, 2013, 2015, 2017 and 2019

most parts of the proposed study hardly any bare soil was seen because of various developmental activities due to urbanization.

Results and Discussion

LULC Classification

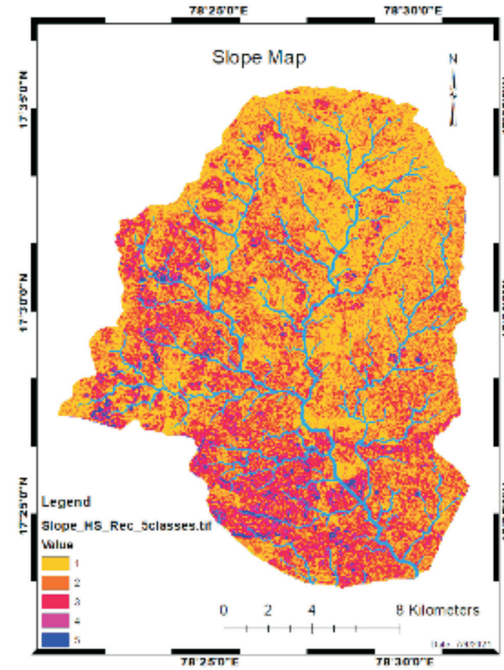
Details of land use land cover plays a prominent role in identification of flood affected areas. With changes in the land use the areas vulnerable to floods have constantly increased which were represented in Table 1 and were graphically shown in Figure 6. From the analysis it was observed that there is a rapid expansion in the built-up area from 2005 to 2019 which has contributed to increase in the impervious layer in the chosen area.

Multi Criteria Decision Approach

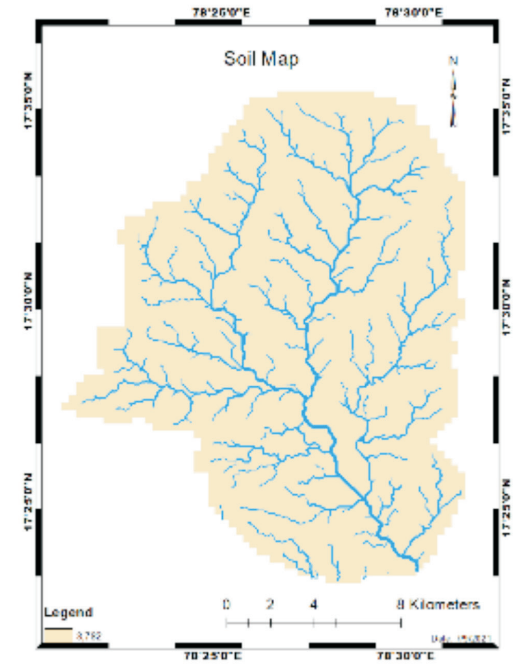
In multi criterion decision-making approach, based on the significance of selected thematic map,

Table 3. Comparison of Flood Risk Potential Zones (2005 – 2019)

Flood Risk Zones Year	Very Low Risk	Low Risk Area (Km^2)	Risk	High Risk
2005	0.12	113.04	150.20	20.59
2007	0.36	112.42	149.74	21.38
2009	0.25	106.91	155.14	21.64
2011	0.21	104.08	158.75	20.84
2013	0.55	100.26	159.47	23.64
2015	1.59	102.45	159.14	20.66
2017	0.09	84.96	167.48	31.43
2019	0.08	79.67	172.95	31.23



(a)



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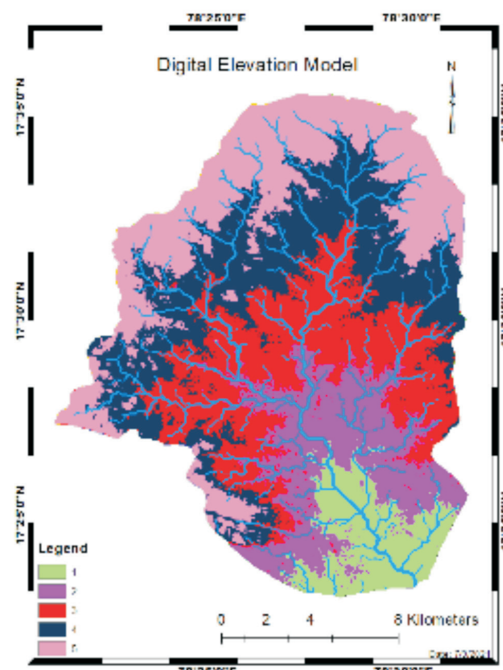
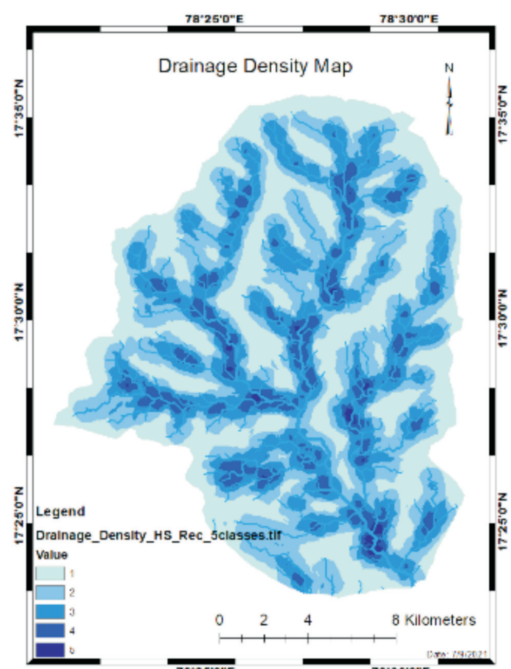


(b)



(d)

Fig. 5a. Slope, 5b:DEM, 5c: Soil Maps, 5d: Drainage density map

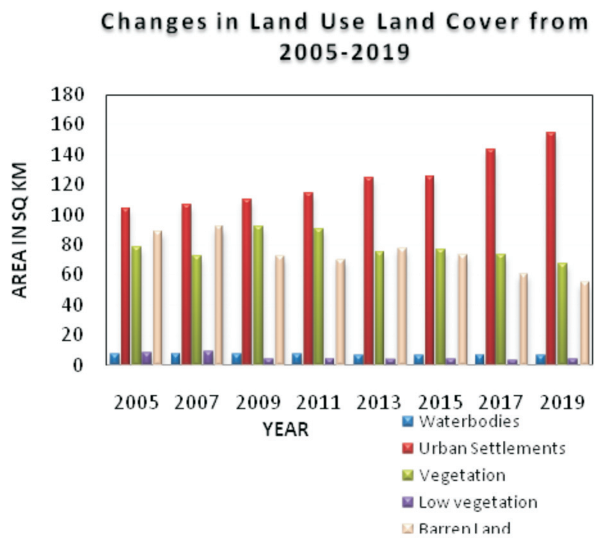


Fig. 6. Comparison of LULC Pattern during 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019

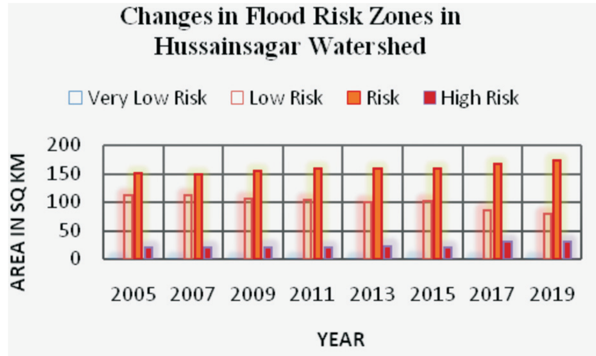


Fig. 7. Statistical analysis of changes in the flood potential zones

weights were assigned accordingly to identify potential flood risk zones. During the analysis ranking values of 1 to 5 were assigned for each and every parameter considered based on their importance which is shown in Table 2. During the process each class that was considered were qualitatively placed into one of the following categories viz., Very low, Low, High, and Very High. In this approach, the higher value represents zones having the highest risk of flood while the smaller ones represent the lowest possible risk in the proposed study as shown in Table 3.

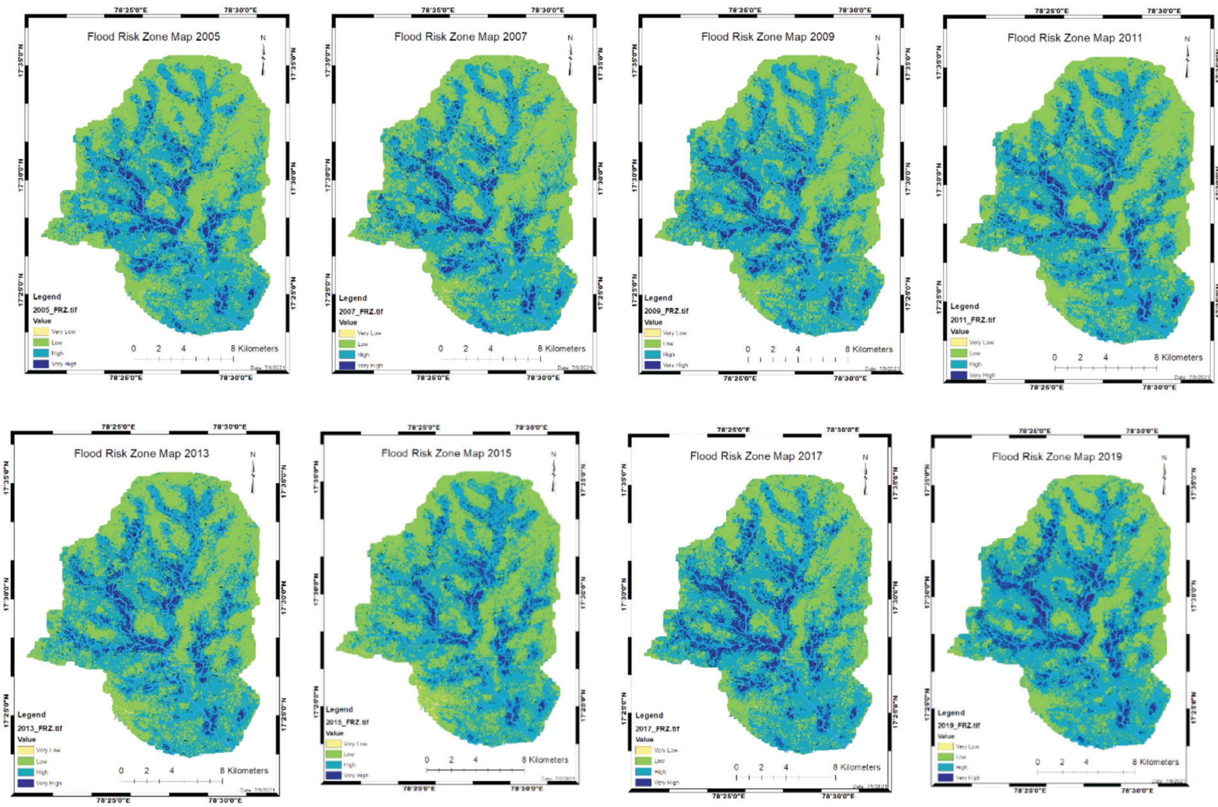


Fig. 8. Comparison of Flood Hazard Maps of Study area for different years (2005, 2007, 2009, 2011, 2013, 2015, 2017, and 2019)

Conclusion

In the recent past the city has witnessed several instances of flooding even with low intensity rainfall which is solely contributed to increase in the built-up area. The Hyderabad city is growing at an alarming rate and the results show that there is a considerable decrease in the area of water bodies from 2005 to 2019, and there is an increase in the areal extent of the urban settlements at a faster rate which had not only intensified the flood flows and increased surface runoff but also the areas at risk. GIS and MCDM are efficient tools that can be used for identification of potential flood risk zones in Hussainsagar watershed of Musi River. Hussainsagar watershed is classified into four flood risk potential zone categories i.e. "Very-low risk", "Low risk", "High risk", and "Very high risk". Out of the total 287 Km^2 area, due to changes in the land use over the past one and half decades the zones falling under different categories have altered i.e. zones with low flood risk have decreased from 113.04 km^2 to 79.67 km^2, while zones with high flood risk have increased from 150.20 km^2 to 172.95 km^2 and zones with very high flood risk have increased from 20.59 km^2 in 2005 to 31.23 km^2 during the years 2005 to 2019.Changes in the land use land cover have greater impact on the basin hydrology which have resulted in increased runoff in the study area and also have increased the potentially high-risk flood zones which are represented in Figures 7 and 8.

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