DEMONSTRATION OF DECISION TREE BASED URBAN MODEL FOR CHARACTERIZING EVOLUTION OF A CITY

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ABSTRACT: Transformation in the pattern of an urban landscape is a consequence of rapid urbanization. The scale of urbanization may differ from one city to another. This depends upon the significance of the city in terms of socio-political and socio-economical context. Consequently, urban policies for sustainable planning are certain to differ as socio-political and socio-economical factors vary. Therefore, it is necessary to assess an urban landscape of a city from socio-political / economical perspectives. It would enable urban planners to identify factors which are significant in transforming the landscape of a city. Furthermore, growth and evolution of a city should also be assessed with respect to surrounding cities to determine the possible impact of their growth on the city. Identification of urban processes responsible for inconsistencies in a city in terms of urban landscape transformation is a necessity. It will enable urban planners to develop robust urban models which can monitor the growth of a city in a sustainable way.

This work aims to develop an urban model to assess and quantify various aspects of the urban landscape pattern considering the aforementioned factors, i.e. socio-political / economical factors and influence of surrounding cities on growth of the city. The model is developed using decision tree, and GIS. Satellite remote sensing data is used in this study to characterize and quantify the spatio-temporal complexities of the city. Results obtained from the proposed model succeed in highlighting the significance of socio-political / economical factors and influence of surrounding cities in shaping landscape pattern of the city. In addition, possible influence of different surrounding cities in shaping the city is categorized in terms of their significance. The results of this study can be used to devise robust and sustainable urban policies.

1. INTRODUCTION

Transformation in the pattern of an urban landscape is a consequence of rapid urbanization. The scale of urbanization may differ from one city to another. This depends upon the significance of the city in terms of socio-political and socio-economical context. Consequently, urban policies for sustainable planning are certain to differ as socio-political and socio-economical factors vary. Therefore, it is necessary to assess an urban landscape of a city from socio-political / economical perspectives. It would enable urban planners to identify factors which are significant in transforming the landscape of a city. Furthermore, growth and evolution of a city should also be assessed with respect to surrounding cities to determine the possible impact of their growth on the city. Identification of urban processes responsible for inconsistencies in a city in terms of urban landscape transformation is a necessity. It will enable urban planners to develop robust urban models which can monitor the growth of a city in a sustainable way.

Mcgranahan et al.(2016) alarms about the growth first strategies for urbanisation as doing so may create situations which would be irreversible. This observation made by the authors is based on the examples of emerging economies. They attempt to assess the possibility of inclusive urbanization. Inclusive urbanization can be instrumental in achieving the idea of sustainable development. Phillis et al.(2017) attempted to modify the SAFE model which is primarily aimed for making sustainability assessment of cities all across the world. The SAFE model was earlier designed for assessing the sustainability of different countries. It also needs to mentioned at this stage of discussion that sensitivity analysis can be performed using the SAFE model. Most of the other models do not have the option of sensitivity analysis. With the help of sensitivity analysis, the observations such as municipal waste generation and GHG emission are threatening problems of the cities in developed world. However, cities of developing countries have other problems such as crime and poverty. At this stage, it needs to be highlighted that the model primarily uses reasoning which mimics human thinking and the results obtained from this model are in subjective nature to some extent. This can be considered as limitation, but it needs to be understood here that there has not been a universally accepted definition for sustainability. In that scenario, it is very difficult to remove these limitations from the model. Simon et al. (2015) discussed and reported about an interesting project where researchers and locals associate with each other in five different cities which are different from each other in terms of diversity. The problems regarding availability of data required for assessing the characteristics of a city were observed. But a study like this can be considered as a reality check for the process of finishing the United Nation's sustainable goal. Clawson(1962) highlighted the fact that generally, urban sprawl is criticized by many citing reasons about its significant role in escalating the cost of social services. This phenomenon is also criticized for its role in land wastage. But others back this phenomenon with statement such as aforementioned problems are just part of a growth process and they even say that these problems are not threatening . But it needs to be understood that mostly do not choose the pattern where they are residing. In fact, no one puts adequate effort to change it. Al-Hathloul & Mughal (2004) discussed about a methodology which aims for putting urban limits and then, asses its impact on the cities. There were some recommendations made by the authors based on their study such as the urban sprawl phenomenon can be controlled by backing the idea of infill development. Similarly authors like Allen & Sanglier(1979) and Alig & Healy (1987) have performed investigation to assess the different aspects of urbanization.

This work primarily aims to assess the impact of factors which shapes a city. The factors which are presently instrumental in shaping the characteristics of a city needs to be assessed and quantified as they are drivers for evolution of a city in a certain manner. There are different factors affect the characteristics of a city ranging from socio-political, to economical to impact of surrounding regions. Therefore, this work considered factors such as infrastructure, land use and land cover, and highway in the analysis as establishments of infrastructures in a planned manner or in a random manner is a consequence of the socio-political and economical situation of a city. Then, highways are one of the most important indicative parameter to assess the importance of surrounding regions. So the objectives of this study can be stated as following:

- ❖ To assess and quantify the significance of different influential factors in triggering changes in the urban landscape.
- ❖ To assess the evolution of city in terms of possible changes in urban landscape pattern in different quadrants of the city.
- ❖ To demonstrate the efficacy of urban model developed using Fuzzy-AHP based decision tree in characterizing the evolution of the city in terms of possible changes in urban landscape pattern.

This article is organized in five different sections beginning from introduction. Next, description of study area followed by methodology, results and discussion and conclusion.

2.CHARACTERISTICS OF THE STUDY AREA

The study area, Ranchi, is geographically bounded between 23° 24' 06'' N to 23° 25' 47'' N and 85° 26' 57'' E to 85° 27' 26'' E. Unprecedented growth in infrastructures of various types ranging from commercial, administrative, industrial to institutional has been acting as a catalytic force in attracting people from outside. They come into the city in search of better opportunities. However, the city is not planned in proper manner to meet the demand of rising pressure on the city. Therefore, problems such as randomness in urban landscape pattern can be easily observed in the city. It may have happened after making Ranchi city the capital of Jharkhand state. Therefore, it is necessary to assess the factors which are influencing the evolution of the city in terms of changes in urban landscape pattern. Therefore, Ranchi city is selected as the study area for this study. Figure 1 shows the study area.

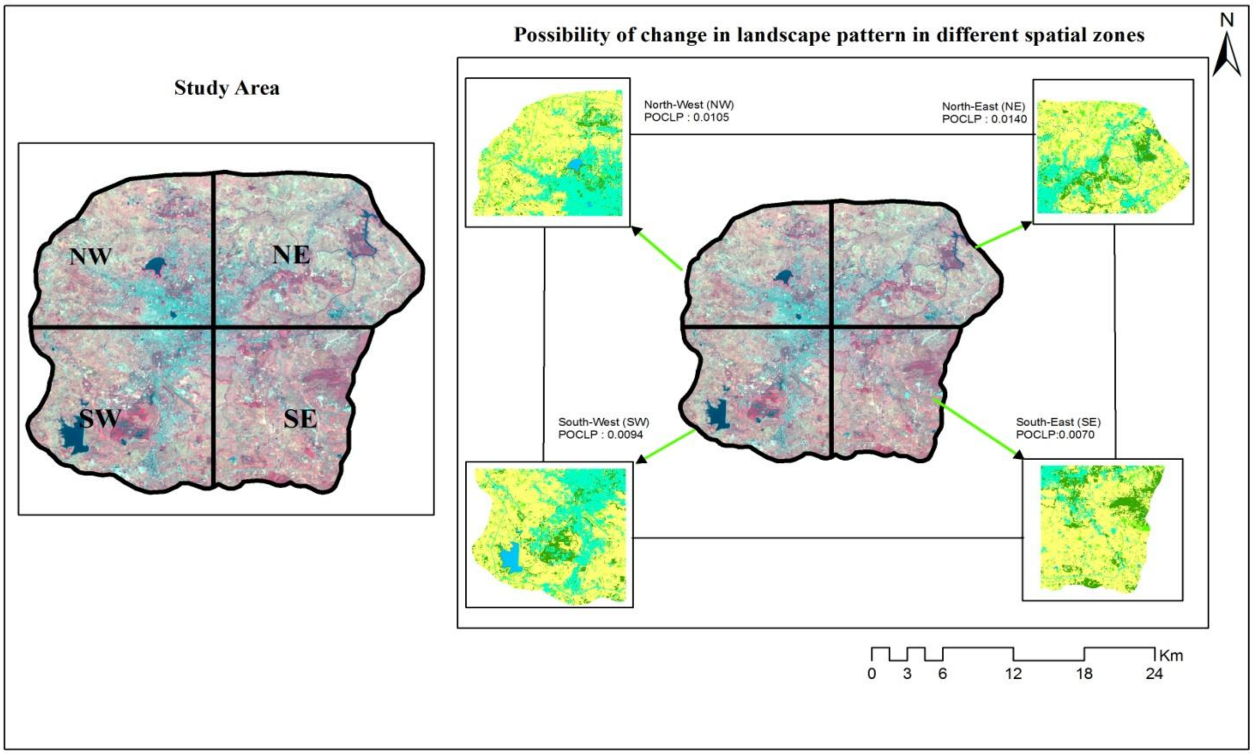

Figure 1. Study area and result map representing POCLP (Possibility of change in landscape pattern in different spatial zones)

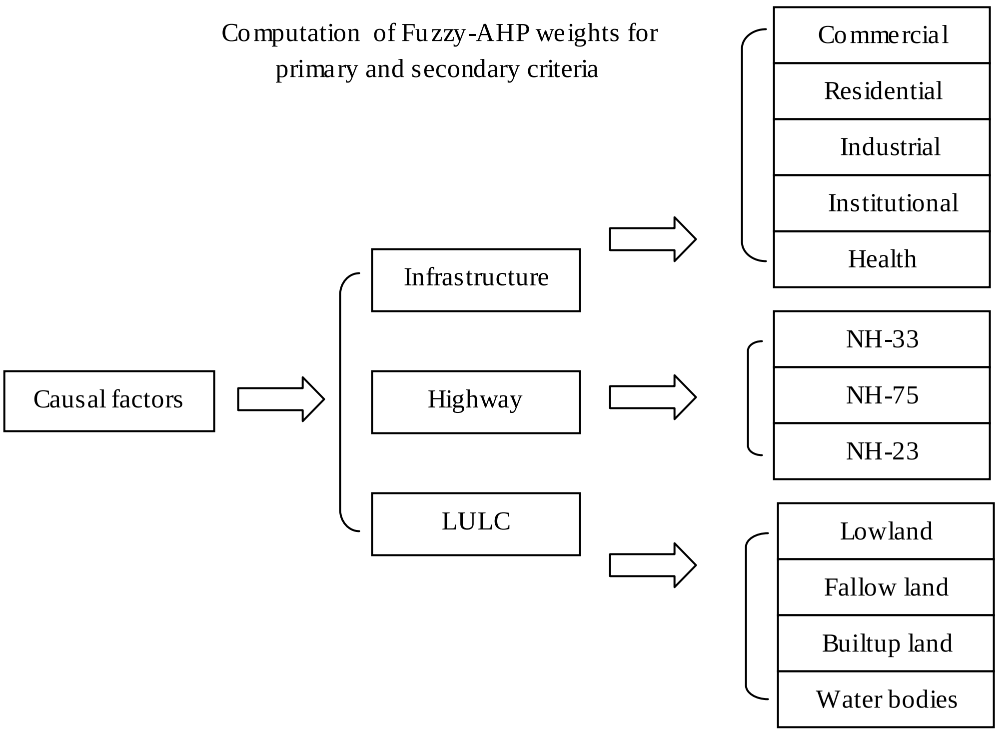

Figure 2. Fuzzy-AHP decision tree framework

3. RESEARCH METHODS

Factors ranging from socio-economic to socio-political dimension influence the evolution process of cities in terms of changes in the landscape pattern of the city. Besides socio-economic and socio-political factors, structural orientation also influences landscape processes. Hence, consideration of factors, such as direction may have significant role in assessing the evolution of cities. Therefore, this work aims to assess the evolution of the cities using different directional zones of the study area. In addition, it aims to demonstrate the utility of an urban model designed using Fuzzy-AHP (Ayhan, 2013; Tang & Beynon, 2005) based decision tree for assessing the evolution of the study area. The research methodology flowchart is shown in Figure 3 and Figure 2 presents the framework of Fuzzy-AHP decision tree.

3.1 Collection and preprocessing of data: The digital Landsat series data are collected for this study. The earth observation data may be significant in extracting vital information in understanding the behaviour of cities. This information further can be used in the proposed Fuzzy-AHP model for achieving the objective of the study. It was then classified using supervised classification algorithm.

3.2 Assessment of the evolution of the study in terms of changes in urban landscape pattern in different directional zones: The study area is segmented into four different spatial zones. It is noteworthy to mention that there could be a significant link between extension of a city and spatial directions. A city may have notable extension in a particular direction than other spatial directions due to structural and functional compositions. So, there should be attempts to assess the impact of spatial directions in affecting the evolution of cities. Therefore, these spatial zones are decided based on spatial directions. Considering centre of the study area as reference point, four different spatial zones viz. North-east spatial zone (NESZ), North-west spatial zone (NWSZ), South-west spatial zone (SWSZ), and South-east spatial zone (SESZ) are formed. Then these spatial zones are extracted as subsets from the satellite imageries of different years. These subsets are further used to extract information about landscape pattern of the city in terms of land use and land cover (LULC) statistics .Having generated primary dataset of this work, this work is categorized into three different modules to achieve the objective. First module focuses on identification of primary and secondary factors which could influence the evolution of the cities in the context of the study area. In addition, it quantifies the significance of different causal factors i.e. primary and secondary factors in terms of their role in catalyzing the change in landscape pattern. The importance value of different causal factors is computed using Fuzzy-AHP technique. Then integrated effect of primary and secondary factors on urbanization phenomenon is determined using the importance values of causal factors. Second module determines the intensity of functional aspects of causal factors in different spatial zones. Finally, third module combines the results obtained from the first and second module to assess the behaviour of city in different zones of the study area as it would help to understand the relationship between the causal factors and nature of evolution of city in different zones of the study area. The steps required to perform the above operation is as following:

- The influential factors which may affect the behaviour of city were identified and categorized into primary criteria and secondary criteria
- Factors such as Infrastructure, Land use and land cover (LULC), and Highway was assigned to the primary criteria class.
- Factors such as Commercial, Residential, Industrial, Institutional, Health (Infrastructure), Low-land, Fallow-land, Vegetation, Built-up, Water body (LULC), NH-33, NH-75, NH-23 (Highway) were assigned to the secondary criteria class
- The details pertaining to the landscape pattern of the city in terms of land use and land cover pattern was extracted for different quadrants of the city which were basically designed on the basis of spatial directions.
- Using Fuzzy-AHP, the significance of different primary and secondary factors in inducing changes in the landscape pattern of the city were computed. Then using these weights triggering potential (TP) was computed with the help of formula:

Triggering Potential =Fuzzy-AHP Weight of Primary criteria × Fuzzy-AHP Weight of the Corresponding Sub Criteria

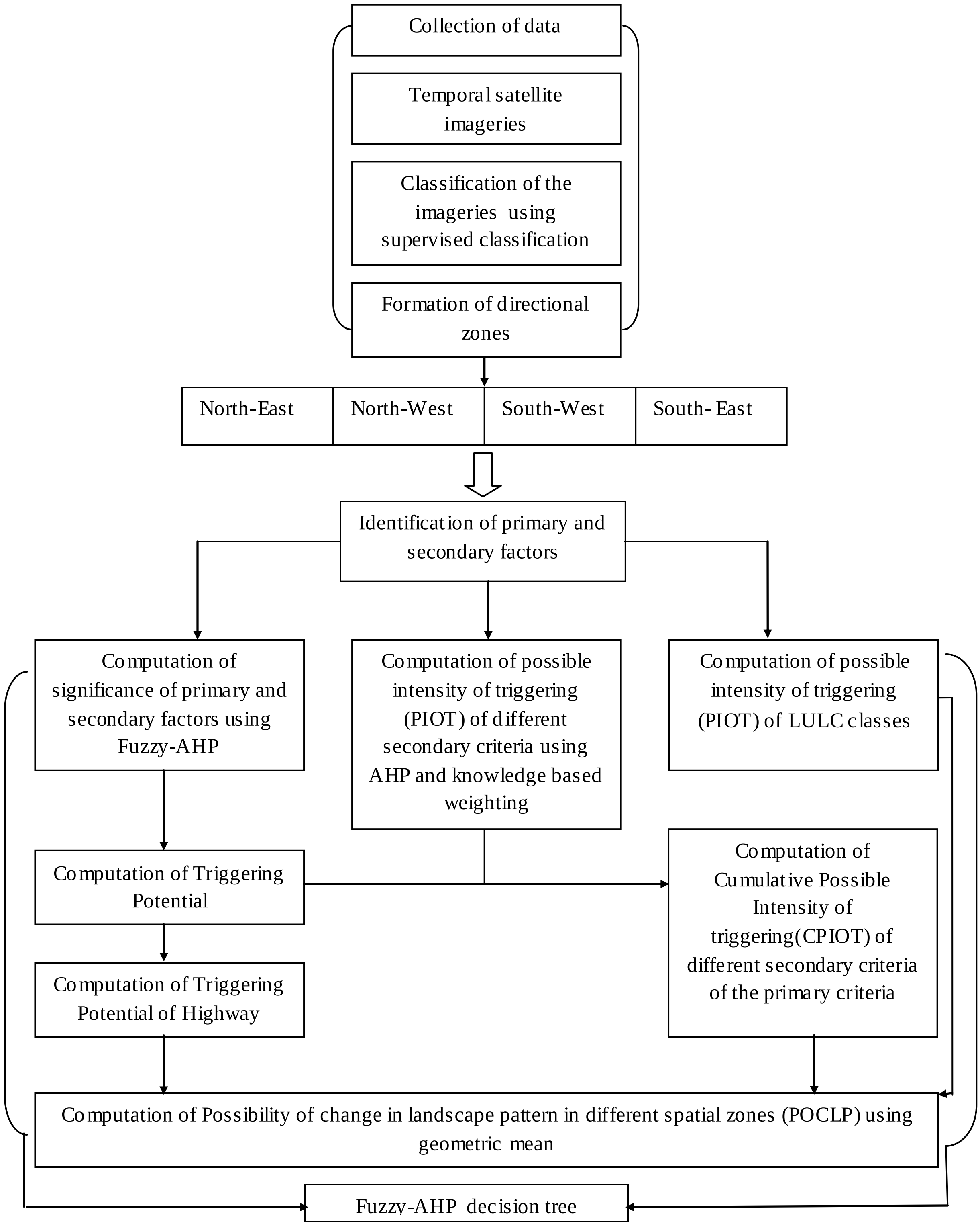

Figure 3. Research methodology framework

- The intensity of presence of different secondary criteria of influential factors in different spatial quadrants were quantified using Analytic Hierarchy Process technique (AHP) (Saaty, 1980; Al-Harbi, 2001) an Knowledge Based Weighting and termed it as Possible Intensity of Triggering (PIOT)

- Then Cumulative Possible Intensity of triggering (CPIOT) for different secondary criteria of ‘Infrastructure’ which correspond to the possibility of landscape pattern change in terms of land use and land cover change due to this criteria in different quadrants of the study area is determined with the formula -

$$\mathbf{CPIOT = TP \times PIOT}$$

- Possible Intensity of triggering (PIOT) of the secondary criteria LULC was computed.

- Then the pattern of evolution of the city in different quadrants in terms of change in landscape pattern was determined by getting the geometric mean of ‘CPIOT’ of different secondary criteria of ‘infrastructure’, ‘CPIOT’ of LULC criteria and ‘TP’ of Highway criteria.

4. RESULTS AND DISCUSSION

The land use and land cover change statistics in different spatial zones of the study area is presented in the Table 1. The spatial zones are constructed on the basis of direction as direction may have significant role in shaping the characteristics of the city. The weights computed using Fuzzy-AHP for different primary and secondary criteria are presented in the Tables 2, 3, 4 , and 5 respectively. Table 6 contains the intensity values of LULC classes in different directional zones of the study area and Table 7 presents the Intensity value or possible intensity of triggering of different sub-criteria of Infrastructure. Information pertaining to possible composite impact or triggering potential of different criteria and sub-criteria is presented in the Table 8. Finally, the Table 9 contains the results pertaining to possibility of change in landscape pattern in different spatial zones as this value is an indicative assessment about the nature of evolution of the city in different directional zones. As it is evident from the Table 9 that the North East (NE) zone has the highest ‘POCLP’ value followed by the NorthWest(NW), SouthWest(SW), and SouthEast(SE) spatial zones. That suggests that the city may experience significant changes in land use and land cover pattern in this zone. Therefore, it can be inferred from this result that the evolution of the city in terms of land use and land cover change will be significant in this directional zone. From table 2, it can be said that the impact of neighboring cities have definite impact on shaping the characteristics of the study area as the causal factor ‘Highway’ is considered in this study as the indicative variable for assessing the impact of neighboring cities on the study area. For example, NH33 which is the secondary criteria of the ‘Highway’ has the highest weight which suggests that this highway is the most important from the perspective of the study area. There may be various reasons for this such as it may connect with a city which is close to the study area and hence affects its characteristics or this may connects important locations around the study area and hence, affects the stud area. Similarly, it can be inferred from Table 3 that industrial infrastructures may be the most influencing factors in shaping the characteristics of the urban landscape as it has the highest weight i.e. 0.422 followed by commercial infrastructures with value 0.246. It needs to be highlighted here that establishments of infrastructures is a consequence of socio-political and economical setup of a city. If it is planned in a proper manner then it would affect the evolution of a city positively. Figure 1 presents the results of ‘POCLP’.

Table 1. Land use and land cover change statistics in different directional / spatial zones

Spatial Zones	Lowland		Fallow land		Builtup land		Water bodies	
	1992	2014	1992	2014	1992	2014	1992	2014
NorthEast (NE)	127.03	102.65	9.35	8.83	3.11	28.19	0.74	0.60
NorthWest (NW)	102.32	79.10	6.73	6.72	8.89	33.02	1.43	0.77
SouthEast (SE)	101.23	94.59	8.59	4.62	1.35	11.80	0.09	0.07
SouthWest (SW)	108.82	90.82	12.03	5.70	7.65	32.82	3.23	2.29

Table 2. Computation of Primary criteria using Fuzzy-AHP

	In			H			LULC			Normalized Weight (NW)
In	0.67	1	1.33	0.01	0.33	0.66	0.17	0.5	0.88	0.159
H	1.77	3.03	4.80	0.01	1	2.26	0.01	0.5	1.76	0.434
LULC	1.5	2	2.5	1.5	2	2.5	0.5	1	1.5	0.407

Table 3. Computation of secondary criteria of 'Infrastructure' using Fuzzy -AHP

	C			R			In			Inst			HS			NW
C	0.01	1	2.835	2.165	4	5.835	0.01	0.33	2.165	1.165	3	4.835	1.165	2	3.835	0.246
R	0.01	0.25	0.665	0.585	1	1.415	0.01	0.17	0.585	0.01	0.3	0.715	0.115	0.5	0.915	0.055
In	0.590	3.03	5.470	3.440	5.88	8.32	0.01	1	3.44	3.44	5	7.440	3.44	5	7.440	0.422
Inst	0.01	0.33	1.895	1.765	3.33	4.895	0.01	0.20	1.765	0.565	1	2.565	0.01	0.5	2.065	0.159
HS	0.01	0.50	1.250	1.250	2	2.750	0.01	0.20	0.950	1.250	2	2.750	0.250	1	1.750	0.118

Table 4. Computation of secondary criteria of 'Highway' using Fuzzy-AHP

	NH33			NH75			NH23			NW
NH33	0.01	1	3	1	3	5	3	5	7	0.686
NH75	0.01	0.33	0.665	0.665	1	1.335	0.665	1	1.335	0.158
NH23	0.01	0.20	0.60	0.6	1	1.4	0.6	1	1.4	0.155

Table 5. Computation of secondary criteria of 'LULC' using Fuzzy-AHP

	LL			FL			BL			WB			NW
LL	0.01	1	4	0.01	3	6	2	5	8	4	7	10	0.473
FL	0.01	0.333	2.667	0.01	1	3.334	0.666	3	5.334	2.666	5	7.334	0.306
BL	0.01	0.2	1.6	0.01	0.333	1.733	0.01	1	2.400	1.6	3	4.4	0.164
WB	0.01	0.143	0.572	0.01	0.2	0.629	0.01	0.333	0.762	0.01	1	1.429	0.056

Table 6. Intensity value of LULC for different spatial zones

	RCLLND	RLND- 14AHPSCORE	RBPD	Composite Score
NE	0.29	0.12	0.27	0.0093
NW	0.35	0.11	0.30	0.0115
SE	0.11	0.14	0.14	0.0021
SW	0.25	0.11	0.29	0.0079

where RCLLND is change in lowland density, RLND- 14AHPSCORE corresponds to the importance of lowland in the current year, RBPD is change in builtup-land density

Table 7. Intensity value or possible intensity of triggering of different sub-criteria of Infrastructure (AHP & Knowledge based weighting)

		NE	NW	SW	SE	PV	CI	CR
	NE	1.00	0.33	0.50	2.00	0.16	0.03	0.31
C	NW	3.00	1.00	2.00	4.00	0.47		
	SW	2.00	0.50	1.00	3.00	0.28		
	SE	0.50	0.25	0.33	1.00	0.10		
In	NE	1.00	4.00	2.00	4.00	0.50	0.03	0.03
	NW	0.25	1.00	0.50	1.00	0.13		
	SW	0.50	2.00	1.00	2.00	0.25		
	SE	0.25	1.00	0.50	1.00	0.13		
H	NE	1.00	2.00	3.00	4.00	0.47	0.09	0.10
	NW	0.50	1.00	2.00	3.00	0.28		
	SW	0.33	0.50	1.00	2.00	0.16		
	SE	0.25	0.33	0.50	1.00	0.10		
Inst	Equal weight for each spatial zone					0.25		
R	Equal weight for each spatial zone					0.25		

Table 8. Possible composite impact or triggering potential of different criteria and sub-criteria

		Sub-criteria weights	Parent weight	Possible composite impact
	C	0.25	0.16	0.04
Infrastructure	R	0.05	0.16	0.01
	In	0.42	0.16	0.07
	Inst	0.16	0.16	0.03
	H	0.12	0.16	0.02
	LL	0.47	0.41	0.19
Land use/cover	FL	0.31	0.41	0.13
	BL	0.16	0.41	0.07
	WB	0.06	0.41	0.02
	NH33	0.68	0.43	0.29
Highway	NH75	0.16	0.43	0.07
	NH23	0.16	0.43	0.07

Table 9. Representation of the nature of evolution of the study area in different directional / spatial zones in terms of its possibility to landscape pattern change

Spatial zones	PTC = IVC * PCIC	PTR= IVR*PCIR	PTIn = IVIn*PCIIn	PTInst-IVInst*PCIInst	PTH=IVH*PCIH	PCIHI	IVLULC	POCLP
NE	0.0064	0.0025	0.0350	0.0075	0.0094	0.29	0.0093	0.0140
NW	0.0188	0.0025	0.0091	0.0075	0.0056	0.07	0.0115	0.0105
SW	0.0112	0.0025	0.0175	0.0075	0.0032	0.07	0.0079	0.0094
SE	0.0040	0.0025	0.0091	0.0075	0.0020	0.29	0.0021	0.0070

Note: PTC = Possible triggering in different spatial zones due to commercial infrastructures (Table 9)

IVC= Intensity value of commercial infrastructures in different spatial zones (Table 7)

PCIC= Possible composite impact of commercial infrastructures (Table 8)

PTR= Possible triggering in different spatial zones due to residential infrastructures

IVR = Intensity value of residential infrastructures in different spatial zones

PCIR = Possible composite impact of residential infrastructures

PTIn = Possible triggering in different spatial zones due to industrial infrastructures

IVIn = Intensity value of industrial infrastructures in different spatial zones

PCIIn = Possible composite impact of industrial infrastructures

PTInst = Possible triggering in different spatial zones due to institutional infrastructures

IVInst = Intensity value of institutional infrastructures in different spatial zones

PCIInst = Possible composite impact of institutional infrastructures

PTH = Possible triggering in different spatial zones due to health infrastructures

IVH = Intensity value of health infrastructures in different spatial zones

PCIH = Possible composite impact of health infrastructures

PCIHI = Possible composite impact of highways

IVLULC = Intensity value of LULC in different spatial zones

POCLP = Possibility of change in landscape pattern in different spatial zones

5.CONCLUSIONS

The aim of this study is to assess the evolution of a city in terms of change in land use and land cover changes in different directional zones of the study area. As there are different factors responsible for evolution of a city, therefore different primary and secondary factors are considered for performing this investigation. Their significance in affecting the evolution of the city is computed using Fuzzy-AHP decision tree method. Further, 'POCLP' which correspond s to the possibility of change in landscape pattern in different spatial zones was computed. The results obtained from the application of Fuzzy-AHP decision tree method and integrated approach are very close to actual scenario of the field. Hence, it can be said that the model proposed in this work succeed to a large extent in representing the characteristics of the city.

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