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THEME: Geo-Budget: Enabling Sustainable Growth

GEOMORPHIC EFFECTS ON URBAN EXPANSION: A CASE STUDY OF SMALL TOWN IN CENTRAL INDIA

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ABSTRACT

In the present paper, an attempt has been made to study the geomorphic effects on urban expansion of a small town in central India. Geomorphology is an important aspect for urban planning, which gives an idea about the variations in landscape/landform and indirectly facilitates in evaluating the resources of an area. For detailed study, multi-temporal satellite remote sensing imageries such as Landsat, IRS LISS-III, LISS-IV Mx, & QuickBird and ArcGIS-10 software were used to compile and create database that provided a visual and historical perspective of the urban expansion practiced in the study area since 1972 to 2011. Progressive urban mapping improves a historical viewpoint of urban expansion by interspersing an assortment of databases into an integrated, multi-scale, and multi-resolution catalogue, which delivers the baseline information for the planner and decision-makers to observe/monitor and predict the patterns and future trends of urbanization. The different thematic map such as landuse change pattern analysis, topography, and geomorphology highlights the profound changes to the landscape/landform that have incrementally developed over time. Geomorphological maps along with other relevant terrain related information such as slope, lithology, and geological structures can delineate suitable area for specific type of urban development and planning. This paper reviews that geomorphological and progressive urban maps have instant applications in monitoring of urban sprawl/urban expansion and predictive modeling techniques to better forecast future areas of urban growth. This study shows an inexperienced approach of simplistic amalgamation of geomorphology and terrain information can afford appreciated inputs for urban planning and development.

KEYWORD: Urban Geomorphology, Urban Expansion, Remote Sensing and GIS

1. Introduction

Urban geomorphology or urban geosciences can be described as an interdisciplinary field in geo-and-socio-economic sciences addressing Earth-related problems in urbanized areas (Legget

1973). Apart from the more traditional disciplines such as petrography, structural geology, geomorphology, and some interdisciplinary fields such as engineering geology, hydrogeology and environmental geology play a dominant role in urban geomorphology (Mulder et al. 2001). Urban geomorphology is the study of man as a physical process of change whereby he metamorphoses a more natural terrain to an anthropogene landscape/cityscape (Maria et al. 2006). In such a context urban geomorphology is the surface component of urban geology, which is one of the important subfields of environmental geology (Coates 1976). Urban geomorphology examines the changes caused by the requirements of urban residential, economic and traffic functions (Cooke 1976, Cooke et al. 1982). Towns are adjusted to the relief and the relief is also adjusted to the needs of construction and planning (Ahnert 1998). The changes that occur as a result of urban expansion are also influenced by their interaction with the disturbed geomorphological process response systems, such as weathering on building stone resulting from air pollution (Viles 1993).

Local landforms have played a central role throughout history in the choice of sites for settlements and their further development has often been influenced by the regional geomorphology (Bathrellos, 2007). Near by the Sagar town, comprises of hills of horizontal Vindhyan and Deccan Trap, the former commonly standing up above the level of the latter. The topography of the Vindhyan in the Sagar area is one that is characteristic of horizontal sedimentary rocks, where the highest bed is massive sandstone; the hills are generally flat topped (Pareta 2004). Settlement geography is incomplete without taking into account the morphography and geology of the area (Ahnert 1996).

2. Study Area

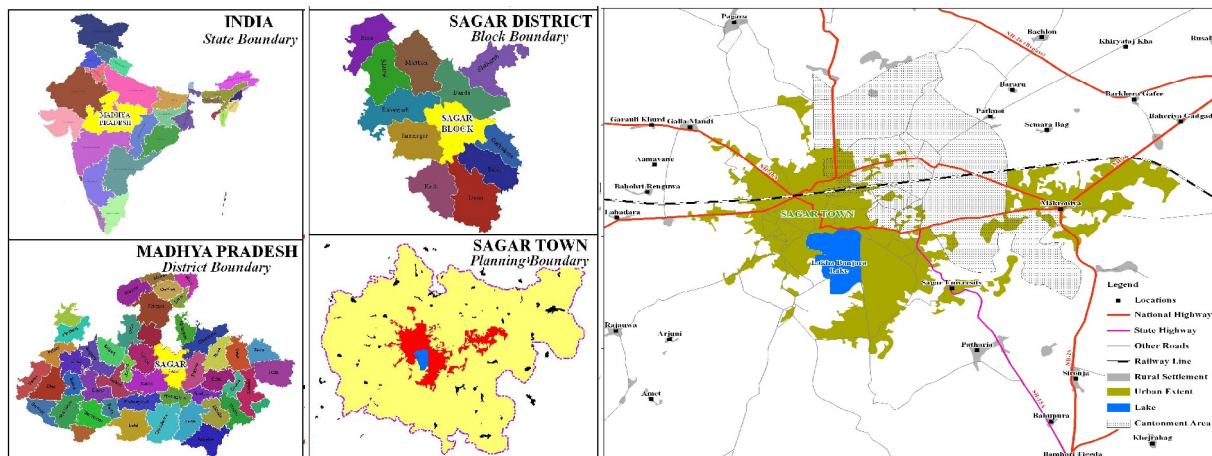


Figure - 1: Location Map of the Study Area

Sagar was founded by Udan Singh in 1660; he founded a village known as Perkota, which now forms a part of the town. The present fort and a settlement under its walls was founded by Govind Rao Pandit, an officer of the Peshwa, who held charge of Sagar and the surrounding territory after 1735 A.D., when it came under the Peshwa's possession, and was constituted a municipality in 1867 (Guru, 1974). The town of Sagar lies in the north central region of Madhya Pradesh. It was spelled as SAUGOR during the British period. It is known all over India due to its university named as Dr. Hari Singh Gaur University, which is now a central university. Sagar town is also known because of huge beautiful lake situated in the heart of the town. The study area covered 2713.99 Hectare and situated between 23.80 to 23.88N latitude, and between 78.70 to 78.81E longitude (Fig.1). The study area is divided into two catchment areas viz, Dhasan and Bewas catchment. The average level over much of the study area varies between 447.2 m to 621.3 m amsl. The normal annual rainfall of the study area is 1234.8 mm.

3. Data Used and Methodology

Table 1: Different Data Layers / Maps and Sources

S. No.	Data Layer / Maps	Source	
1.	Base Map	Topographical Map Survey of India (1:50,000) 55I/09, & 55I/13	
2.	Urban Extent Mapping	Remote Sensing Data	
		LANDSAT-1 MSS (57 m)	30 November 1972
		LANDSAT-3 MSS (57 m)	16 April 1981
		LANDSAT-5 TM (30 m)	15 November 1990
		LANDSAT-7 ETM (30 m) & PAN (15 m)	10 January 2000
		IRS-P6 LISS-IV Mx (5.8 m)	19 January 2006
		QuickBird MSS (2.4 m)	26 September 2011
3.	Elevation Map	ASTER - DEM (30 m)	02 December 2007
4.	Landuse/Landcover Map	Digitally land use and land cover map has been prepared by using Unsupervised Classification method in ERDAS IMAGINE 2010 with limited field check	
5.	Geological Map	Sagar District Geological Map has been collected from Geological Survey of India and updated through IRS-P6 LISS-IV Mx data with limited field check	
6.	Geomorphological Map	Landforms & geomorphological map have been prepared by using remote sensing Imagery	
7.	Demographic Map	Census of India, 2011	

4. Results and Discussion

4.1 Geology

In order to understand the geology & urban geomorphology of the study area, a general lithological map has been prepared with the help of IRS-P6 (ResourceSAT-1) LISS-IV Mx satellite imagery and shown in Fig.2. Through the general geology of the area has been mapped by the GSI in usual way, several other studies and researchers have contributed to the diverse geological aspects of the study area. Notable among these are Medlicott (1859, 1860), Blanford (1869), Dubey (1952), Barrooah (1962), West (1964-81), Choubey (1967), Babu (1967), Durge (1970), Dixit (1970), Gandhe (1970), Mishra (1970), Subramanyan (1972, 81), Pascoe (1975), Rajrajan (1978), Alexander (1979), Wadia (1981), Krishan (1982), Pareta (2004) etc. They recorded the principal rock formations namely upper vindhyan supergroup, deccan traps/intertroppean beds, and alluvium.

In the Sagar town, Vindhyan hills are exposed at Purwau, Itawari, Shukuwari, Sanichari, Gopal Ganj, and Parkota, where Deccan Trap has been completely removed and the original Vindhyan topography can be seen which consists of moderate to steep slopes surrounding the hills (Pareta, 2004). This platform is not horizontally flat but sloping gently away from the sharps unlike the usual horizontal deccan trap platforms, and can be appropriately termed as pediment. A further difference between the topography of the two formations in the study area can be seen in the shapes of the contours on the scarp slopes. In the case of the Vindhyan scarps, the contours are fairly smooth, with few indentations but on the Deccan Trap scarps the contours are indented by many small streams which unite lower down to provide a dendritic pattern of drainage.

4.2 Geomorphology

The use of remote sensing technology for geomorphological studies has definitely increased its importance due to the establishment of its direct relationship with allied disciplines, such as, geology, soils, vegetation/landuse & hydrology (Rao, 2002). The authors have prepared a geomorphological map (Fig.3) by using IRS-P6 LISS-IV Mx satellite imagery, geological map, SoI toposheets of 1:50,000 scale, ASTER (DEM) and field observations. The various geomorphic units and their component were identified and mapped. The descriptions of different geomorphic units of study area are given below:

- Alluvial Plain [AP]: A level or gently sloping tract or a slightly undulating land surface produced by deposition of alluvium
- Valley Fills [VF]: The unconsolidated sediment deposited to fill a valley. Sometime controlled by fracture forming linear depression
- Denudational Hill (Volcanic) [DNH (V)]: High relief, steep sided hills, composed mainly of basalt
- Deccan Plateau [DP]: Low relief undulating topography. Normally cultivated soil thickness varies from place to place
- Buried Pediment (Sand Stone) [BP (SST)]: Broad, gently sloping, erosional surface covered with detritus of sandstone and thin veneer of soil
- Denudational Hill (Vindhyan Sediments) [DNH (VC)]: High relief, moderate to steep slope, barren, moderate to high hills
- Structural Hills (Vindhyan Sediments) [SH (VC)]: Linear to actuate hills showing definite trend lines
- Pediplains (Vindhyan Sediments) [PP (VC)]: Thin soil covered erosional surface developed over meta-sedimentary rock i.e. QTZ, BHQ. Low relief, gently sloping, undulating terrain

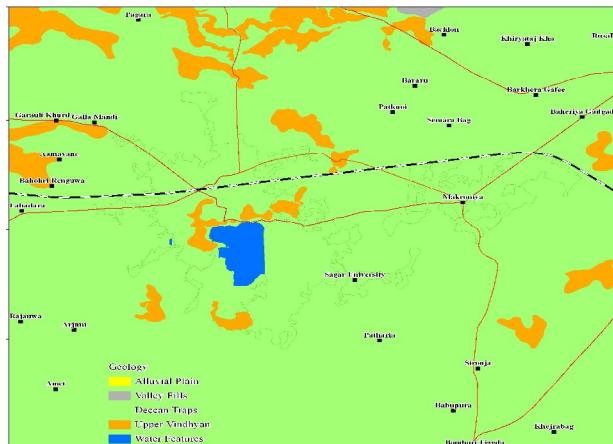


Figure - 2: Geological Map

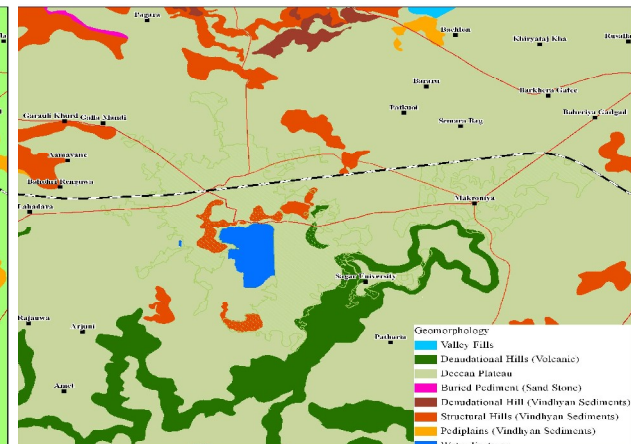


Figure - 3: Geomorphological Map

4.3 Urban Expansion

Multi-temporal remotely sensed data (Landsat-1, 3, 5, 7; IRS-P6 LISS-IV Mx, and QuickBird-MSS data) were used for this urban extension detection, which is provided a visual and historical perspective of the urban expansion experienced in Sagar town between 1972 and 2011. We adopted a simple method of vectorisation directly on the images of different dates to find 'where' the urban had extended. ArcGIS-10 software was used to assemble and integrate the data in order to create the spatio-temporal urban map for the Sagar Town (Fig.4).

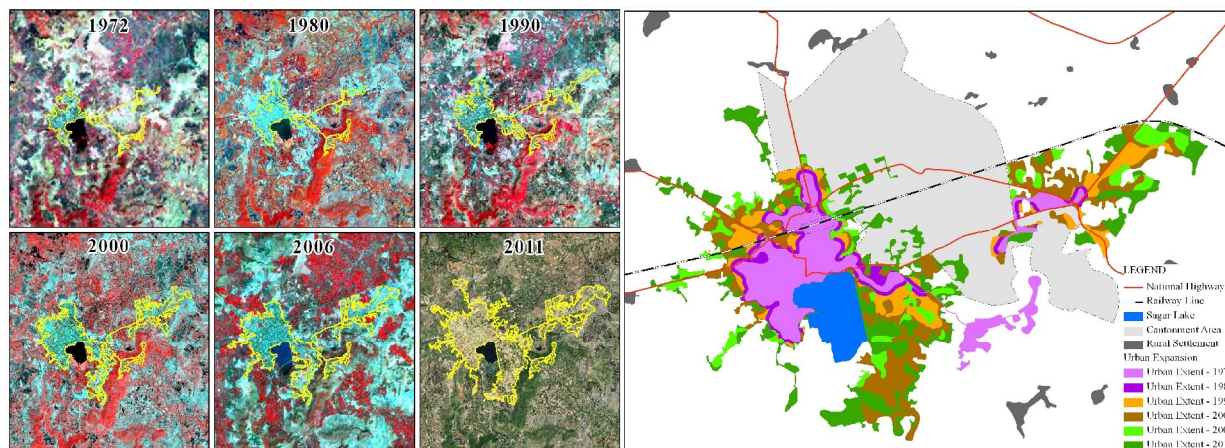


Figure - 4: Urban Expansion Map of the Study Area

It is evident from the interpretation and integration of multi-temporal and multi-resolution aerospace data and other maps that Sagar town has experienced a significant urban growth in the period of 1972 to 2011. The change detection shows that the urban area of Sagar town was respectively 420.31 Ha in 1972, 523.34 Ha in 1981, 714.49 Ha in 1990, 1132.11 Ha in 2000, 1322.29 Ha in 2006, and 1796.86 Ha in 2011 (Table 2). This town had extended by 1376.55 Ha in the period 1972-2011 at a growth rate of 35.30 Ha/year. The computed total area of Sagar metropolitan town (including Sagar town; Bhainsa, Gaur Nagar, Kapuria, Makronia Buzurg, Rajakhedi villages; and Sagar cantonment) is about 2397.74 hectares, while the urban and non-urban areas are 1796.87 ha and 600.86 ha respectively.

Table 2: Showing the Urban Expansion corresponding to the Population Growth in Sagar Town

Year	Urban Area (in Ha.)	Population	Year	Urban Area (in Ha.)	Population
1972	420.31	154,785	2000	1132.11	232,321
1980	523.34	207,479	2006	1322.29	-
1990	714.49	195,346	2011	1796.86	273,357

During this period (1972 to 2006, 34 years) 50.19%, land has been converted to urban from rural. Table 3 shows the urban expansion in terms of area and percentage during 1972 - 2006 and Table 4 is showing the projected urban expansion for the year 2021.

It was projected that by the year 2021 the total urban area will be 2713.99 hectares, indicating that 66.21% area will be urbanized in the Sagar metropolitan town. Fig.5 is showing the past, present and future (projected) urban expansion scenarios. Sagar is having horizontal expansion along with the vertical intensification. This vertical intensification has started mid 70's and added a new dimension in the town growing process. This recent phenomenon of high rise building in both commercial and residential sectors, clearly manifest the town to adopt this process to cope with the ever increasing population pressure and unavailability of land within central part of Sagar town.

Table 3: Rate of Urban Expansion from 1600 to 2011 in Sagar Town

Type	Description		% of Urban Area Increase	Cumulative % of Urban Area Increase
	Expansion Period	Area (Ha.)		
Urban Expansion	1660-1972	420.31	23.39	23.39
Urban Expansion	1972-1981	103.03	5.73	29.13
Urban Expansion	1981-1990	191.15	10.64	39.76
Urban Expansion	1990-2000	417.62	23.24	63.00
Urban Expansion	2000-2006	190.18	10.58	73.59

Urban Expansion	2006-2011	474.57	26.41	100.00
Total Urban	1660-2011	1796.87		
Total Rural	1660-2011	600.86		
Total Area		2397.74		

Table 4: Projected Urban Expansion Trend for Sagar Town in the year 2021

Areal Extent	Projected Year	Projected Urban Area (Ha.)	% of Projected Urban Area Increase	Cumulative % of Projected Urban Area
Urban	2011-2021	917.13	33.79	133.79
Total Urban	2021	2713.99	66.21	

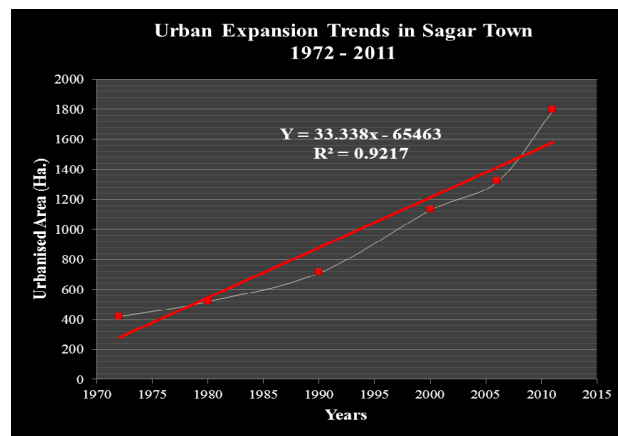


Figure 5: Urban Expansion Trend of Sagar Town: Past, Present, and Future

4.4 Geomorphic and Habitat Characteristics

In this section attempt has been made to quantify the influence of topographical settings in the land conversion process. In the geomorphological map, eight major geomorphic units were identified based on geological origin, lithology, and surface morphology and land elevation. Using GIS map overlay technique geomorphological map was overlaid with the urban expansion trend map in order to quantify the rate of urbanization per geomorphic unit in the period of 1972-2011. Result of this analysis giving the clear indication that topographical settings have the direct influence in the urbanization process (Table 5).

From this result, it is also obvious that urbanization especially it's structural growth in Sagar town has followed the natural trend of spatial encroachments filling the hilly area to the flat area during the period of 1972-2011. Thus, the first level urban development took place at the relatively higher terrace, elevation ranging between 540-520m amsl. Within a range of 3 Kms from the town center most of the high land is already built-up and occupied by man's activities. The second level of urban development took place in the relatively lower terrace elevation between 520-510m amsl. Due to the high rate of population increase and shortage of higher land, recent and the third level of urban development is taking place on the medium to low terrace, depression, back swamps having elevations between 510-490m amsl.

Table 5: Relationship between Geomorphological Settings and Land Conversion Trend in Sagar Town during 1972-2011

Topography		FLAT AREA		HILLY AREA				Total Urban Area
Geology		Deccan Traps		Upper Vindhyan		Upper Vindhyan		
Geomorphic Unit		Deccan Plateau		Denudational Hill		Structural Hills		
Drainage Basin		Bewas	Dhasan	Bewas	Dhasan	Bewas	Dhasan	
Urban Area	Ha.	85.35	241.63	11.64	14.38	0	67.31	420.31
	1972	77.79		22.21				
Urban Area	Ha.	104.53	319.70	12.14	16.78	0	70.79	523.34

1981	%	81.06		18.94				
Urban Area 1990	Ha.	180.17	425.97	12.56	23.26	0	72.53	714.49
	%	84.06		15.17				
Urban Area 2000	Ha.	320.04	685.60	14.12	30.16	0	82.20	1132.11
	%	88.83		11.17				
Urban Area 2006	Ha.	393.74	800.92	14.62	30.80	0	82.22	1322.29
	%	90.35		09.65				
Urban Area 2011	Ha.	528.42	1098.40	19.84	43.37	0	106.83	1796.86
	%	90.54		09.46				

Sagar town is situated on deccan plateau, vindhyan hills, and around the Lakha Banjara Lake, so the agricultural land is very limited in-and-around Sagar town. As Sagar is small town in central India with no any major industries / occupation there, so most of the Sagariyan people are depend on the agriculture labour as agriculturalist, and they not want to encroachment the natural agricultural land. The urban areas in 1972 are covered 77.79% (326.98 Ha.) flat area & 22.21% (93.33 Ha.) hilly area, while in 2011 the urban area covered 90.54% (1626.82 Ha.) flat area, and only 9.46% (170.04 Ha.) hilly area. Deccan plateau occupied 1626.82 hectares of land, which is 90.54% of the total physical extent of Sagar town (Fig.6). Suitable land elevation of deccan plateau is providing favourable condition for urban growth. Therefore, highest urbanization took place in this geomorphic unit in the period of 1972-2011. This unit is almost filled-up with various kinds of infrastructure, high and medium density urban areas. The existing urban areas of this geomorphic unit generally consists of Dharanshree, Machharyai, Bada Bazar, Moti Nagar, Shastri Nagar, Tulsi Nagar, Bhagwan Ganj, Tilak Ganj, Sadar Bazar, Katra Bazar, Civil Line, Tehsilli, Tilli, Kaka Ganj, and Makroniya. The other geomorphic unit such as vindhyan hill generally consists of Purwau Hills, Itawari Hills, Shukuwari Hills, Sanichari Hills, Gopal Ganj, and Goughat-Parkota Hills. Due to limited hilly area in Sagar town & very heavy pressure on flat area (agricultural land), the flat area developed 326.98 Ha in 1972 to 1626.82 Ha in 2011, almost 398%, while the hilly area developed only 93.22 Ha to 170.04 Ha (182%). In comparison with hilly area, flat areas are developed 17 times over a period of 39 years during 1972-2011. This is also giving a very clear indication of extreme reduction of the natural agricultural areas by the urbanization process over the period. This process started from the mid 70'ies and continuing without proper planning.

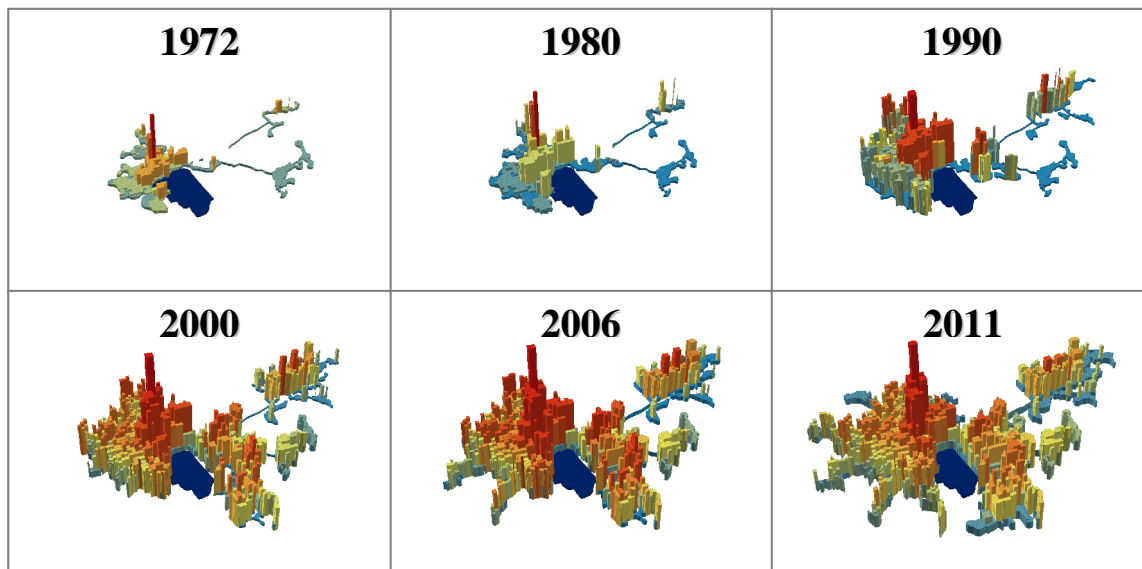


Figure - 6: Urban Expansion - 3D View Map of the Sagar Town

5. Conclusion

Remote sensing and GIS techniques combined with human-demographic-data are an excellent practical-and-economical-tool to study the urban expansion and geomorphological analysis for Sagar town. Historical overviews of urban development provide insights into future development and expansion trends. The maps-and-database can contribute to the research and technology base needed to understand the dynamics of urban phenomena. A progressive database and map of the urban land conversions, showing the changes effective by geomorphic-landform, is needed by urban and regional planners, policy and decision makers, earth scientists, and urban geomorphological researchers to measure trends in urban expansion, understand the impacts of geomorphology on urban development/expansion. The study of the geomorphic effects on urban expansion of Sagar town successfully demonstrated the utility of integrating multi-temporal satellite imagery with geomorphological map to dynamically urban land characteristics. A new urban planning, considering the factors such as water resources, slope-landform and urbanisable area choice, is recommended to improve the present situation and control the future expansion of the town.

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