Use of GIS in Decision Making for Geotechnical Investigation

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ABSTRACT

Geological Information System (GIS) is a tool which is used in different Areas to subside the human effort. The GIS was earlier developed to maintain the geological data of earth, but during the time GIS is used in different areas for research. The purpose of the study is to utilize GIS technique in the field of geotechnical engineering in different work like preliminary survey, availability of digitize Soil data of location, topographic survey. Due to availability of GIS, data can easily digitize according to the geographical coordinates. The satellite imageries of Nagpur city are collected from Earth Explorer a digital platform for researchers to access the satellite images of any Location. This satellite images are Landsat 7 ETM+, these images are later used to form composite image to develop Landuse Landcover map. Using ArcGIS Bore log data from sixty locations are compiled to form digital data for geotechnical soil properties. This will reduce the effort and time of engineers. From the above research the landuse landcover map is generated showing percentage area covered agriculture (36.3%), forest (8.80%), waterbodies (1.3%), urban (53.6%), For Nagpur the elevation at different location is shown which varies from 280m to 380m. From the Combination of three different data set consisting of LULC pattern, Elevation and bore logs the execution of geotechnical project will be easier. In this research the trend of growth at study area is determined with the elevation at different location and geotechnical properties of soil which is essential for the execution of any geotechnical project.

Keywords: land use; land cover; Landsat data; Arc GIS; Geotechnical investigation

1 Introduction

Geographic information system is characterized as "the science and innovation managing with the structure and character of spatial data, its capture, its classification and capability, its capacity, handling, portrayal and dissemination, including the infrastructure necessary to secure optimal utilize of this data"(Raju, 2003). GIS is exceptionally effective program which is for the most part utilized for the examination of all the information i.e., air, temperature, water, land, forest, rural which are exceptionally much vital for human presence. GIS collects the information from satellite imageries and after applying correction to these images, we are able to effectively recognize the surface of particular land area which can be of forest, water, agriculture, Urban. This Geographic information system is additionally described as "the craftsmanship, science or innovation managing with the acquisition, storage, preparing generation, presentation and dispersal of geoinformation"(Ehlers, 2008). In the GIS, Satellite with proper coordinates is used, this coordinate is the address of particular location where research is to be conducted.

Presently in geotechnical designing or civil designing, the engineers ought to work on land i.e., development of reservoirs, houses, streets, etc. The work of a geotechnical Engineer is exceptionally much monotonous he has to do surveying, soil testing, and collecting of field data. Secondary using the data he does designing of

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structures. This complete process is time consuming. To reduce the effort the soil data and survey can be done using GIS. Consequently, information will be accessible to all the people groups who need to know the soil properties of that area. The aim of this research is to aware the engineers about the benefits of GIS and make them implement this practice. It will also help the contractors who are not performing any test before construction of residential buildings or small projects. GIS is used by many researchers for different nature of work. The Geotechnical engineering deal with the behaviour of soil under different actions. GIS and Geotechnical engineering are two different field and with the help of GIS the user can do interpretation and determine the missing data if required. The Geotechnical engineering consist of different levels of data whose storing is difficult as they are available on paper but with the help of Geospatial technique the geotechnical data can be digitized and stored on web which will save time and can easy to access and retrieval by engineers.

The objective of the present research is to answer three scientific questions: (1) To calculate the area for the year 2019 under different classes i.e., Agriculture, Urban, Forest, Barren, Water. (2) estimation of topographic map and elevation map for the purpose of surveying, (3) To digitize the bore log data for study area to know the geotechnical properties of soil.

1.1 Location of Site

The research was done in Nagpur city, Maharashtra, India. It lies between 21° 8' 47.8788" N latitudes and 79° 5' 19.8960" E longitudes approximate area is 228 sq.km as shown in **Figure** .

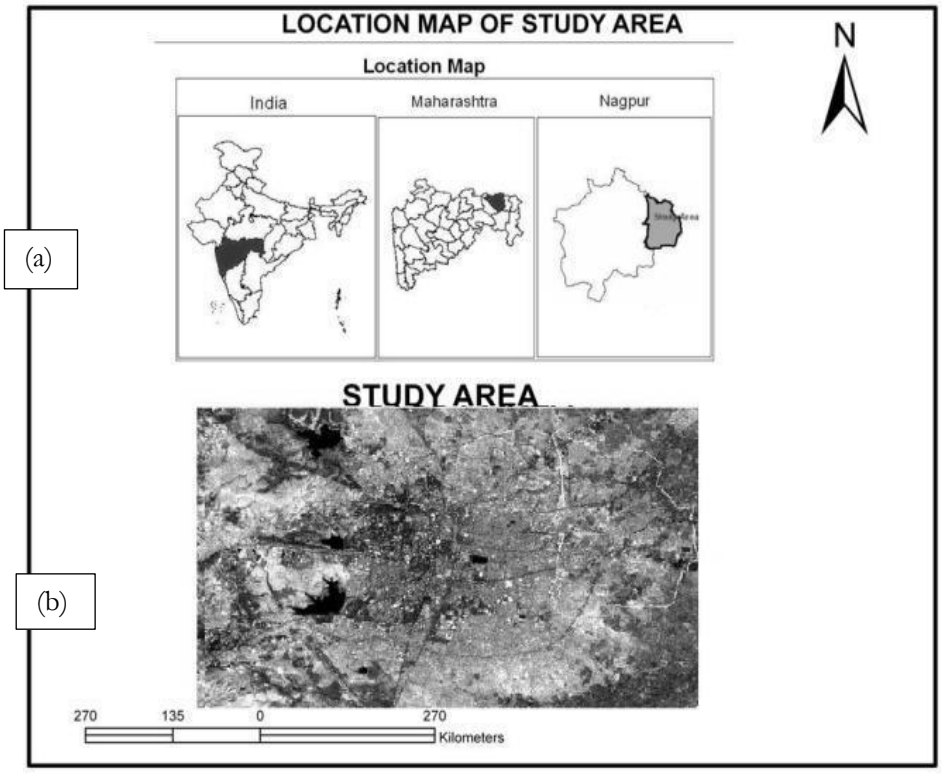

Figure **1. *(a) Boundary of study area (b) Location Map of Nagpur, Extracted from satellite imageries.***

It is Centrally located in Indian peninsula. The average elevation is 310m of Nagpur city. It has tropical savannah climate with dry conditions prevailing for most of the year. It receives an average of 163 mm rainfall in the month of June. The rainfall is increased in the month of July to 294 mm. The amount of rainfall decreases from July to August (278 mm) and September (160 mm). The Average temperature of Nagpur is 35°C to

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45°C(Nandankar et al., 2011). The total population of Nagpur is 2,405,665 making it India's 13th largest city(*District Census Handbook*, 2011).

2 Literature review

Now a day GIS is been used by many geotechnical engineers for different research purposes. According to the study conducted by (Mhaske & Choudhury, 2011) GIS and GPS are used to determine the index property of soil for Mumbai. 450 no. of soil testing reports are collected from different geotechnical labs to create soil database of Mumbai. The research data consists of soil properties like specific gravity (G), moisture content (W_C), water table, liquid limit (L_L) etc. In another study soil data is used to process and present maps describing soil types and strength (SPT values) for different depth(Wan-Mohamad & Abdul-Ghani, 2011). (Williams et al., 2002) Conducted a successful pilot study to investigate the development of a GIS to better manage and distribute soil information obtained from test boreholes results, which makes it easier to obtain information regarding soil types at a specific project location.

(Khan et al., 2018b)Has used ArcGIS to organize different bore log data with its location under single software, also classify landuse/landcover of 15 years (2002-2017) and make a prediction model of land cover and changes for next 13 years viz. year 2030. By this research author came to know about the changes which has taken place for past 15 years and what changes should be there in future with respect to previous data. Similar work has done by (Khan et al., 2018a) to calculate the land change pattern with reference to water, Forest, Urban land, Barren land which will affect the engineering work in Nagpur city, result shows decrease in water bodies, Forest, Barren land and increase in Urban land.

The layer of peat under an engineering structure is very critical issue for construction as this may cause geotechnical problems. To determine the extent to which peat layer is extends (Al-Ani et al., 2014b) soil characterisation was done using GIS. The properties of peat and thickness of peat layer was determined from laboratory tests results. The variation of soil properties has been plotted and examined. In other study (Al-Ani et al., 2014a) author has used ArcMap10 Spatial Analyst extension to develop zonation maps for different depth of the study area. Each depth has interpolated as a surface to create zonation maps for SPT-N value of soil at every depth. Author used Inverse Distance Weighting method for representation of zonation maps. (Al-Ani et al., 2013)has further done research for production of zone maps having data for different SPT-N values for different places with in study area having peat layer of R.L. -10 to -19.6 m. These maps are produced by using interpolation technique of ArcGIS10 which can give values based on given data. This GIS zone maps will give a better overview of bed rock, subsurface geology, and geotechnical properties of soil in study area.

GIS can be used for different purposes as discussed by (Hellawell et al., 2001) author has explained the use of GIS as a tool in geotechnical engineering using different case studies viz. 1. An archaeology desk study, 2. A contaminated land assessment, 3. A landscaping assessment, 4. A construction planning technique.

3 Methodology

The research Involves different process which are used for generating results. In this research the area is studied using reconnaissance survey. The preliminary idea of the geography and research location is achieved. The imageries are collected for Nagpur city. This satellite images are downloaded using Earth explorer. The united states geological survey enables user to access the satellite data free of cost for research and study purpose. The imagery comprises of different bands of images from Band 1 to Band 7 and Pan band having different wavelength and resolutions.

Table 1 Landsat 7 imagery details(Quinn, 2001)

Landsat 7 (ETM+ sensor)	Wavelength (μm)	Resolution (m)
Band 1	0.45 - 0.515	30
Band 2	0.525 - 0.605	30
Band 3	0.63 - 0.69	30
Band 4	0.75 - 0.90	30
Band 5	1.55 - 1.75	30
Band 6	10.40 - 12.5	60
Band 7	2.09 - 2.35	30
Panchromatic Band	0.52 - 0.90	15

Different progression involved in map generation and research are

3.1 Digitization

It is a process of making any data computer usable or digital, which can be easily accessed and/or edited on computer. In this research the author has digitized topographic map of study area, which makes it easy to use for software purpose. This map is collected from Survey of India. Another necessity of digitizing the toposheet is to extract the boundary map of Nagpur city. The process of digitization is done using ArcGIS 10.8

3.2 Map generation for geotechnical usage

The maps generated for different criteria consist of different layers of data which are stack over another. These layers carry specific data which are necessary for generating final map. The Different data layers are stack together to generate the maps of desired nature. The integration of different information layers to form new maps is the key aspect of ArcGIS.

3.3 Landuse/Landcover

Recently, researchers have shown an increased interest in Urbanization, the rural areas are decreasing due to migration of people to urban area in search of works, education, health care. This has increased the demand of land. The inclination of Researchers towards urban is due to the demand, as industries are in urban, roads are developing more in urban so there must be some impact due to this so researcher shows interest toward this area has scope of research is more in urban as compared to rural as per the study of literature by author. As a geotechnical engineer every construction work requires attention towards the soil properties and bearing capacity before construction of superstructure. The LULC map will help in understanding the development trend in urban region and this will help engineers for preliminary survey because it contains elevation data, terrain view, soil data, availability of water.

The landuse/landcover map are made deciding classes which affect the trend of development. This classes are Agriculture, forest, waterbodies, Urban and barren land. This five classes coverage is important for any area. So, in this research the LULC map is generated for the year 2019 of Nagpur city which will show the trend and can give the statistical data of each class coverage. The maps generated for study area are LULC map for trend, elevation for knowing the topography and bearing capacity of soil in ArcGIS. The general methodology is explained using flowchart in **Figure 2**

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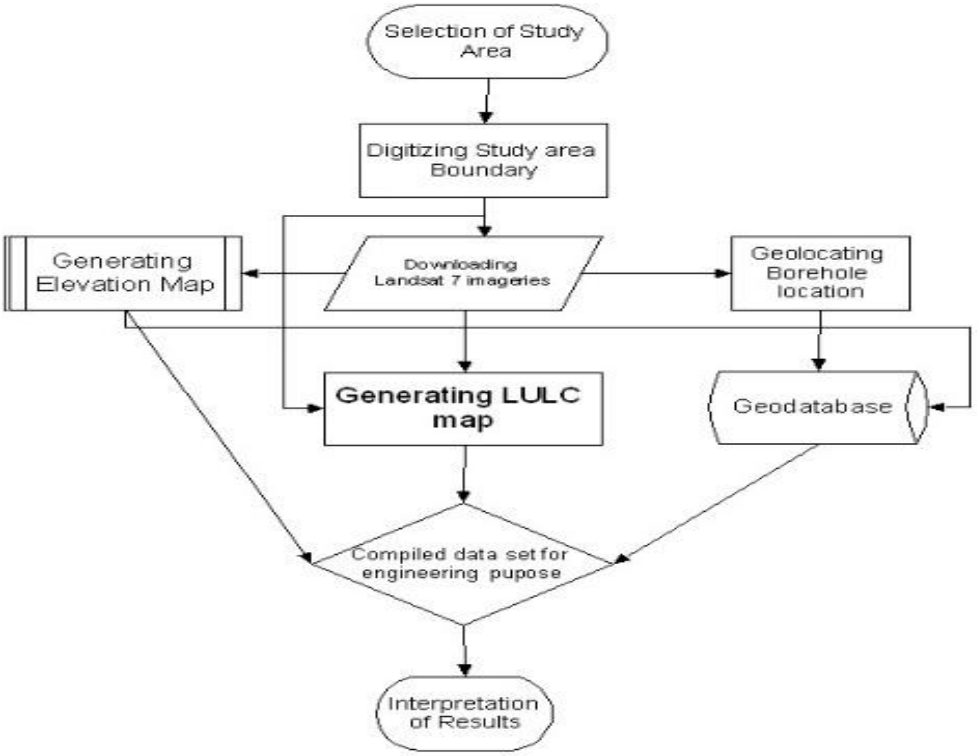

Figure 2 ***Flow chart of Methodology***

3.4 Elevation Map

The elevation is important for the construction purpose. This Map helps to show the variation in elevation throughout the study area. The elevation map generation is explained in results.

4 Results and Discussion

4.1 Surface map and boreholes locations

The results of the above study consist of surface map of study area with location of different boreholes, complete bore log is connected with respective boreholes which will make data availability easy for all.

In the **Figure 3** below the author has generated the map of Nagpur city in ArcGIS and after that connected the borehole file with the map which consist of borehole locations viz. Latitude and longitude.

Here in this study sixty borehole location is taken and all the sixty bore logs have been connected to the respective map

Figure 4 below shows the sample borehole data of random bore hole of study area.

By generation of Digital map, it will be convenient for all the researchers to understand the geography of Nagpur.

For satisfying the objective the complete bore logs with water table, bearing capacity, depth of bore, soil type i.e., soil, soft rock, hard rock is connected with the respective coordinates of bore holes.

The figure 4 is an example for a random bore hole location whose details are shown in the ArcGIS software it is the result of all the incorporation done by author.

The author has collected different borehole location varying from place to place.

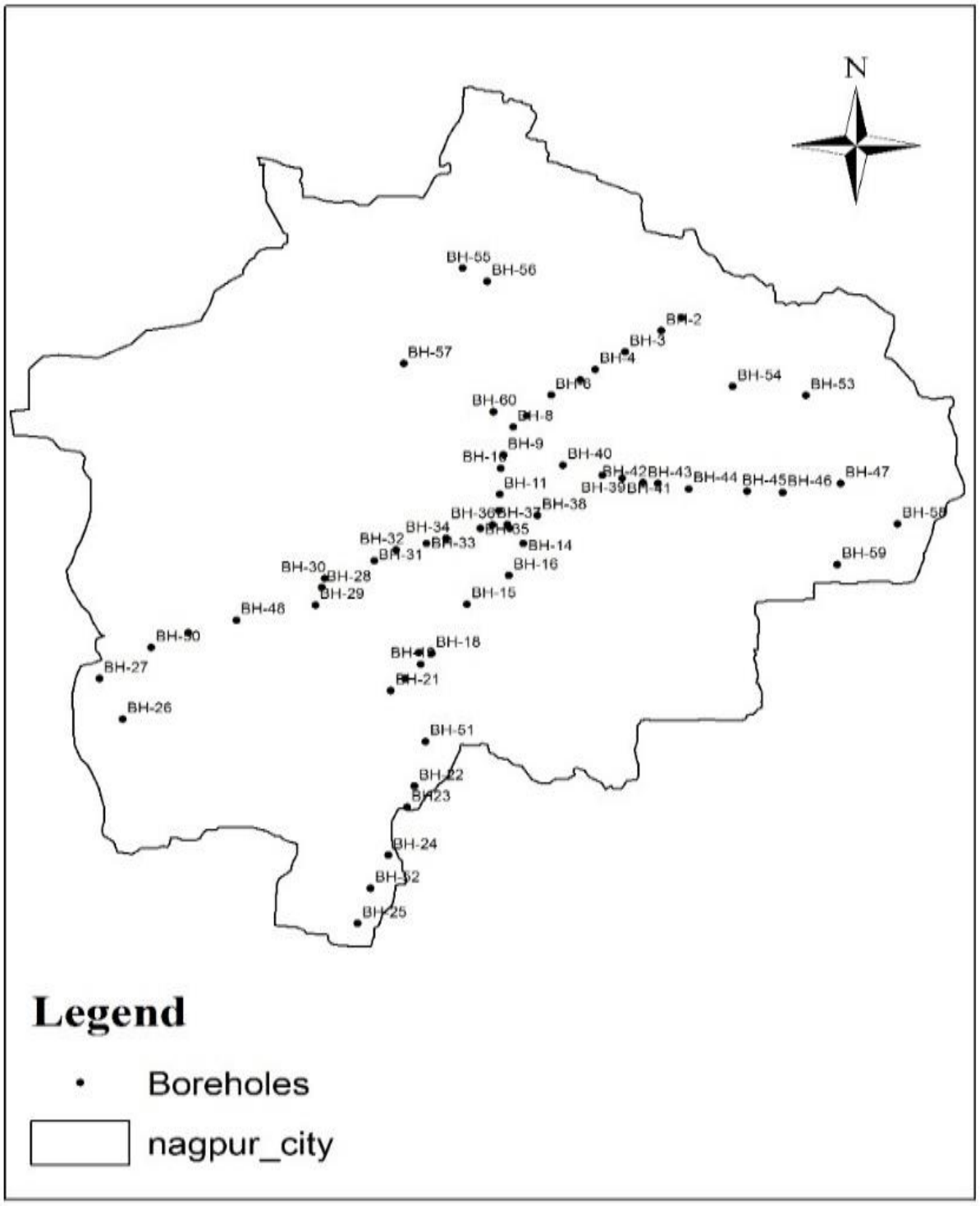

Figure 3 ***Surface map with boreholes location***

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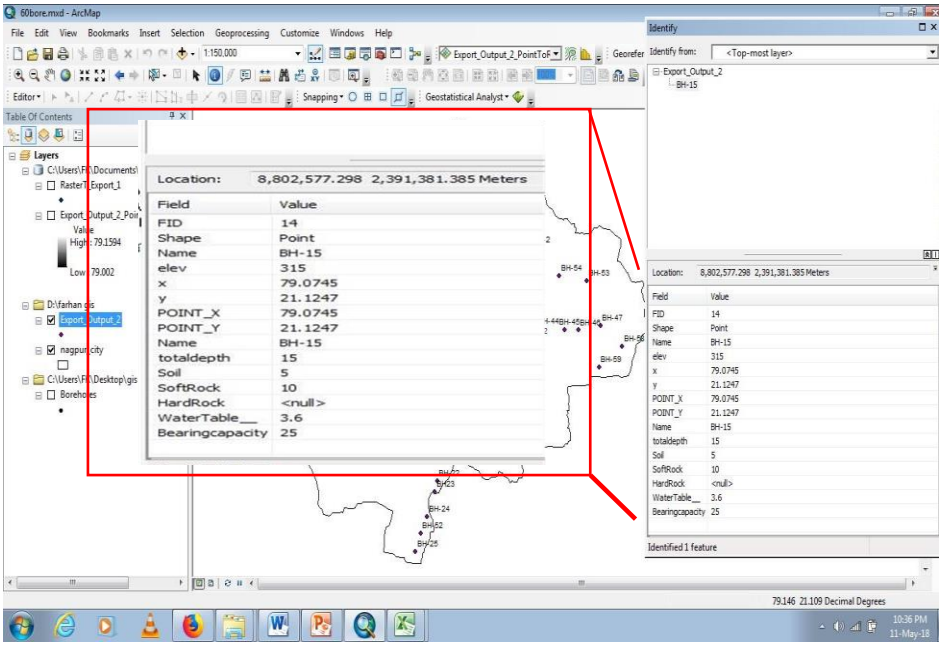
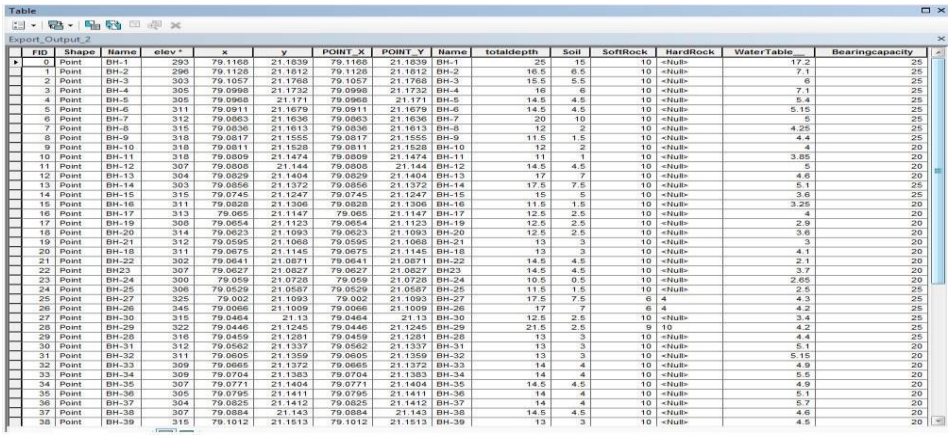


Figure 4 ***Sample of Random Borehole data.***



FID	Shape	Name	elev *	x	y	POINT_X	POINT_Y	Name	totaldepth	Soil	SoftRock	HardRock	WaterTable__	Bearingcapacity
0	Point	BH-1	293	79.1168	21.1839	79.1168	21.1839	BH-1	25	15	10	<Null>	17.2	25
1	Point	BH-2	296	79.1128	21.1812	79.1128	21.1812	BH-2	16.5	6.5	10	<Null>	7.1	25
2	Point	BH-3	303	79.1057	21.1768	79.1057	21.1768	BH-3	15.5	5.5	10	<Null>	6	25
3	Point	BH-4	305	79.0998	21.1732	79.0998	21.1732	BH-4	16	6	10	<Null>	7.1	25
4	Point	BH-5	305	79.0968	21.171	79.0968	21.171	BH-5	14.5	4.5	10	<Null>	5.4	25
5	Point	BH-6	311	79.0911	21.1679	79.0911	21.1679	BH-6	14.5	4.5	10	<Null>	5.15	25
6	Point	BH-7	312	79.0863	21.1636	79.0863	21.1636	BH-7	20	10	10	<Null>	5	25
7	Point	BH-8	315	79.0836	21.1613	79.0836	21.1613	BH-8	12	2	10	<Null>	4.25	25
8	Point	BH-9	318	79.0817	21.1555	79.0817	21.1555	BH-9	11.5	1.5	10	<Null>	4.4	25
9	Point	BH-10	318	79.0811	21.1528	79.0811	21.1528	BH-10	12	2	10	<Null>	4	20
10	Point	BH-11	318	79.0809	21.1474	79.0809	21.1474	BH-11	11	1	10	<Null>	3.85	20
11	Point	BH-12	307	79.0808	21.144	79.0808	21.144	BH-12	14.5	4.5	10	<Null>	5	20
12	Point	BH-13	304	79.0829	21.1404	79.0829	21.1404	BH-13	17	7	10	<Null>	4.6	20
13	Point	BH-14	303	79.0856	21.1372	79.0856	21.1372	BH-14	17.5	7.5	10	<Null>	5.1	25
14	Point	BH-15	315	79.0745	21.1247	79.0745	21.1247	BH-15	15	5	10	<Null>	3.6	25
15	Point	BH-16	311	79.0828	21.1306	79.0828	21.1306	BH-16	11.5	1.5	10	<Null>	3.25	20
16	Point	BH-17	313	79.065	21.1147	79.065	21.1147	BH-17	12.5	2.5	10	<Null>	4	20
17	Point	BH-19	308	79.0654	21.1123	79.0654	21.1123	BH-19	12.5	2.5	10	<Null>	2.9	20
18	Point	BH-20	314	79.0623	21.1093	79.0623	21.1093	BH-20	12.5	2.5	10	<Null>	3.6	20
19	Point	BH-21	312	79.0595	21.1068	79.0595	21.1068	BH-21	13	3	10	<Null>	3	20
20	Point	BH-18	311	79.0675	21.1145	79.0675	21.1145	BH-18	13	3	10	<Null>	4.1	20
21	Point	BH-22	302	79.0641	21.0871	79.0641	21.0871	BH-22	14.5	4.5	10	<Null>	2.1	20
22	Point	BH23	307	79.0627	21.0827	79.0627	21.0827	BH23	14.5	4.5	10	<Null>	3.7	20
23	Point	BH-24	300	79.059	21.0728	79.059	21.0728	BH-24	10.5	0.5	10	<Null>	2.65	20
24	Point	BH-25	306	79.0529	21.0587	79.0529	21.0587	BH-25	11.5	1.5	10	<Null>	2.5	25
25	Point	BH-27	325	79.002	21.1093	79.002	21.1093	BH-27	17.5	7.5	6	4	4.3	25
26	Point	BH-26	345	79.0066	21.1009	79.0066	21.1009	BH-26	17	7	6	4	4.2	25
27	Point	BH-30	315	79.0464	21.13	79.0464	21.13	BH-30	12.5	2.5	10	<Null>	3.4	25
28	Point	BH-29	322	79.0446	21.1245	79.0446	21.1245	BH-29	21.5	2.5	9	10	4.2	25
29	Point	BH-28	316	79.0459	21.1281	79.0459	21.1281	BH-28	13	3	10	<Null>	4.4	25
30	Point	BH-31	312	79.0562	21.1337	79.0562	21.1337	BH-31	13	3	10	<Null>	5.1	20
31	Point	BH-32	311	79.0605	21.1359	79.0605	21.1359	BH-32	13	3	10	<Null>	5.15	20
32	Point	BH-33	309	79.0665	21.1372	79.0665	21.1372	BH-33	14	4	10	<Null>	4.9	20
33	Point	BH-34	309	79.0704	21.1383	79.0704	21.1383	BH-34	14	4	10	<Null>	5.5	20
34	Point	BH-35	307	79.0771	21.1404	79.0771	21.1404	BH-35	14.5	4.5	10	<Null>	4.9	20
35	Point	BH-36	305	79.0795	21.1411	79.0795	21.1411	BH-36	14	4	10	<Null>	5.1	20
36	Point	BH-37	304	79.0825	21.1412	79.0825	21.1412	BH-37	14	4	10	<Null>	5.7	20
37	Point	BH-38	307	79.0884	21.143	79.0884	21.143	BH-38	14.5	4.5	10	<Null>	4.6	20
38	Point	BH-39	315	79.1012	21.1513	79.1012	21.1513	BH-39	13	3	10	<Null>	4.5	20

Figure 5 ***(a) Boreholes data***

39	Point	BH-40	317	79.0934	21.1534	79.0934	21.1534	BH-40	12	2	10	<Null>	3.9	20
40	Point	BH-41	309	79.1051	21.1507	79.1051	21.1507	BH-41	12.5	2.5	10	<Null>	4.35	20
41	Point	BH-42	307	79.1092	21.1498	79.1092	21.1498	BH-42	13.2	3.2	10	<Null>	4.7	21
42	Point	BH-43	304	79.1121	21.1496	79.1121	21.1496	BH-43	13.15	3.15	10	<Null>	4.6	21
43	Point	BH-44	293	79.1182	21.1485	79.1182	21.1485	BH-44	13	3	10	<Null>	4	21
44	Point	BH-45	291	79.1297	21.148	79.1297	21.148	BH-45	13	3	10	<Null>	2.9	20
45	Point	BH-46	293	79.1368	21.1478	79.1368	21.1478	BH-46	14.5	4.5	10	<Null>	3.6	21
46	Point	BH-47	287	79.1482	21.1496	79.1482	21.1496	BH-47	14.5	4.5	10	<Null>	3	21
47	Point	BH-48	322	79.029	21.1214	79.029	21.1214	BH-48	10.5	0.5	10	<Null>	4.1	21
48	Point	BH-49	320	79.0195	21.1188	79.0195	21.1188	BH-49	11.5	1.5	10	<Null>	2.1	25
49	Point	BH-50	341	79.0122	21.1157	79.0122	21.1157	BH-50	17.5	5.5	8	4	3.7	25
50	Point	BH-51	303	79.0663	21.0963	79.0663	21.0963	BH-51	17	7	10	<Null>	2.65	25
51	Point	BH-52	300	79.0555	21.066	79.0555	21.066	BH-52	12.5	2.5	10	<Null>	2.5	25
52	Point	BH-53	292	79.1413	21.1678	79.1413	21.1678	BH-53	21.5	10	11.5	<Null>	4.3	20
53	Point	BH-54	292	79.1269	21.1697	79.1269	21.1697	BH-54	13	3	10	<Null>	4.2	20
54	Point	BH-55	302	79.0736	21.1941	79.0736	21.1941	BH-55	14.5	4.5	10	<Null>	3.4	20
55	Point	BH-56	300	79.0785	21.1914	79.0785	21.1914	BH-56	13	3	10	<Null>	4.2	20
56	Point	BH-57	329	79.062	21.1744	79.062	21.1744	BH-57	12	2	10	<Null>	4.4	20
57	Point	BH-58	300	79.1594	21.1413	79.1594	21.1413	BH-58	12.5	2.5	10	<Null>	5.1	25
58	Point	BH-59	299	79.1475	21.1329	79.1475	21.1329	BH-59	13.2	3.2	10	<Null>	5.15	25
59	Point	BH-60	324	79.079667	21.164444	79.079667	21.164444	BH-60	13.15	3.15	10	<Null>	4.9	25

Figure 5 ***(b) Boreholes data***

Figure 5 (a), (b) shows the no of borehole, elevation of different borehole location, its coordinates, total depth of borehole, depth of soft soil layer, depth of soft rock, depth of hard rock, available water table and bearing capacity of each hole soil.

4.2 Land use/Land cover

The importance of Land use landcover classification is known to all. This classification is needed to understand the area and its occupancy in terms of water bodies, agriculture, urban and forest. Today the need of land in urban areas are increasing due to education, careers, shelter etc., due to the increasing demand the utilization of land is taking place. So, to fulfill the demand the town planner as well as engineers need to understand the area of interest where the land can be developed for all the migrating peoples in such a system that they can yield the benefits of urban area. For Land use land cover classification of Nagpur city for the year 2019 the below mentioned classes are taken into consideration followed by different color coding for better understanding of different classes. The classes with color code are mentioned in **Table 2**.

Table 2 ***Different classification and color coding of LULC Map***

Classification		Type	Color classification
1.	Water Bodies	Lakes, Pond, Rivers, Reservoirs	Blue
2.	Forest	Trees.	Dark green
3.	Urban	Residential, Industrial, Commercial	Red
4.	Agriculture	Farms, Vegetation, Gardens	Light green

This classification is done using ArcGIS 10.8 using supervise classification. This is known accurate method for classification. After the supervised classification the map is generated as shown in **Figure 6** below. This image also gives the detail of area covered by different classes on the basis of which classification was done. The statistics of above Land use/Land cover map is given in **Table 3.**

Table 3 ***Statistics of Land use/Land cover.***

Class	Area in Year 2019 (211.57 Sq. Km)	Percentage area covered (100 %)
Water	2.80	1.3%
Forest	18.61	8.80%
Urban	113.47	53.6%
Agriculture	76.69	36.3%

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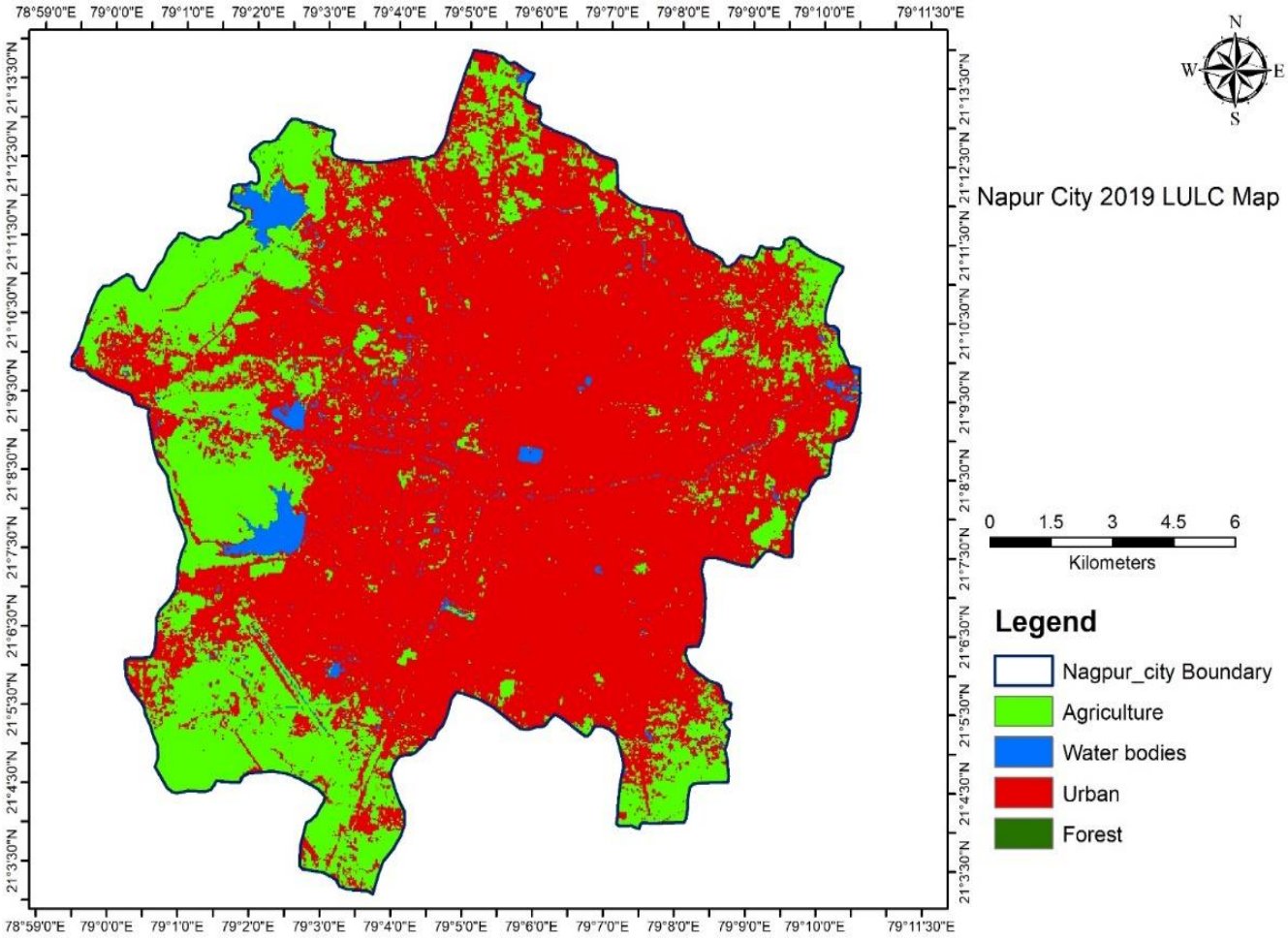

Figure 6 ***Classified image of Nagpur 2019***

4.3 Elevation

The elevation is the first step in construction and design work. It helps in deciding the location for constructing the superstructure. With the help of GIS, the elevation or contour map can be made which will help the engineer deciding suitable location for work where they will get minimum cutting and filling area. This can reduce the manual calculation. The normal Range of elevation for Nagpur City is 280m to 380m. The elevation map of Nagpur city is given in **Figure 7**.

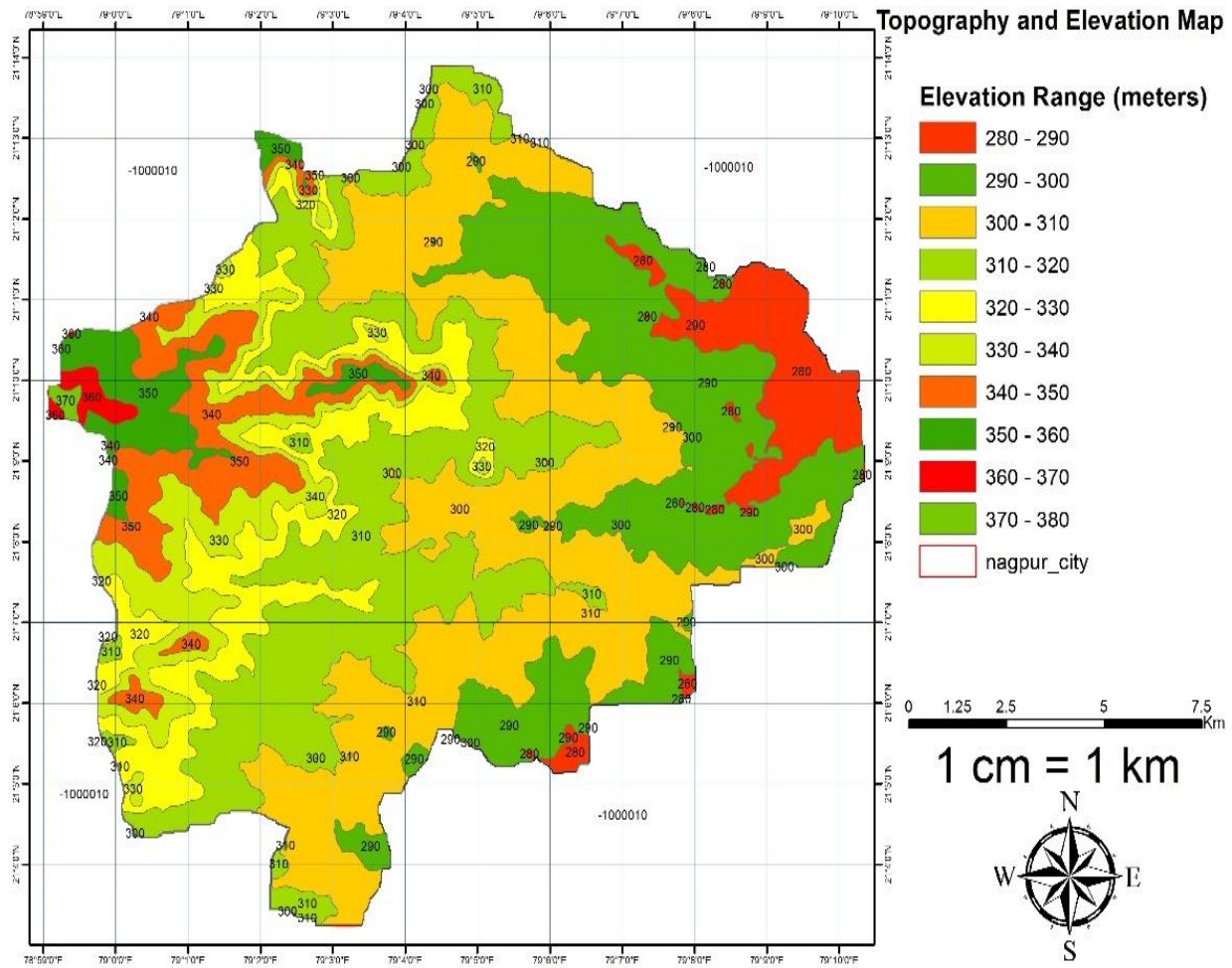

Figure 7 ***Elevation Map for study area.***

5 Conclusion

The complete objective of compiling bore log data with elevation and LULC is achieved. This study has determined the elevation of the study area and by knowing the elevation the different borehole location elevation is determined as shown in figure 5 (a), (b). Then the LULC map of study are is generated which shows the trend of growth in urban region so that the new construction project can be started nearby those areas. Finally, all the three different research are interdependent geodatabase depends on elevation and location and LULC trend depends on development of area which happens due to construction and in construction soil data is required.

From the above research author has tried to show the use of GIS in different ways for Geotechnical and civil engineers. By creating similar data for large area, city, country will be very beneficial for all. The availability of Borehole data with complete details will be easily accessible and be useful for better construction work. Decision making for construction will become easy hence ArcGIS show the trend towards the development. The use of GIS will Minimize the Effort and time. Forthcoming scope can be using the same method for developing soil maps with different soil properties.

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