An Extraction and Analysis of Land Elevation and Coastal Area using Spatial Data Mining Techniques in DEMs

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ABSTRACT. The earth's land surface is always changing its morphology and characteristics due to its inside and outside movements/activities like earthquakes, volcanic eruptions, tsunamis, cyclones, avalanches, asteroid hits, floods, land sliding, and so on. All these earth's movements/activities are the natural phenomenon and not affected the earth's atmosphere that much which is affecting more than the man made things or global warming. The main causes of increase in the earth's temperature are the industrialization, deforestation, and pollutions which are generating more and more artificial disasters. The melting of land ice such as glaciers and ice sheets are the main reasons of increase in global sea levels and is become a big challenge to the people of cities/villages which are located on the sea coasts. Therefore an attempt is made in this paper to extract and analyse the land elevation data, elevation statistics, number of cities/villages located near the sea coasts in India within a specific distance and elevation classes using spatial data mining techniques in DEMs (Digital Elevation Models). The states wise extracted results of this paper are visualized geographically for better understanding and will be useful to plan, monitor and control the by local administrative of that concern province.

Keywords: Elevation data · Sea coast area/cities/villages · Digital elevation model · Spatial data mining · Geographical Information System

1 Introduction

Earth's landform is changing constantly by the movements of tectonic plates which created the mountains, hills, plateaus, canyons and valleys. The change in earth's surface changing its morphology and characteristics year by year and also affects its atmosphere. The global warming is affecting the land ice and melting the same day by day which is one of the major causes of increase in global sea level.

1.1 Digital Elevation Model

To study and analyze the landform and land elevation of a particular province, we must need to have an elevation/terrain data model with us. Now days there are variety of

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elevation data models are available which are processed by different remote sensing techniques. Digital elevation model is a 3 dimensional metrics (XYZ), in which the X and Y are the spatial coordinates which similarly represents the longitude and latitude of earth surface. The Z coordinate represents the elevation values of that location which is associated with that X and Y spatial coordinates.

Digital elevation model is a 3 dimensional spatial data/image contains three coordinates (*X Y and Z*) which is basically generated from contour lines of terrain data. The terrain elevations data from land surface positions are sampled at specific spaced intervals. The digital elevation models can be represented as a raster image or as a vector data such as TIN (Triangulated Irregular Network). The DEMs can be generated using photogrammetry, IfSAR, LiDAR, land surveying techniques [1, 7].

1.2 Spatial Data Mining

The data mining dealing with traditional data (text and numbers) is different from dealing with spatial data (text, numbers, geometries, images, land coordinates). Working with spatial data mining processes are little bit complicated and than the traditional data mining processes and are need much more knowledge and modelling logics because of their more number of features.

2 Methodology

2.1 Data Source

The primary data of my study area (India) such as DEMs are collected from USGS (United States Geological Survey), vector shape-files are downloaded from ESRI (Environment Space Research Institute, USA), remote sensing images are collected from BHUVAN (Indian Geo-platform of ISRO) and other associated data sets such as India gazette, census, coastal data are collected from Indian official sources.

2.2 Data Processing

The main focus of this study is to process and analyze the spatial data which includes the vector maps (shape-files), terrain data (DEMs), raster maps (satellite images) and some official location based records. All these kinds of data are processed and queried using PostgreSql spatial database using some specific features and associated values. The ImageJ open source software is used to classify, analyze, and plot graphs/maps of 3D DEM data matrices using image processing and mapping toolboxes. The step by step data processing of the analytical study is shown in Fig. 1.

The data acquisition process begins with collecting inputs from different types of associated spatial data sets. The data pre-processing step verifies and validates the geo-reference and projection related data and is done using QGIS 3.22.0. If any associated data is not geo-referenced then it will assigns to the same. The WGS-84 EPSG-4326 geodetic datum/spatial reference system is used in this system. The term WGS stands for 'World Geodetic System' and ESPG stands for 'European Petroleum Survey Group'.

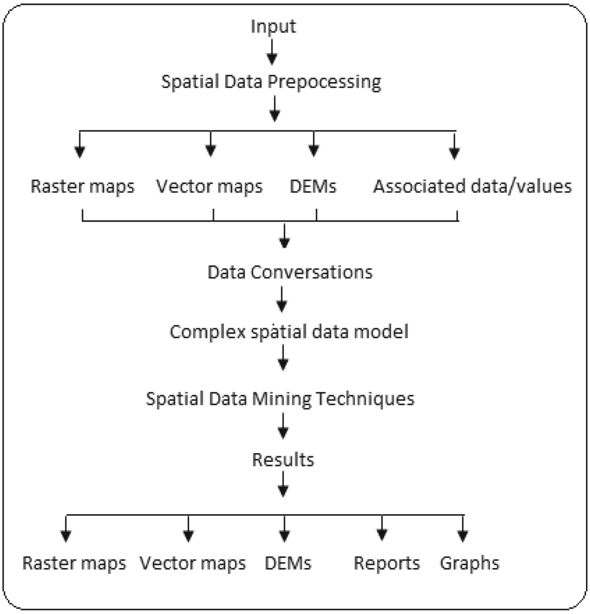


Fig. 1. Methodology used in this analytical study.

Further the system does the required data conversions for compatible spatial computations. Next the validated data will be accessed into a spatial database which is created using PostgreSql. All the associated relations are established between the database fields and spatial data links to form a complex spatial data model. Now we can extract the required information/results by executing queries using spatial data mining techniques [5].

2.3 Spatial Data Mining Techniques

In this study the following spatial data mining techniques are used:

2.3.1 Spatial Classification

This technique assigns an object to a class from a provided set of classes based on the spatial attribute values of this object. The attribute values of the neighboring objects can also be considered in this technique. Using this technique the set of areas and villages are classified differently.

2.3.2 Spatial Clustering

This technique is used to group a set of spatially distributed objects into labeled clusters therefore those spatial objects within a cluster have maximum similarity comparative to others. This technique is applied grouped into 5 classes as shown in the results and discussion section.

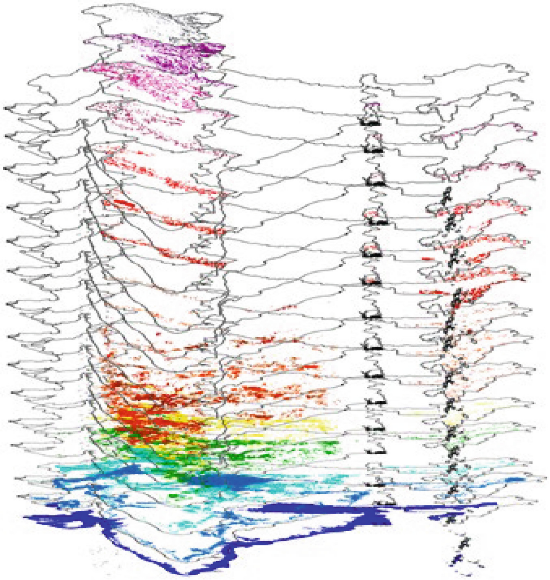


Fig. 2. Elevation sliced map of India.

2.3.3 Spatial Association Rule

Spatial association rule mining is a rule which shows some certain association relationships among a set of spatial and possibly some non spatial attributes/values. A rule must indicate that the model in the rule have relatively frequent occurrences in the spatial database and strong inference of relationships. The spatial attributes are processed which are related to each other like, villages located at specific distances and having the specified elevations [4].

3 Results and Discussion

3.1 Indian Land Elevation

India has a very inconsistent and bumpy land surface elevation. The elevation range begins from 0 i.e. sea level to 8586 m (28169 feet). India's land elevation is to be found increasing in its height as we move from south to north.

The major part of north and north-eastern side consists of highest elevation. The Kangchenjunga is a highest place located at India-Nepal border at 8586 m elevation. The elevation sliced map of India is shown in Fig. 2.

3.2 Elevation Profile

The Fig. 3 showing elevation map (graduated-colored) of India started from the sea level i.e. displayed in blues color and increasing with light-blue, dark-green, light-green, yellow, orange, brown, red, pink, purple to grey as shown in its map legend.

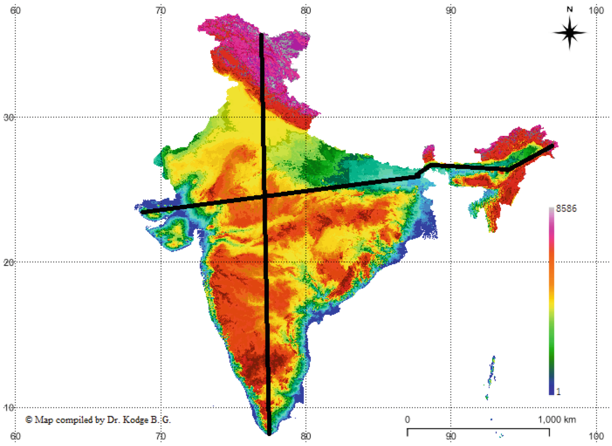
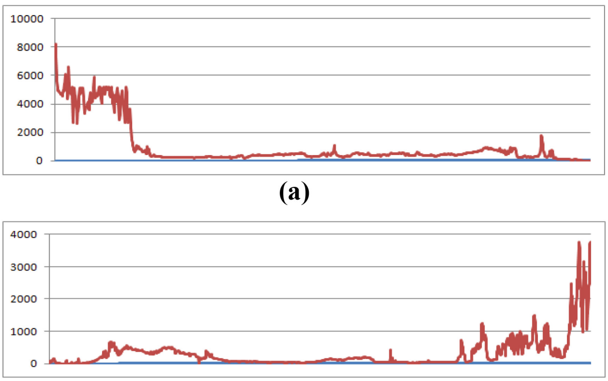


Fig. 3. Elevation map of India

The black lines drawn in Fig. 3 from north side to south (top to bottom) and west side to east (left to right) are used to get the elevation profile of the area. The north to south and west to east line elevation profiles are extracted and shown in Figs. 4(a) and 4(b) respectively.

From Fig. 4(a) and 3(b) it is observed that the India has a very inconsistent and bumpy land surface. The northern and north-eastern part of India is having highest land elevation compared to its other parts. The western and southern part of India is flat in nature and having very small amount of elevated land compared to its north side.

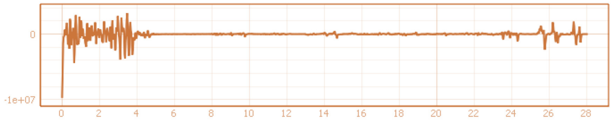
The Fig. 5 showing the slope (in percent) profile of the lines drawn in Fig. 3. Figure 5(a) displaying the slope profile of line north to south, and Fig. 5(b) showing the slope profile of line drawn from west to east.



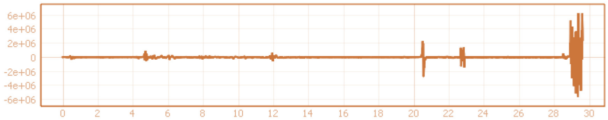
(a)

(b)

Fig. 4. Elevation profile of India: (a) north to south. (b) west to east.



(a)



(b)

Fig. 5. Slope profile (a) north to south, (b) west to east.

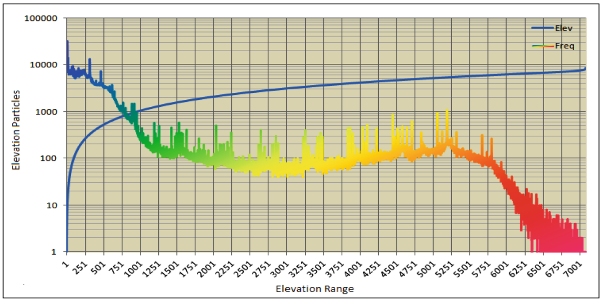


Fig. 6. Frequency of land elevation values with covered area.

3.3 Elevation and Covered Area

According to the Survey of India, India is the seventh largest country having a total area of 32,87,263 square kilometre and has fourth highest mountain in the world i.e. Kangchanjunga located at 8586 m (28,169 feet). The covered area is spreaded with discrete elevation values with different land characteristics.

The Fig. 6 showing the frequency of elevations (graduated) and it's covered area. The elevation range is started from 1 to 8586 m and covered area particles are extracted from a DEM. Majority of the area is in between 500 to 700 m and average elevation is 620 m.

3.4 Coastal Area and Nearby Located Cities/Villages

India contains a vast seacoast line with total length of 7516 km connected to 09 states (Gujarat, Maharashtra, Goa, Karnataka, Kerala, Tamilanadu, Andhra Pradesh, Odisha and West Bengal) and 04 union territories (Dadar & Nagar Haveli and Daman & Diu, Lakshadweep, Pondicherry and Andaman & Nikobar islands).

The coastal area within a specific distance and elevation are classified into 5 classes and are extracted from the spatial database using an association rule and feature extraction techniques. The classes with specific features are defined as follows:

Table 1. Class attributes of extracted coastal area

SN	Class ID	Elevation range (meters)	Color
1	Class_1	0–3.9	Red
2	Class_2	4.0–7.9	Orange
3	Class_3	8.0–11.9	Yellow
4	Class_4	12.0–15.9	Green
5	Class_5	16.0–20.0	Blue

The Fig. 7 showing the extracted coastal area as using specified values as shown in the Table 1. The area of each individual class fall within a specific range of elevation values extracted and their statistical measurements are also calculated. The details of class wise extracted area and their statistical measurements are shown in Table 2.

The extracted values of class wise coastal area such as Total Area Counts, Total Area, Mean, Standard Deviation and Range are shown in Table 2, and the same is displayed in graph as shown in Fig. 8.

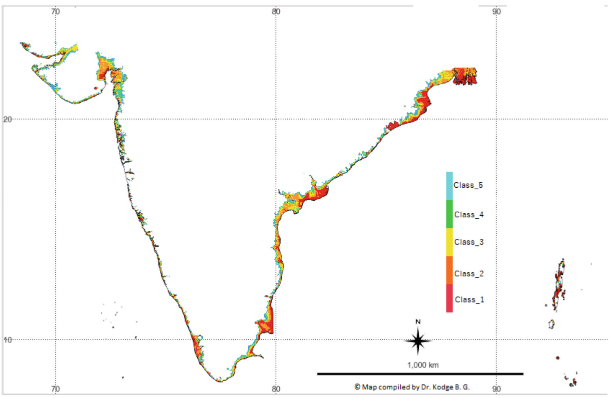


Fig. 7. Specified class wise extracted coastal area.

Table 2. Class wise extracted coastal area and their statistical measurements

	Class_1	Class_2	Class_3	Class_4	Class_5
Area Count	2152	2349	3097	3609	4024
Area	30327	24476	19167	16632	14217
Mean	14.09	10.41	6.18	4.6	3.5
St.Dv.	165	81.18	35.72	30.42	17.6
Range	4219	1843	1070	1308	612

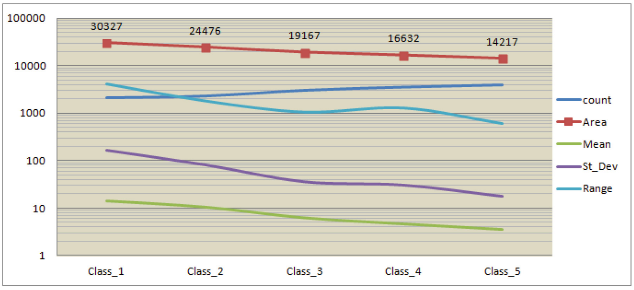


Fig. 8. Class wise extracted area and their statistical measurements.

In Fig. 8, the area of Class_1 (Elevation from 0 to 3.9 m) spread in 30327 square meters which is the highest one and Class_5 has 14217 square meters with lowest area.

From Fig. 9, it is observed that majority of villages are located in nearby coastal areas in India. The villages are shown in red color points are located in just 0 to 3.9 m of elevation. The orange colored points are lies between 4.0 to 7.9 m and yellow points found within 8.0 to 11.9 m. The green colored points are of 12.0 to 15.9 m and blue points are found within the areas of 16.0 to 20.0 m of elevation.

The class wise total number of clustered villages are extracted from the database and shown the following Fig. 10.

From the above Fig. 10, it is found that the major number of villages i.e. 760 belongs to class ‘Class_1’ which are located very close to the seacoast and are on very short/lowest land elevation. The ‘Class_2’ villages are 686 in numbers which are lies between the 4.0 to 7.9 m of elevation, and 474 villages belongs to class ‘Class_3’ are between 8.0 to 11.9 m land elevation. There are 428 villages are found located between the 12.0 to 15.9 m of elevation are of ‘Class_4’, and 304 number of villages are observed within 16 to 20.0 m of land elevation are of ‘Class_5’.

The Fig. 11 showing list of coastal states and union territories on its x-axis denoted as GJ for Gujarat, MH for Maharashtra, GO for Goa, KA for Karnataka, KL for Kerala,

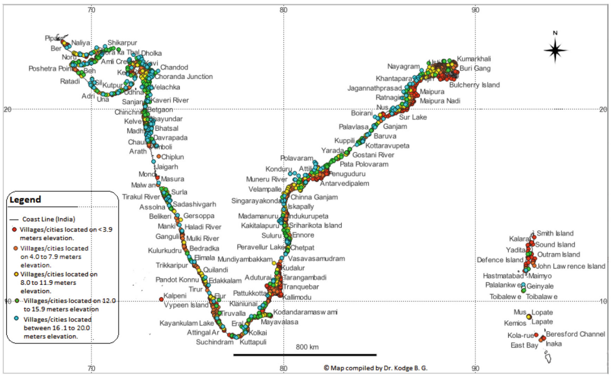


Fig. 9. Class wise extracted cities/villages of specified coastal area.

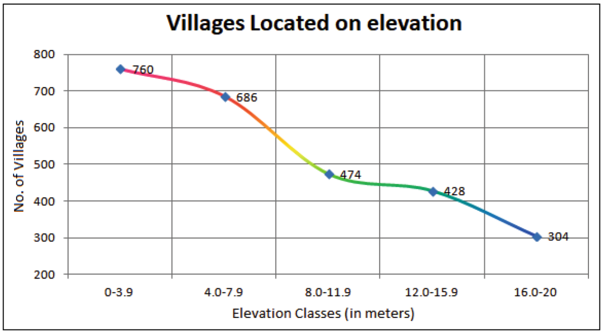


Fig. 10. Class wise extracted number of clustered cities/villages.

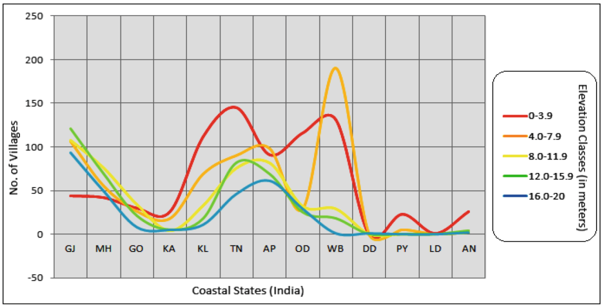


Fig. 11. State wise coastal cities/villages found within their specified classes.

TN for Tamilanadu, AP for Andhra Pradesh, OD for Odisha, WB for West Bengal, DD for Diu Daman, PY for Pondicherry, LD for Lakshadweep and AN for Andaman and Nikobar islands respectively. On y-axis we can see the number of coastal cities/villages associated with their colored graph lines belongs to Class_1 to Class_5. (Refer Table1 for more details).

The values shown in red colored line are belongs to Class_1 and are at high risk or danger zone/locations. These cities/villages are very close to the seacoast and are on very lowest land elevation. If the sea level increases to its 2 to 3 m of more height, then all these 760 villages will be found underwater within the oceans.

According the Fig. 11, the cities/villages of Class_1 in states of Kerala, Tamilanadu, Odisha and West Bengal are more in numbers and are at high risks (Red line). Similarly the orange line (Class_2) is found very high in the state of West Bengal followed by Andhra Pradesh, Tamilanadu and Kerala.

The cities like Mumbai, Thiruvananthapuram, Chennai, Visakhapatnam, Puri, Kolkata are also at high risk. All the shown cities/villages are needs to be move towards a safer location as far as the distance from seacoast and elevation is concern.

4 Conclusion

The proposed study is very important and will be helpful for the planning of location based projects like, formation of new rail lines/routes, installation of wind power terminals, building dams, road networks, coastal area monitoring and other land elevation related movements/activities. The global sea level is increasing day by day due to global warming and the proposed study will help to monitor the extracted coastal areas and their associated cities/villages (Classes 1 to 5) of India.

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