Development of a Soil Information System Using GIS for Urban Environmental Health and Risk Assessment: A Case Study of Tirupati Town, Andhra Pradesh, India

Dr. Hana Kim[1]
Prof. Giulia Conti[1]
[1] University of São Paulo, Department of Environmental Informatics and Public Health GIS Systems, São Paulo, Brazil

ABSTRACT

Geographical Information System is a very effective tool for capturing, displaying and analyzing geographically referenced data.GIS can be used for obtaining data at inaccessible locations, data visualization, data processing as well as preparation of post processing graphs and charts. This paper highlights creation of a soil resource inventory and database creation for thematic mapping using GIS.The results illustrate the vast potential of GIS towards soil mapping and effective management of soil data base. By using GIS, the users can produce the maps of soil classifications; obtain engineering information regarding soil type, an initial indication of soil properties.

Keywords: *Soil Properties, Information System, GIS.*

I. INTRODUCTION

The occurrence and distribution of soils in nature varies from location to location. The type of soil depends on the rock type, its mineral constituents and the climatic regime of the area. [1]. Different engineering property of soils has different influence on the civil engineering structures. They also depend upon each other.

Importance of Soil data

Soil index properties facilitate identification and classification of soils. The interactions among different geotechnical properties of soils can help the researchers while designing the foundations for different types of civil engineering structures. The various properties of soil such as specific gravity, particle size distribution, consistency limits and free swell index are discussed in this paper.

Specific gravity which is defined as the ratio of the mass of soil solids to the mass of an equal volume of water is an important index property of soils that is dependent on mineralogy or chemical composition [2] and also reflects the effect of weathering [3]. It is relatively important as far as the qualitative behaviour of the soil is concerned. It gives an idea about suitability of the soil as a construction material; the higher the value of specific gravity the more the strength. It is also used in calculation of void ratio, porosity, degree of saturation and other soil parameters [4]. The increase in specific gravity can increase the shear strength parameters, load carrying capacity and California bearing ratio [5, 6].

The particle size distribution curve gives an idea regarding the gradation of the soil. In mechanical soil stabilization, desired grain size distribution for any design mix is obtained using grain size distribution of each soil.[4]. It is widely used in classification of soils. Grain size distribution curves are used in the designs of various structures. Suitability of any soil for road construction, air fields etc are determined using particle size distribution curves. It is also used in the assessment of permeability, capillarity of soils and susceptibility to frost action.

The shape of the sand, whether rounded, sub rounded or angular will affect the shearing strength of soil [7]. Increase in shear resistance and more interlock is possible with Angular grains. Well-graded materials provide more contact area between grains than poorly graded materials. Porosity and spaces available for clay within the sand is an important parameter while considering the mixtures of clays and sands.

The properties of fine grained soils can be read from Consistency limits; accordingly fine grained soils can be used for various constructions. These limits are very important properties of fine grained soil. It includes Liquid limit, Plastic limit and Shrinkage limit. Liquid limit is used to classify fine grained soil and to understand the state of consistency of soil at the site. Liquid limit of soil can be used to predict the consolidation properties of soil while

calculating allowable bearing capacity & settlement of foundation. Liquid limit value of soil is also used to calculate toughness index of soil.

As plasticity index is the difference between liquid limit and plastic limit, it will not provide complete idea about soils but only some information about the characteristics of soil at best can be determined. Plasticity index and liquid limit are considered important in co-relating engineering properties, as they are influenced by identical factors like clay minerals exist in soil, Ions exist in pore water and stress history, i.e. whether normally consolidated or over consolidated, of soil deposit.

Plasticity index of soil depends mainly on clay content in soil. Soils having high plasticity index is an indication of more amount of clay. A rapid increase in PI is observed with decrease in particle size. Thus plasticity index is a measure of fineness of particles. Plasticity index and liquid limit provide us valuable information for soil classification.

For same plasticity index, It is observed that permeability, compressibility are increased and toughness and dry strength are decreased for an increase in liquid limit whereas for soils having same liquid limit, permeability is decreased and toughness and dry strength are increased and no change in compressibility for an increase in plasticity index. Soils having high plasticity index are considered clay and those having lower value are considered silt. In case of zero value, soil are considered to have little/no clay or silt and called non-plastic soil.

The Atterberg limits of a soil are used as an integral part of several engineering classification systems to characterize fine-grained soils. Also these limits are used directly in specifications for controlling soil for use in fills, and in semi-empirical methods of design. A wide variety of engineering properties of soils have also been correlated to the liquid limit, plastic limit, and plasticity index of soils (i.e. Compressibility, Permeability, and Strength).

The soils having high free swell index value may show considerable volume changes as compared to the soils having lower free swell index values. A free swell test provides a quick qualitative measure of expansiveness by determining the free swell index. The free swell index may be considered as a property of expansive soil. It reflects the potential of the soil for its expansion.

Need for digitization and development of Soil Information system using GIS

Soil surveys are now being created in digital format to utilize the power contained in GIS technology. The objective of the paper was to create a soil data base at regional level. GIS has shown a very important role in various aspects of geotechnical engineering to better manage and disseminate soils information.

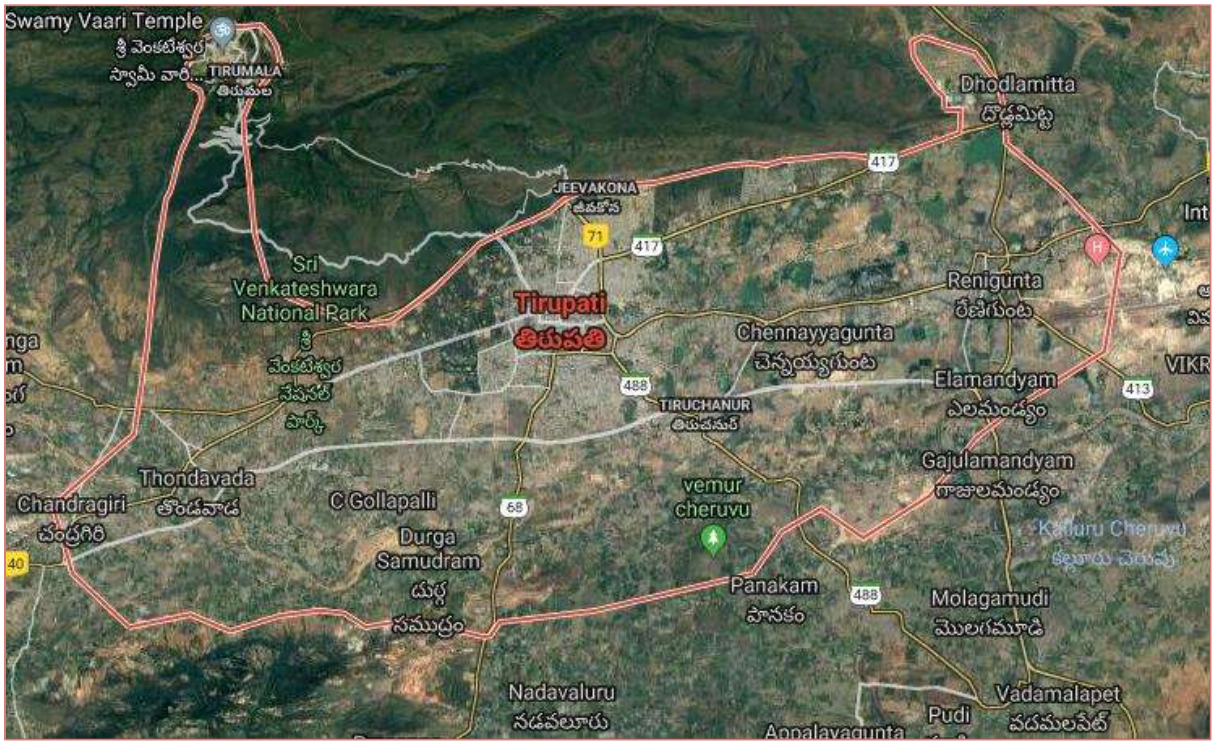
Soil is a heterogeneous material having variety of physical properties, which are not constant and varies from place to place. Soils are identified and classified based on the Index properties of soils and also helps the geotechnical Engineer in predicting the suitability of soils as foundation/construction material [8].In this paper, an attempt is made to map the important index properties of soil by using Geographic Information System (GIS). This will help all the geotechnical engineers for immediate decision making process about soil suitability as foundation and construction materials.

GIS can be used for data integration, data visualization and analysis, planning and data presentation. Data sources can be in variety of forms such as hard copy, electronic, maps, plans reports [9]. Integrating these data can require a significant effort.GIS as a tool can greatly improve the efficiency and effectiveness of these efforts.GIS provides tools for integrating these multiple data types (raster and vector data types, attribute data etc.)

After data has been migrated to GIS it can be used to visualize and analyze the site data. Data can be symbolized to graphically represent relationships and queried to filter out extraneous information. Spatial queries can be performed to identify the relationships between features and help to determine engineering conclusions. For example, which areas or localities are having more gravelly soil or identify the localities having liquid limit greater than 25, which are the localities having Specific gravity more than 2.6 etc.Maps that are produced can be used for dissemination of information.

II. STUDY AREA

Tirupati, one of the important Pilgrimage town in Andhra Pradesh has been selected as the study area. The soil samples were taken from various localities distributed across the Tirupati urban limits such as Tiruchanoor, Leela Mahal Theatre, Radio Station and adjoining areas like Renigunta and Avilala and Gajulamandyam.



Google Image of the Study Area

III. METHODLOGY

The following steps are involved in executing this work.

1) Collection of Soil Samples along with their location coordinates
2) Testing of soil samples for determining their properties.
3) Creation of soil information database (a-spatial data)
4) Creation of Spatial data based on Location coordinates and creation of boundaries.
5) Linking of Spatial data and a-spatial data.
6) Querying and display of results.

Soil samples have been collected from various locations in Tirupati town and various soil parameters such as Gravel(%),Sand(%),Silt+Clay(%),Liquid Limit(%),Plastic Limit(%),Plasticity Index(%),425µ passing, MLL,Free Swell Index(%),Specific Gravity(G), IS Classification are determined.

The latitude and longitude of Soil sample locations has been identified and marked as Point features in GIS. The entire study area is divided in to set of polygons from the sample points taken and the results of the Soil test are assigned to these polygons.

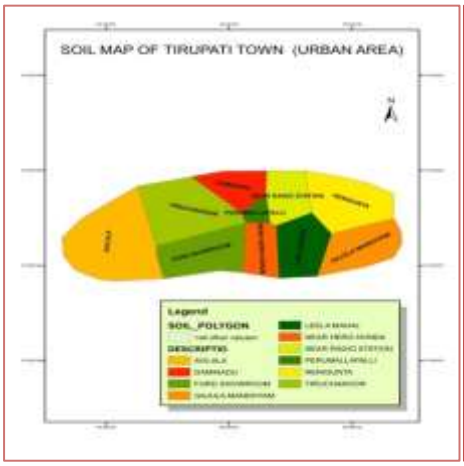
After creation of the soil database, various queries are performed to meet the project requirements.

IV. RESULTS AND DISUCSSIONS

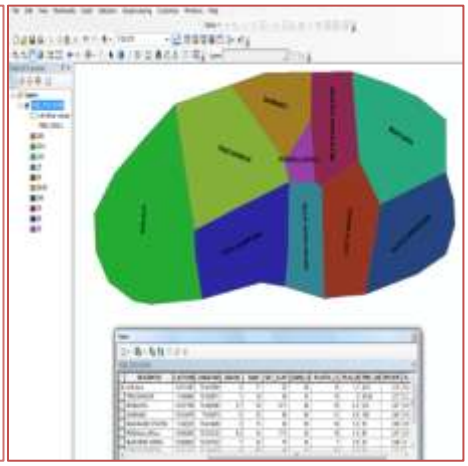
After creation of GIS database various queries were performed and various thematic maps were generated. Based on the above queries it becomes very easy to identify the required site meeting our requirements. Few queries which are performed as part of this work are as below:

1) Display the soil map based on IS classification.

2) Display the locations where the sand composition is more than 50%
3) Categorize the study area based on Specific gravity.
4) Find the localities where the liquid limit is more than 25

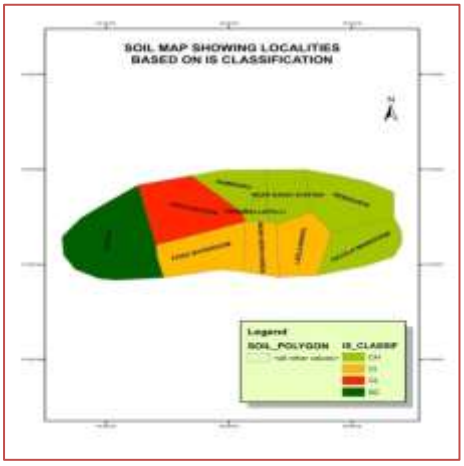


Soil Map of the study area



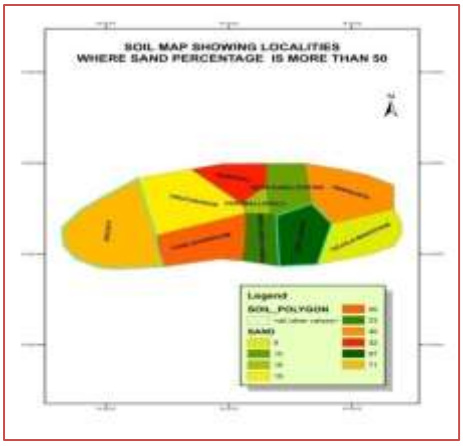
Map showing the spatial and A-spatial data

Query 1: Display the soil map based on IS classification



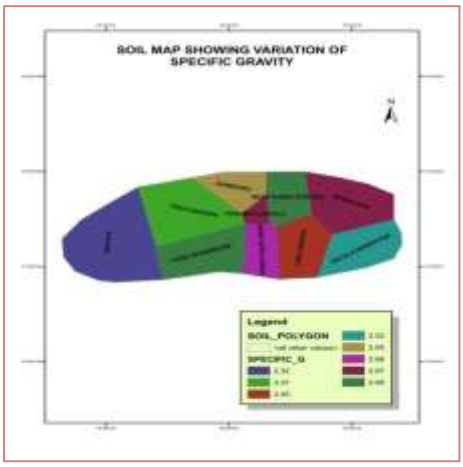
Map showing the classification based on IS classification

Query2: Display the locations where the sand composition is more than 50%



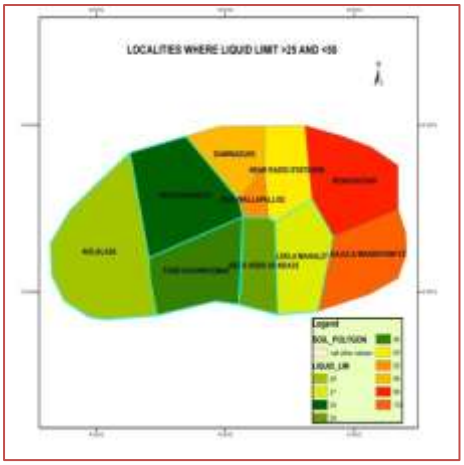
Map showing the classification based on sand content >50%

Query3: Categorize the study area based on Specific gravity



Map showing the soil classification based on Specific Gravity

Query4: Find the localities where the liquid limit is more than 25



Map Showing localities where liquid limit >25 and <50

V. CONCLUSIONS

GIS applications in Soil mapping plays an important role to understand the distribution pattern of similar types of soils [11]. Based on the above study the following conclusions were made

- Properties of Soil can be updated and maintained easily using GIS.
- Use of GIS aids in decision making of which localities are suitable for what type of constructions
- Proper Land use planning can be made by having Spatial and other relevant data of soils and derive maximum benefit.

REFERENCES

1. *Surendra Roy, Sanjeev Kumar Bhalla, Role of Geotechnical Properties of Soil on Civil Engineering Structures, Resources and Environment, Vol. 7 No. 4, 2017, pp. 103-109. doi: 10.5923/j.re.20170704.03.*
2. *Oyediran, A. and Durojaiye, H.F., 2011, Variability in the geotechnical properties of some residual clay soils from south western Nigeria, IJSER., 2 (9), 1-6.*
3. *Tuncer, E.R. and Lohnes, R.A., 1977, An engineering classification for basalt-derived lateritic soils., Eng. Geol., 4, 319– 339.*
4. *S. Prakash and P.K. Jain, Engineering Soil Testing, Nem Chand & Bros, Roorkee, 2002.*
5. *Roy, S. and Dass, G., 2014, Statistical models for the prediction of shear strength parameters at Sirsa, India., I. Journal of Civil and Structural Engineering., 4(4), 483-498.*
6. *Roy, S., 2016, Assessment of soaked California Bearing Ratio value using geotechnical properties of*
7. *soils., Resources and Environment., 6(4), 80-87.*
8. *Dafalla, M.A., 2013, Effects of clay and moisture content on direct shear tests for clay-sand mixtures, Adv. Mater. Sci. Eng., Volume 2013*
9. *Ramamurthy, T.N. and Sitharam, T.G. (2005). Geotechnical Engineering [Soil Mechanics], S. Chand.*
10. *Burrough P.A.(1986) Principles of Geographical Information Systems for Land Resources Assessment, Oxford University Press, New York.*
11. *Maji, A.K et all.(1998b) Dissemination of Soil information for district level land use planning using GIS, GIS India,7,21-25,Hyderabad.*
12. *Maji, A.K and G.P Obi Reddy (2009)" GIS Applications in Soil Survey and Mapping "Soil Survey Manual, pp202-214.*