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Spatial Analysis in Mapping Soil Textural Class Name Based on USDA Soil Textural Triangle for Adami Tulu Jido Kombolcha District, Oromiya Region, Ethiopia

Tadesse Hunduma Banja
Ethiopian Biodiversity Institute, P.O. Box : 3726, Addis Ababa, Ethiopia.
Corresponding author email id: yhundumab@gmail.com

***Abstract* – This study employed the integration of spatial Analysis tools to map soil textural class names from the laboratory analysis results of soil textural proportions such as sand, silt and clay percentages based on USDA soil textural triangle classes' boundary definitions. The study has been done at Adami tulu Jido Kombolch District, Oromiya Region, Ethiopia. In order to represent whole study area, it has been divided into 129 mapping units based on soil forming factors then surface soil samples were collected at depth of 0 to 20 cm from each mapping units. The soil samples were analyzed at laboratory for textual proportions by hydrometer method; the results were used in spatial interpolation kriging and IDW to get continues surface maps for sand, silt and clay percentages. The surface maps were used as input layers to develop the twelve soil textural class names of USDA definitions in raster calculator of spatial analysis tool. As a result, in case of Kriging interpolation only two class names loam and sandy loam were generated which accounts 43.54 and 57.46% area share respectively. While employing IDW five textural class names were identified such as: sandy loam, Loam, Clay Loam, Loamy Sand and Silt but dominating classes are Sandy Loam and Loam totally covers more than 98 percent of the study area.**

***Keywords* – GIS, Raster Calculator, Soil Texture, Spatial Analysis and USDA.**

I. Introduction

Soil texture is a vital variable that reveal a number of soil properties such as soil permeability, water holding capacity, nutrient storage and availability, and soil erosion (Yaser Safari et al. 2012). In addition, the soil texture has effect on soil microbial activities; (Sugihara soh et al. 2010) reported that soil microbes have more considerable impact on tropical sandy soil than on clayey soil in performing as a nutrient pool and decomposers. According to (Huerta, E., & van der Wal, H., 2012) contents of soil clay and silt were correlated to earthworm's abundance as well as the abundance of hymenoptera was related to silt content.

Mapping the soil textural class name by using discrete soil point dataset as continues surface map from sand, silt and clay proportion analyzed at laboratory, is very inferential for related soil properties. The investigation of spatial variability of soil texture at a detail scale is crucial for several activities like agricultural production and environmental management (Liao et al. 2013). However, estimation of soil texture was started with feel method which depends on interpretation by hand resulting high error in estimation (Gozdowski et al. 2015), currently it is at level of more reliable method to determine soil texture particle size analysis in laboratory as well as estimating from bands of remote sensing sensors (Tarik M et al. 2018).

Generating map of area in soil textural names based on the revised (USDA, 1999) soil textural class boundary definitions of twelve classifications such as sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay in continues map coverage for an area of land need somewhat composite implementation of spatial analysis and models. The soil mapping unit approach considers dominant components and some of minor components those influence the easily perceptible natural properties of soil and fix the textural class name based on mapping unit boundary. Digital Soil Map (DSM) used spatial autocorrelation for prediction in geo-statistical interpolation techniques for modeling continuous properties for non-sampled locations (Ballabio et al., 2016).

In case of Adami Tulu Jido Kombolcha District, farmers and other stakeholders frequently inquire the basic soil information about their farm land for purpose of irrigation and fertilizer managements of their agricultural practices. Hence it was very tedious to do at once for all area of the whole District which sum up to 109451 hectares, in response Batu Soil Research Center had planned to map soil fertility status and collected about 129 soil samples from unique mapping units for each sample. For all 129 sample points soil data, they analyzed at laboratory for soil textural proportions of sand, silt and clay in percentage but not mapped as revised USDA soil textural triangle class boundary definitions. Hence to create map as USDA definitions, integration of geo-statistical interpolation and raster calculator is vital approach in spatial analyst tool.

The predicting values for non-sampled location change the discrete point data to continuous information of the total area. Samples points were from many composite points and central to mapping unit, the adjacent mapping units were divided based on factors; slope, aspect, parent material, land use, drainage density, rainfall and temperature of the study site. The textural percentage values should be used in order to determine the soil textural names as the boundary definitions to infer properties of the soil on the area further to use the information for any land management practices particularly agriculture. Hence the study is aimed to Develop Model in ArcGIS Model builder for soil textural class map preparation and to map soil texture class Percentage and class name for Adami Tulu Jido Kombolcha District based on USDA soil textural triangle class boundary definitions. The study also helps in using the model developed here to use for other study areas by only changing the input datasets of specific area or process extent.

II. Materials and Methods

2.1. *Description of Study Area*

2.1.1. *Location*

The study was conducted in Adami Tullu Jido Kombolcha District of East Showa zone, Oromiya Region, which is 170km to south west of the capital city Addis Ababa, Ethiopia. The extent of the study area ranges from 380 05’10’’ to 380 48’ 43’’ the east and 070 37’50” to 080 04’ 30” to the North. The location map of the study area is as in Figure 1.

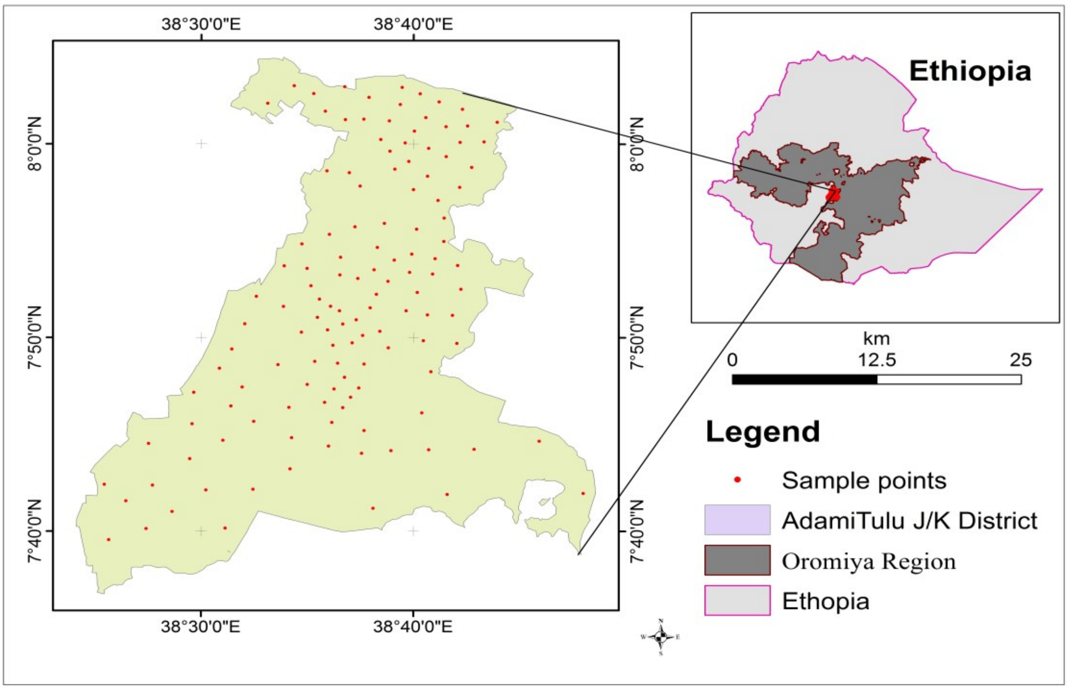

Fig. 1. Location Map of Study Area.

2.1.2. *Elevation*

The study area has minimum elevation of 1666 meters and maximum elevation 2193 meters with average of 1700 meters above sea level which could be categorized as mid land.

2.1.3. *Slope*

The slope ranges from 0 to maximum slope 61.12 percent. As a result, the study area is mainly dominated by flat and gentle topography, thus average slope of the study area is 1.67 percent.

2.1.4. *Climate*

As climate referred the two major elements are rainfall and temperature of the area both has their unique measurement and description method. In Batu, the climate is warm and temperate. The summers here have a good deal of rainfall, while the winters have very little. This location is classified as Cwb by Koppen and Geiger. The average annual temperature is about 19.3 °C in Batu. In a year, the average rainfall is about 837 mm.

2.1.5. *Temperature and Precipitation*

April is the warmest month with an average temperature of 20.4 °C while December is the coldest month with average temperature of about 17.6°C. The precipitation varies 141 mm between the driest month and the wettest month. Throughout the year, temperatures vary by 2.8 °C.

2.2. *Methods*

2.2.1. *Soil Sample Collection*

2.2.1.2. *Mapping Unit Delineation*

Based on the Parent materials, Topography, drainage Density and land use/cover the district divided into 129 mapping units.

2.2.1.3. *Central Point Generation*

For each mapping unit central point/ centroids was generated and its coordinates was also determined by ArcGIS software. The coordinate points were used by uploading to hand held GPS in order to collect soil sample surrounding the central point.

2.2.1.4. *Composite Soil Sample Collection*

From each mapping unit one representative composite soil sample by mixing 20 to 30 sub-composite random samples surrounding the center point within the mapping unit was collected and taken to laboratory analysis. Totally, 129 soil samples were collected to represent the whole study area.

2.2.1.5. *Laboratory soil sample analysis*

For each sample sand, silt, and clay percentage was determined by Hydrometer method at Batu SoiL Research Centre Laboratory.

2.3. *Data Analysis*

Soil Sample Analysis (Sand, Silt & Clay) percentage results descriptive statistics were summarized by attribute table statistics in ArcGIS.

2.3.1. *Geo-Statistical Interpolation*

The laboratory results of soil textural separate (Sand, Silt & clay) percentage were interpolated to create continuous surface map in Spatial Analyst tool of ArcGIS software. The kriging and IDW method were used to statistically ignore out layers results and include actual values in the map respectively. The outputs of both interpolations were as indicated in Figure 2 (A, B & C).

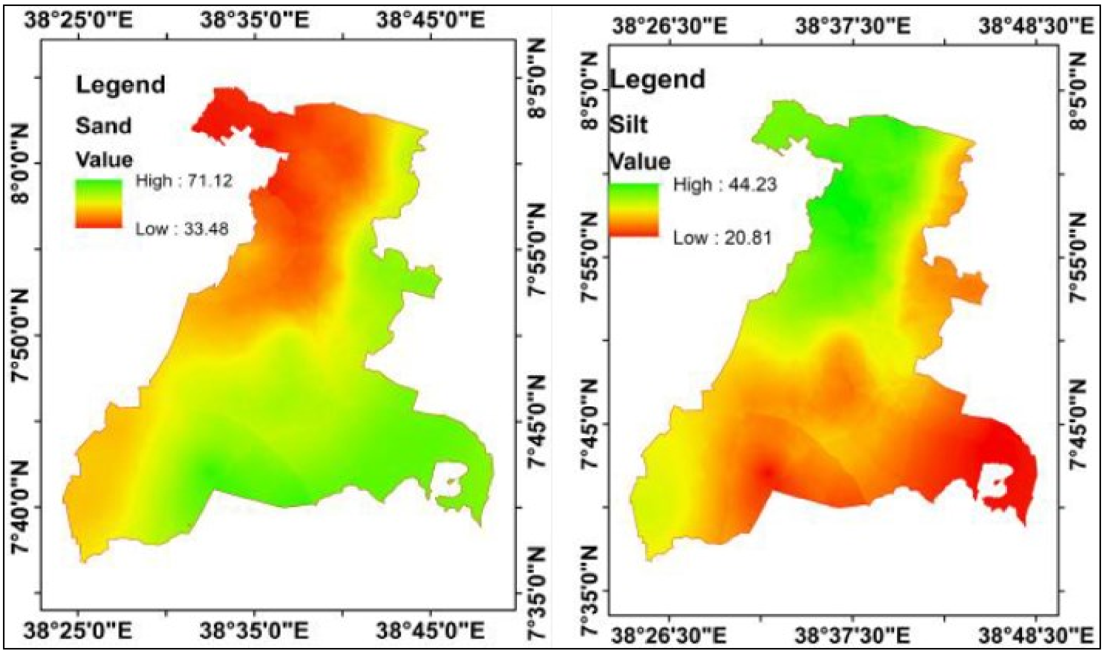

Fig. 2A. Soil Textural class percentage map.

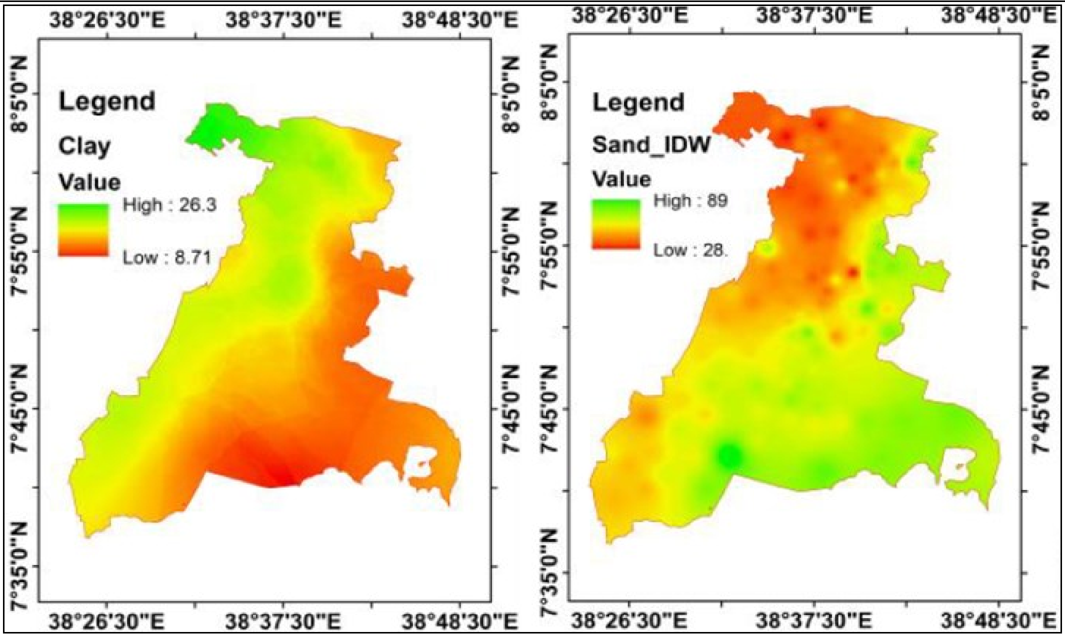

Fig. 2B. Soil Textural class percentage map.

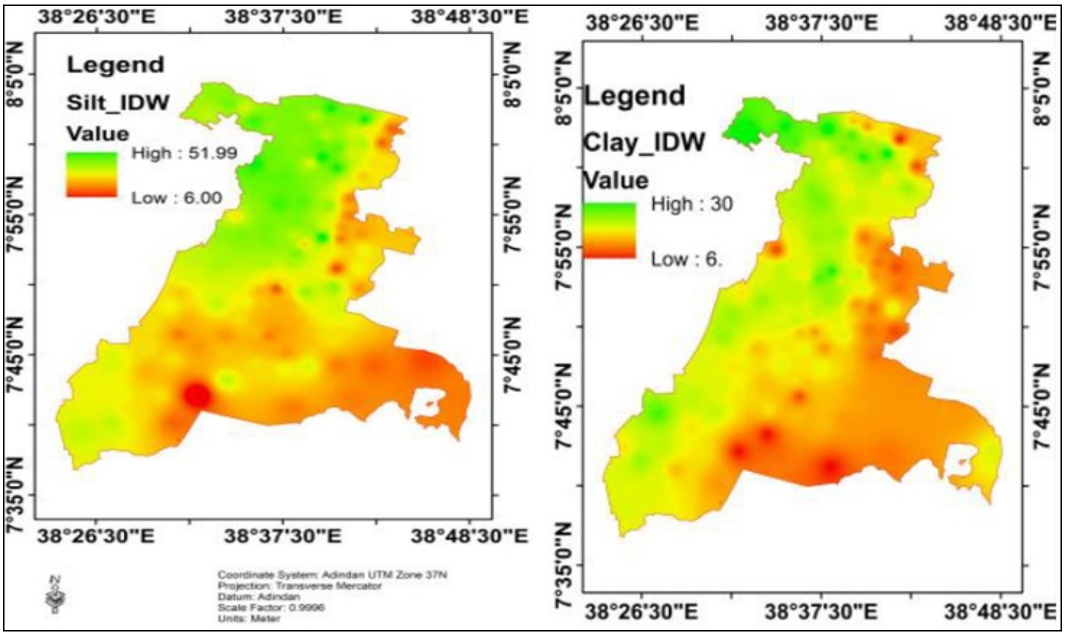

Fig. 2C. Soil Textural class percentage map.

2.4. *Modeling and Mapping the soil Textural Class Names*

Soil textures are classified by the fractions of each soil separate (sand, silt, and clay) present in a soil. In this study based on USDA soil textural triangle classes revised boundaries, from interpolated vales of Sand%, Silt% and clay% percentage continuous raster map, soil textural classes name was developed by creating model in Model builder of ArcGIS to combine the percentages. The triangle has 12 different soil textural classes that are associated with various proportions of sand, silt, and clay. The dominant particle within each class provides the soil its characteristic texture. The twelve classifications are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. For each class the following definitions were applied in Raster Calculator of Map Algebra by Spatial Analyst tool of ArcGIS software Table 1.

Table 1. Revised Texture Class Definitions of USDA.

No	Textural Class Name	Texture Class Definitions
1	Sand	A) Sand > 85% and Silt + (1.5 * Clay) < 15%
2	Loamy sand	A) Sand > 70% and Sand < 91% and Silt + 1.5 * Clay >= 15% and silt + 2 * Clay < 30%
3	Sandy loam	A) (Clay >= 7% and Clay < 20% and Sand > 52% and Silt + 2 * Clay >= 30%) or B) (Clay < 7% and Silt < 50% and Silt + 2 * Clay >= 30%)
4	loam	A) Clay >= 7% and Clay < 27% and Silt >= 28% and Silt < 50% and Sand <= 52%
5	Silt loam	A) (Silt >= 50% and Clay >= 12% and Clay < 27%) or B) (Silt >= 50% and Silt < 80% and Clay < 12%)
6	Silt	A) Silt >= 80% and Clay < 12%
7	Sand clay loam	A) Clay >= 20% and Clay < 35% and Silt < 28% and Sand > 45%
8	Clay loam	A) Clay >= 27% and Clay < 40% and Sand > 20% and Sand <= 45%
9	Silt clay loam	A) Clay >= 27% and Clay < 40% and Sand <= 20%
10	Sandy clay	A) Clay >= 35% and Sand > 45%
11	Silt clay	A) Clay >= 40% and Silt >= 40%
12	Clay	A) Clay >= 40% and Sand <= 45% and Silt < 40%

Sources: https://www.nrcs.usda.gov

2.5. *Model used to Run USDA Definitions in ArcGIS Model Builder*

The following flow diagram was used to run the Geostatistical interpolation and evaluate the input layers as revised USDA soil textural triangle classes name boundary definition Figure 3.

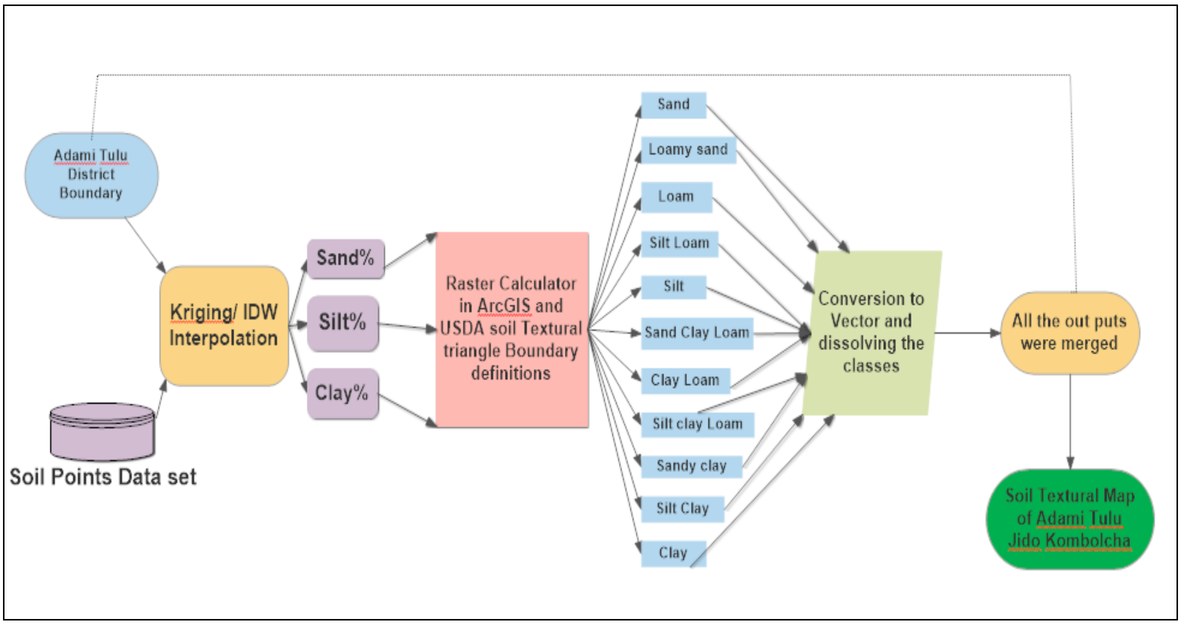

Fig. 3. Flow Diagram for Soil Textural Classes Name Mapping.

III. Results and Discussion

3.1. *Soil Analysis Results*

The values of point soil dataset textural proportions are summarized as in Table 2 below Sand % ranges from 28 to 88 with mean of 50 percent, Silt% ranges from 6 to 52 with mean of 33 percent and Clay % ranges from 6 to 30 with average of 17 percent.

Table 2. Textural Class Percentage Summary Statistics.

Parameter	Sand%	Silt%	Clay%
Minimum	28	6	6
Maximum	88	52	30
Mean	50	33	17
Standard Deviation	11.73	8.22	5.26
Number of samples	129	129	129

3.2. *Soil Interpolation Results*

The interpolation results of continuous surface sand, silt and clay proportion are as indicated in figure 2. In Kriging interpolation sand ranges from 33.48 to 71.12% with mean value of 52.95%, Silt ranges between 20.81 to 44.23% with average of 30.81% and Clay ranges from 8.71 to 26.30% having average of 16.46%. In the IDW (Inverse Distance weighted) interpolation sand ranges from 28.00 to 89.00% with mean value of 52.12%, Silt ranges between 6.00 to 52.00% with average of 31.37% and Clay ranges from 6.00 to 30.00% having average of 16.51%. From the average values, notwithstanding minimum and maximum values dissimilarities, both interpolation methods values are almost similar.

3.3. *Map of Soil Textural Class*

After running the model developed for the study area, the soil textural class name maps were generated for study area as fulfilling the conditions employed in raster calculator from textural class boundary definitions for each class name. As the result by using kriging interpolation only sandy loam and Loam are dominating classes as indicated in Table 3 and Figure 4. The area coverage of Sandy loam is 61792.08 hectares which accounts about 57.46 percentage of study area while Loam textural class name cover 43.54 percent of study area which is 47658.46 hectares.

Table 3. Soil Textural Names Classes by Kriging Interpolation.

No	Name	Area (ha)	Area (%)
1	Sandy Loam	61792.08	56.46
2	Loam	47658.46	43.54
	Total	109450.55	100.00

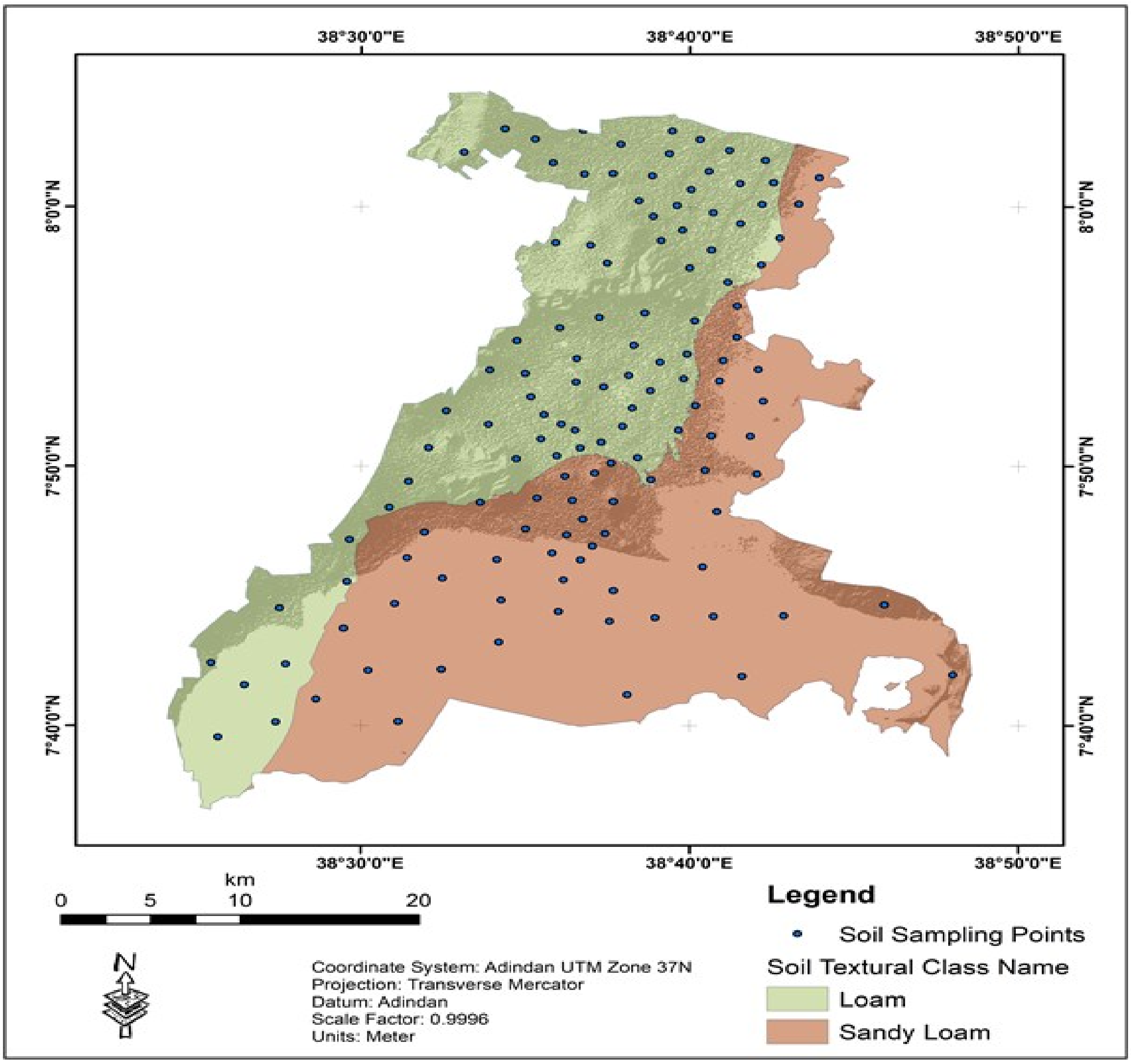

Fig. 4. Map of soil textural classes by Kriging.

While using the model developed by employing IDW interpolation about five textural class names were identified such as: sandy loam, Loam, Clay Loam, Loamy Sand and Silt Loam account 54.59, 43.87, 1.17, 0.35 and 0.02 percent of study area respectively. Dominating classes are Sandy Loam and Loam totally covers more than 98 percent of the study area; others are non-significant as compared to sandy loam and loam. As indicated in Table 4 and Figure 5. The area coverage of Sandy loam is 59751.38 hectares as well loam is 48015.96 hectares, thus summed up about 98 percent of the study area.

Table 4. Soil Textural Names Classes by IDW Interpolation.

No	Name	Area (Ha)	Area (%)
1	Clay Loam	1277.06	1.17
2	Loam	48015.96	43.87
3	Loamy Sand	388.17	0.35
4	Sandy Loam	59751.38	54.59
5	Silt Loam	17.98	0.02
	Total	109450.55	100.00

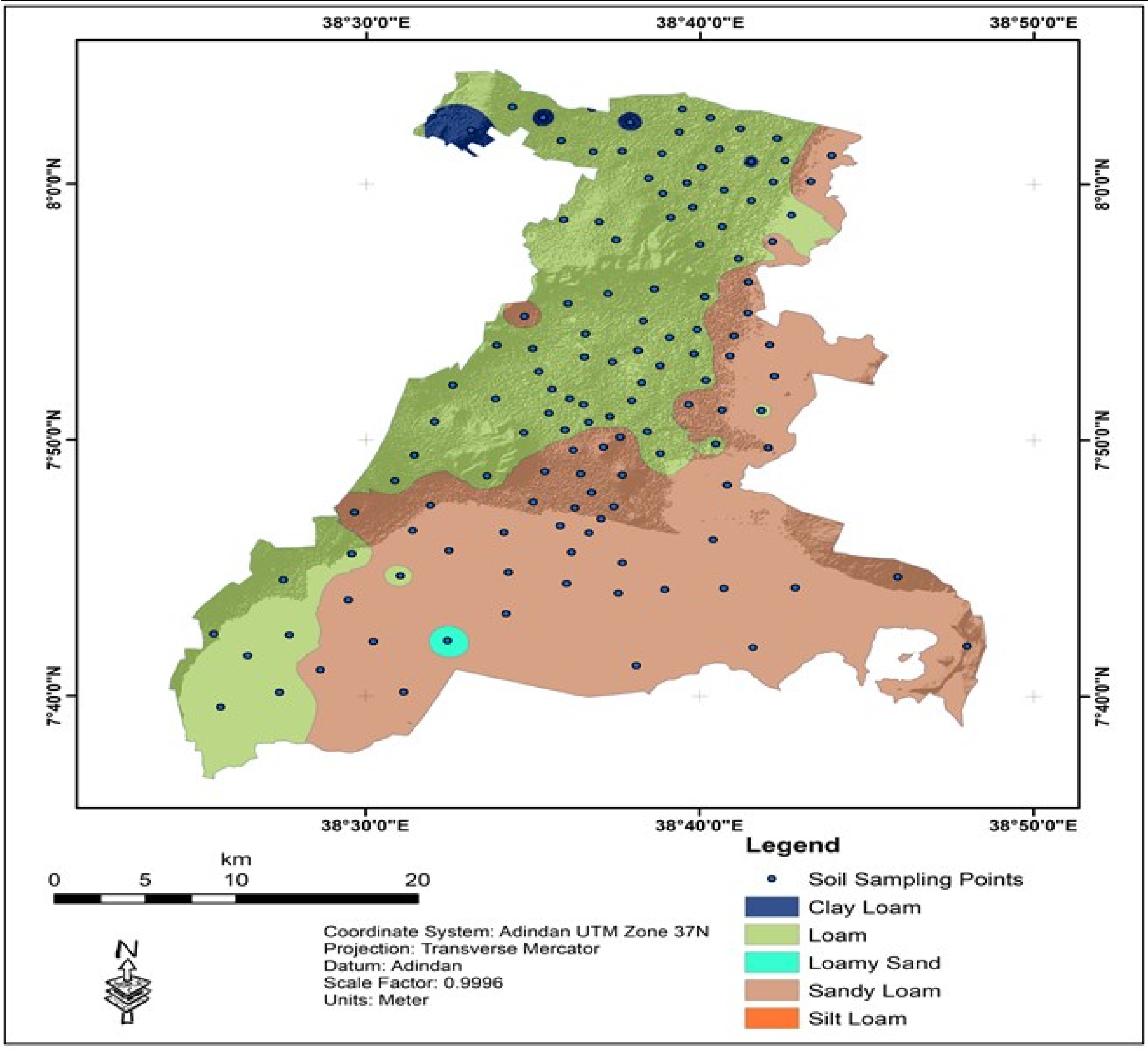

Fig. 5. Map of soil textural classes by IDW.

IV. Conclusion

The study has been done at Adami Tulu Jido Kombolch District, Oromia Region, Ethiopia. It employed the combination of Spatial Analysis tools to map soil textural class names from the laboratory analysis results of soil textural proportions such as sand, silt and clay percentages based on USDA soil textural triangle classes' boundary definitions. The study area has been divided into 129 mapping units from which surface soil samples were collected and analyzed at laboratory for relative textual proportions by hydrometer method. The results were used in spatial interpolation kriging and IDW to get continues surface maps for sand, silt and clay percentages. The interpolated surface maps were used as input layers to evaluate for the twelve soils textural class names of USDA definitions in raster calculator of spatial analysis tool. The results revealed in both interpolation methods only two class names loam and sandy loam were dominating classes of the study area.

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AUTHOR'S PROFILE

First Author

Mr. Tadesse Hunduma Banja was born at Wine Roge, Ethiopia on December, 21, 1981. His Educational *Backgrounds* are: MSc in Geoinformation Science from Addis Ababa University, Addis Ababa, Ethiopia. He has B.Sc. in Land Resources Management & Environmental Protection (Soil and water conservation) from Mekelle University located in Mekelle, Ethiopia. He has also BA Degree in Pure Economic from Haramaya University. He had worked as GIS and Cartography Associate researcher-II in Oromia Agricultural Research Institute. Currently he is working as GIS Associate Researcher-II at Ethiopian Biodiversity Institute. In the past he had served on Position soil researcher. Mr. Banja. T.H. had published a book *titled* GIS and Remote Sensing based Fertilizer suitability mapping for wheat at Lume Watershed, Ethiopia: LAMBERT academic publishing in year 2014. Further he did more than five publications at different publishing organization.