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Developing a Town Based Soil Database to Assess the Sensitive Zones in Nutrient Management

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***Abstract*—**For this study, a town based soil database created in Gümüşçay District of Biga Town, Çanakkale, Turkey. Crop and livestock production are major activities in the district. Nutrient management is mainly based on commercial fertilizer application ignoring the livestock manure. Within the boundaries of district, 122 soil sampling points determined over the satellite image. Soil samples collected from the determined points with the help of handheld Global Positioning System. Labeled samples were sent to a commercial laboratory to determine 11 soil parameters including salinity, pH, lime, organic matter, nitrogen, phosphorus, potassium, iron, manganese, copper and zinc. Based on the test results soil maps for mentioned parameters were developed using remote sensing, GIS, and geostatistical analysis. In this study we developed a GIS database that will be used for soil nutrient management. Methods were explained and soil maps and their interpretations were summarized in the study.

***Keywords*—**Geostatistics, GIS, Nutrient Management, Soil Mapping.

I. Introduction

AGRICULTURAL inputs and outputs must be balanced in amount basis for a sustainable production. Disruption of the balance causes extra cost for production and nutrient accumulation [1].

Nutrients are crucial agents in crop production and yield. Environmental pollution is another concern in nutrient management. Therefore, each nutrient must be assessed based on its movement capabilities in soil and plant uptake potential [1]. There are two kinds of nutrient sources in intensive crop production including organic and mineral originated [2]. Farm manure is the most common source for the organic nutrients, which are not useful for direct intake and must be interact with soil organic matter [3], [4]. On the other hand mineral nutrients (commercial fertilizers) are readily available for crops [5]. Based on the soil conditions, crop to be produced and nutrient management skills of the producers, accumulation and lack of nutrients in the soil may create major problems [6].

Manure is a good source of nutrients including nitrogen (N), phosphorus (P_2O_5), potassium (K_2O), iron, manganese, copper, and zinc [2]. However, some of these nutrients are in organic form and need to be mineralized before plant uptake [3], [4]. On the other hand mineral fertilizers are in inorganic form and ready to use for plants [5]. Both of the nutrient sources need a proper management for application. Otherwise some accumulation and lack of nutrients are may become a major issue [6].

Agricultural nutrient management requires delicate calculations and accurate data [7]. One of the most important data is current amount of nutrients in soil. Laboratory analysis of soil samples, taken from the fields, determines nutrient status. However, the amount varies as the soil profile changes. Gathering more samples increase precision but also increase cost and labor [7]. Some estimation methods which use empirical calculations can be used for reducing the sample number.

Geostatistical analysis, a method in Geographic Information Systems (GIS), is used to develop a town based nutrient database. According to database, classified nutrient and soil parameter maps are generated.

II. Material and Methods

A. Study Area

Gümüşçay District is located northwest of the Biga Town, Çanakkale, Turkey (Fig. 1).

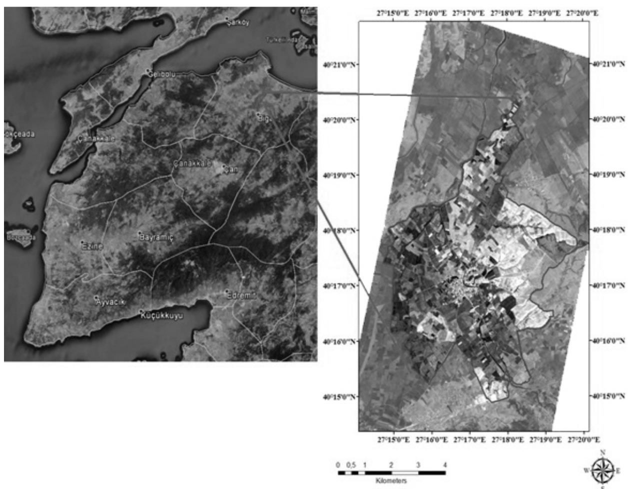

Fig. 1 Gümüşçay District location

According to 2011 Turkish Statistical Institute (TUİK) data district has 35,000,000 m^2 surface areas of which 29,000,000 m^2 is agricultural land [8]. As the land use changes annually, data need to be updated. For this reason, land use land cover map, generated by [9] (Fig. 2), from Landsat 8 satellite image

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(acquired on May 18, 2013), was modified for the study area. Updated agricultural land area from the classification map is 2,016,000 m^2 less than the TUİK data (Table I).

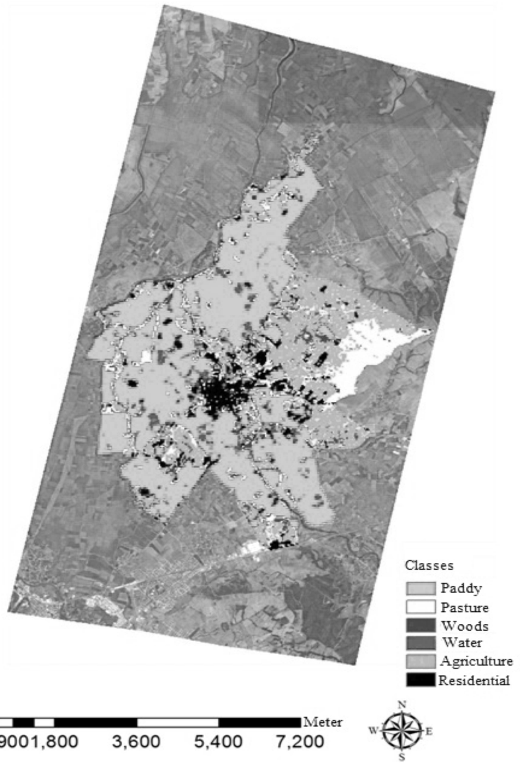

Fig. 2 Gümüşçay District land use land cover map (Modified from [9])

Field area and accuracy analysis results are given in the Table I.

TABLE I
CLASSIFICATION MAP LAND AREA VALUES

Class Names	Area (m^2)	Proportional (%)	Accuracy Analysis Results (%)
Paddy	19,763,620	56.05	75.76
Pasture	3,872,890	10.99	78.95
Woods	787,520	2.23	84.38
Water	791,120	2.24	100
Agriculture	7,219,870	20.48	85.51
Residential	2,822,860	8.006	90.63
Overall	-	-	84.77
Kappa Statistic	-	-	81.20

District population is 2078 and the 90% of the population employed in agriculture [8].

Digitized parcel and district border maps were provided from the Directorate of Cadaster (Fig. 3).

All of the generated and used maps have Universal Transverse Marcator (UTM) projection and 1984 World Geodesic (WGS84) coordinate system.

B. Satellite Image

Satellite images which are used for planning before field survey and visualition were obtained from the Google Earth software and coordinated by reference points.

Fig. 3 Digitized parcel and district border map

C. Kriging

Simple Kriging Technique was used as the geostatistical analysis method in ArcGIS 10 software (ESRI, Redlands CA, USA).

Kriging technique is an interpolation tool in geostatistics which uses weighted values of reference points. Beyond the deterministic interpolation, kriging technique uses multifactorial calculations to assess more realistic results. Within the scope of land characteristic tendency, kriging determines a weight to simulate the area [10].

Simple kriging uses the (1) to estimate unknown point values [10].

$$Z^*(x) = \sum_{i=1}^{n} \lambda_i Z(x_i) \quad (1)$$

where, Z(xi) is observed Z variable on xi point, and Z*(x) is estimated Z variable on x point, x is coordinates of estimated point, x_i is coordinates of observed i point, n is rate value of estimation, and λ_i is weight of observed I point.

Estimated point must have a weight factor (λ) (2) according to surround observation points number and ranges [11]:

$$\lambda_i = \frac{D_i^{-a}}{\sum_{i=1}^{n} D_i^{a}} \quad (2)$$

where, Di is range between de observed i point and interpolation zone, and α is range weight.

D. Method

Study components and progress is explained in Fig. 4.

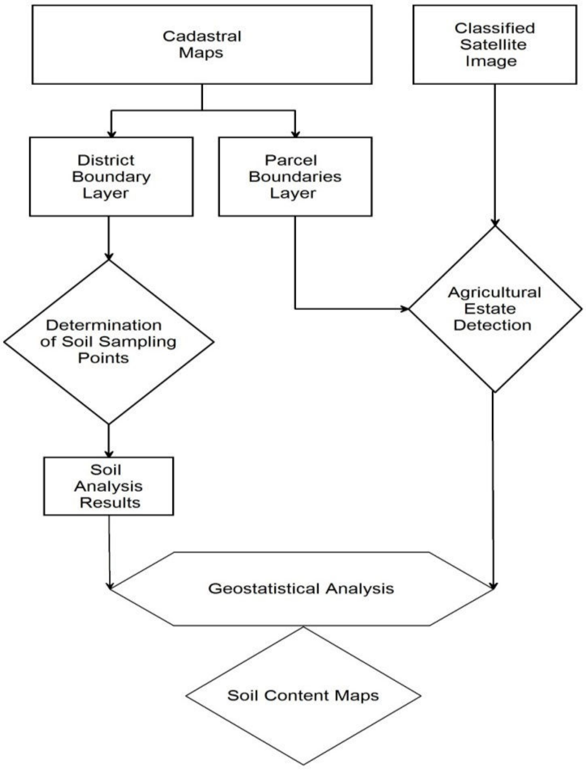

Fig. 4 Study Flowchart

E. Soil Sampling

Grid method for the sampling point determination, minimize the error rate [12]. A square grid of 500 meters side length was generated. Generated grid was located over the digitized map and coordinated as original map (Fig. 4).

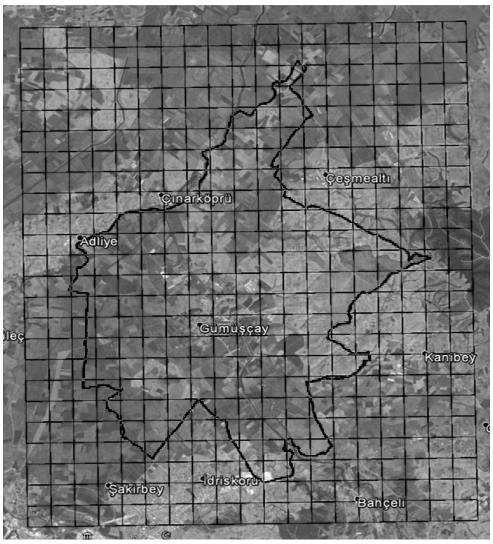

Fig. 5 Digitized grid frame

Within the cadastral boundaries, sampling points was chosen to represent the whole soil type in related square. Total of 124 sampling point marked on map.

Determined sampling points loaded to handheld Global Positioning Systems (GPS) via software interface (Fig. 6). Handheld GPS units have 30-cm-precision under proper conditions.

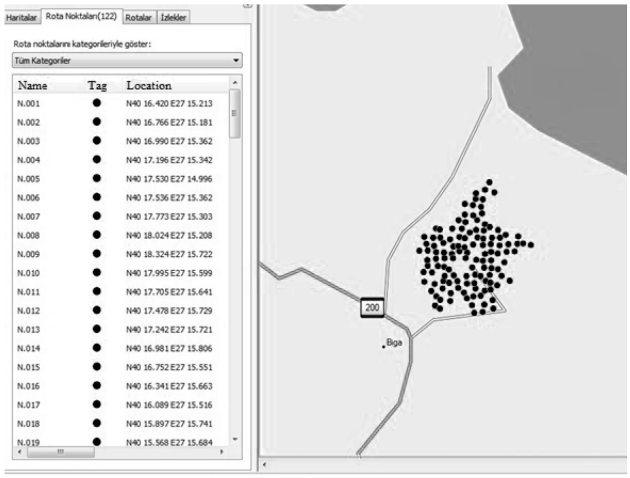

Fig. 6 Coordinated soil sampling points

All of the soil sampling procedure completed between April 25 and May 5, 2013. Samples were taken with a shovel from 15 cm depth and sealed in sampling bags before storing in icebox.

F. Soil Samples Analysis

Soil samples were sent to a commercial laboratory to be analyzed. Table II shows the methods used in analysis.

TABLE II
SOIL SAMPLES ANALYZE METHODS

Analysis	**Method**	**Measurement Uncertainty**	**Unit**
Saturation	Richards, 1954 [13]	1.609	%
pH	Richards, 1954 [13]	0.02	-
Total Salt	Richards, 1954 [13]	0.0007	%
Lime ($CaCO_3$)	Allison & Moodie, 1965 [14]	0.11	%
Organic Matter	Jackson, 1962 [15]	0.0007	%
Total Nitrogen (N)	Kjeldahl	0.0007	%
Phosphor (P_2O_5)	Olsen et al., 1954 [16]	-	kg/1000m^2
Potassium (K_2O)	Jackson, 1958 [17]	-	kg/1000m^2
Iron (Fe)	Lindsay & Norvell, 1978 [18]	0	ppm
Manganese (Mn)	Lindsay & Norvell, 1978 [18]	0	ppm
Copper (Cu)	Lindsay & Norvell, 1978 [18]	0	ppm
Zinc (Zn)	Lindsay & Norvell, 1978 [18]	0	ppm

G. Geostatistical Analysis

Soil analysis results transferred to MS Excel to be used with GIS software. Raster and vector layers were joined and the kriging procedure applied for every parameter.

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III. Results and Discussion

A. Salinity

Salinity maps showed that salinity is not a concern for the study area (Fig. 7). According to harvested crop, critical limit is 0.15% [19] and none of the district fields exceeded it. Results are admissible except for the salt sensitive plants.

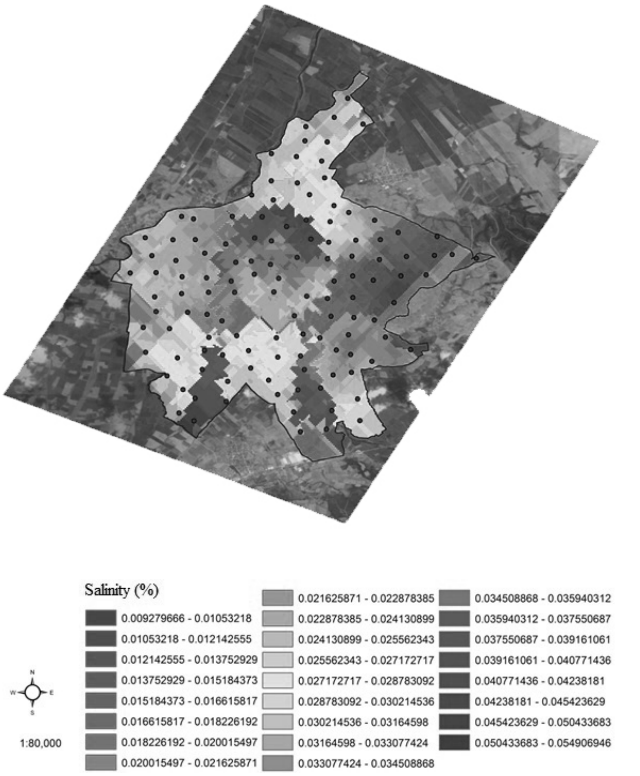

Fig. 7 Salinity Map

B. pH

The pH maps were examined in 7 classes (Table III). Distribution map showed that the 66% of fields were light alkaline, that were are affected by the rice production. Also, more than 18% were light acid. Pasture lands had acidic characteristic (Fig. 8).

TABLE III
pH Classes

pH	Class	Area (m^2)	Proportional (%)
<4	Very Strong Acid	1,240	0.003
4-5	Strong Acid	11,190	0.031
5-6	Mediocre Acid	2,991,490	8.479
6-7	Light Acid	6,696,670	18.982
7	Neutral	1,986,870	5.632
7-8	Light Alkaline	23,582,600	66.848
8<	Alkaline	74,600	0.021

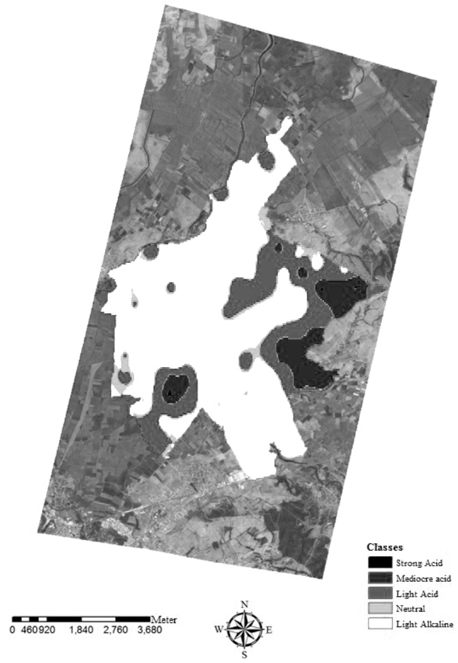

Fig. 8 pH map

C. Lime

Lime levels were investigated under 5 classes between 1% and 25% [19] (Fig. 9). However, the 84% of lands was between 1% and 5% levels. Resulting lime levels didn't affect soil salinity.

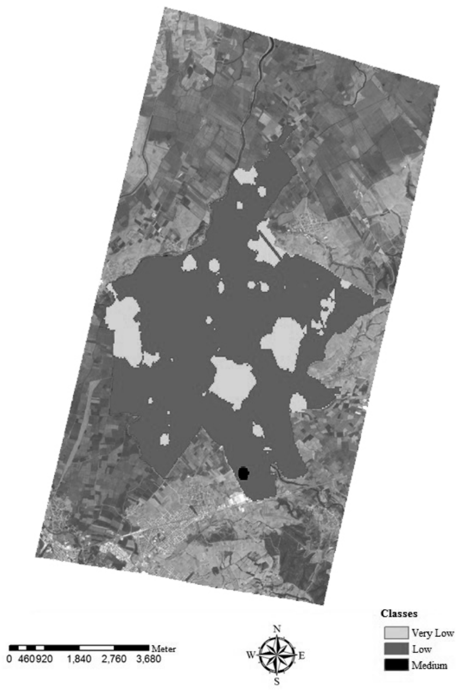

Fig. 9 Lime Map

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D. Organic Matter

Plant nutrients are converted to usable forms by various microorganisms in soil. Existence of microorganisms depends on the availability of organic matter. Therefore, reducing organic matter causes yield losses. Recommended organic matter content of a soil is between 3 and 4%. However, more than 99% of district soils have organic matter content of less than 2%.

Fig. 10 Organic Matter Map

E. Nitrogen

Nitrogen (N) is an essential element for vegetative parts of plants. For a fertile soil, between 0,04% and 0,4% N must be maintained [19]. District's soil had a minimum of 0,04% and maximum of 0,08% N content. So, there was no accumulation observed (Fig. 11).

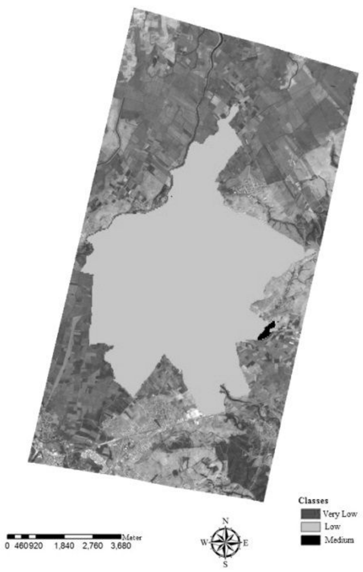

Fig. 11 Nitrogen Map

F. Phosphorus

Phosphorus (P) has a significant role on energy transfer metabolism. The element was assessed in 3 classes between 0.004 kg/m^2 and 0.012 kg/m^2 [16]. Generated map showed that 86% of field had P levels of in between these values (Fig. 12).

Fig 12 Phosphorus Map

G. Potassium

Potassium (K) level in plant determines fruit quality. The amount of potassium in soil varies between 0.03 kg/m^2 and 0.095 kg/m^2 [16]. Within the study area, K levels were in between 0.016 kg/m^2 and 0.043 kg/m^2. The current K condition is given in Fig. 13

Fig. 13 Potassium Map

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H.Micronutrients

Micronutrients are trace elements and the crop needs small amounts of them. For the study area, iron, manganese and copper are in adequate levels. But more than 99% of fields are lack of zinc (Fig. 14). Structural deficiencies can be observed according to zinc lack.

Fig. 14 Zinc Map

IV. Conclusion

Intensive crop production activities require increasing nutrient intake. Producers are aimed to use more mineral fertilizer to provide increasing crop needs. Manure originated nutrient use decreased as a result of its soil organic matter interaction needs. Therefore, non-recycled manure comes up as a waste problem. Likewise, over use of mineral fertilizer tend to nutrient accumulation in soil. Both accumulated mineral fertilizer and non-recycled manure constituted a threat for natural resources.

A comprehensive nutrient management is essential for sustainable production. Hence, the soil nutrient content is a major factor in this objective.

For this study, a town based soil database was created in Gümüşçay District of Biga Town, Çanakkale, Turkey. With the help of satellite images, 122 sampling points were determined and samples analyzed for 11 parameters. Distribution maps were generated by using geostatistical methods. Maps demonstrated the sensitive fields. Almost every field had lack of organic matter and needed to retreat with manure. Also, lack of zinc was found to be another concern within the study area.

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