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Characterization of Soil Resources Using Geographical Information System for Improved Crop Management

Hina Bansal[1], P.K. Sharma[2], Neetu Jabalia[1], Ankur Chaurasia[1], Malti Rani[3] and H. Pathak[3]

[1]Amity Institute of Biotechnology, Amity University, Noida, Uttar Pradesh, India
[2]Department of Microbiology, CCS University, Meerut, Uttar Pradesh, India
[3]Division of Environmental Sciences, IARI, New Delhi, India

Correspondence should be addressed to Hina Bansal, hinabansal@gmail.com

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Abstract There is a continued need for enhancing the productivity and keeping the natural resources sustainable. The biggest challenge for agriculture research and development is to suggest solutions that can best match the multiple and often-conflicting development objectives of various stakeholders, such as increased income and employment, improved natural resource quality and food security. Soil survey data and geographic information system (GIS) are important tools in land use planning and to improve crop management. Three villages, located in block Daurala, tehsil Sardhana and district Meerut of Uttar Pradesh were selected in the study. Data of crops and cropping systems were collected by survey of the individual farmers and their fields. A simulation model was applied to evaluate the effects of various conservation agriculture practices and their impact on crop yield and environment. The climatic data were recorded from the nearest weather station. The GIS maps were generated for soil properties. The maps can be used to improve and update the soil and fertilizer information for the villages and assist the planning process to provide comprehensive, accurate and visual information. The users can use these GIS maps for any future land-use planning and to improve crop management in their future agricultural research endeavors.
Keywords *GIS, Improved Crop Management, Land Use Planning*

1. Introduction

Increasing demand for land, coupled with limitations in its supply, is a major cause for conflicts over land use throughout the world. Agricultural activities are the major forms of land use, including row crops, rangelands, animal farms, aquaculture, and other agribusiness activities. Cropping activities involve soil and water manipulation through tillage and irrigation, thereby affecting runoff of water and groundwater resources. When used improperly, fertilizers and plant protection chemicals in agricultural operations can affect agricultural ecosystems. The biggest challenge for agriculture research and development is to suggest solutions that can best match the multiple and often-conflicting development objectives of various stakeholders, such as increased income and employment, improved natural resource quality and food security.

One of the greatest uses of Geographic Information Systems (GIS) today is in the area of agriculture and farming. One important fallacy in the area of GIS use in agriculture is that GIS is only used as a tool for precision agriculture applications. Balancing the inputs and outputs on a farm is fundamental to its success and profitability. The ability of GIS to analyze and visualize agricultural environments and work flows has proved to be very beneficial to those involved in the farming industry. From mobile GIS in the field to the scientific analysis of production data at the farm manager's office, GIS is playing an increasing role in agriculture production throughout the world by helping farmers increase production, reduce costs, and manage their land more efficiently. While natural inputs in farming cannot be controlled, they can be better understood and managed with GIS applications such as crop yield estimates, soil amendment analyses, and erosion identification and remediation.

GIS technology uses digital information, for which various digitized data creation methods are used. The most common method of data creation is digitization, where a hard copy map or survey plan is transferred into a digital medium through the use of a computer-aided design (CAD) program, and geo-referencing capabilities.

Soil survey data and geographic information systems (GIS) are important tools in land use planning and to improve crop management. The GIS maps helps in visualizing the information in new ways that reveal relationships, patterns, and trends not visible with other popular systems [1]. New ways of effective land-use planning include information management through GIS (Geographic Information Systems), computer simulation, and spatio -temporal data modeling on present land use, alternative scenarios, and assessment of consequences. Thus, it is essential to have exploratory land use analysis and planning, which can be applied for generating options for policy and technical changes for food security of the region as a whole, characterized by food production, income, employment and environmental impact assessment. There is a continued need for enhancing the productivity and also keeping the natural resources sustainable in the north-west India, an extremely important region in view of its share in the national food basket and also, the wide variation of the agro ecologies existing therein.

Under dry land and rainfed regions, the probability of occurrence of extreme climatic and episodic events is relatively higher, thus raising the need of evolving the methodology for dealing with these kinds of situations for sustaining the agricultural production. Hence, it was strongly felt to devise a methodology to link the relational database layers with simulation/decision tools for production estimates and land use planning. A prominent industrial town of the Meerut district of Uttar Pradesh is Daurala. Sugarcane and rice fields surround the town. Daurala region is thus an appropriate example of the challenge to develop production system that lead to increased future food security and to solutions that can increase farmers' income. The objectives of the present study were to generate resources inventory of bio-physical and socio-economic aspects of the selected farmers in three sample villages of Daurala town and generate bio-physical and socio-economic maps of the selected site by using GIS tool. These maps will provide information to the investigator and ultimately to the farmers for improved crop management including better land use-planning.

2. Material and Methods

The three villages covered under the study area, Panwadi, Bahrala and Ekloata, are located in Block Daurala, Tehsil Sardhana, District Meerut of Uttar Pradesh State. The villages are situated about 5-7 km from Daurala. The villages cover the total area of about 156 ha, 174 ha and 74 ha, respectively and have around 412, 313 and 161 families, respectively. Daurala is a prominent Block of the Meerut district of Uttar Pradesh, which comprises 51 villages undertaking farming. It is 15 km. from Meerut and 90 km. from Delhi. It is located on the Delhi-Deharadun National Highway. Being a commercial hub, Daurala is well connected by road, rail and airways. Bus service is very regular from Daurala to Meerut and Daurala to Sardhana and vice-versa. Daurala Railway Station and the Indira Gandhi International Airport are the nearest rail station and airport respectively. Daurala is located at 29.12Â° North latitude and 77.68 Â° East longitudes. It is located at a height of 223 meters (731 feet) above mean sea level. According to the 2001 census report, Daurala had a population of 10,684. Males constitute 54% of the population and females constitute 46% of the population. In Daurala, 17% of the population is less than six years of age. Daurala has an average literacy rate of 56% which is lower than the national average of 59.5%. Male literacy rate is 65% and the female literacy rate is 45%. The main occupation of the people is agriculture. Sugarcane and rice fields surround the town. The town has a big sugar mill known as the Daurala Sugar Works, which was established in the pre-independence era in the year 1932. This town of Meerut region with agriculture as the major occupation has been selected for the present study.

2.1. Collection of Data on Crops and Farm Management Practices

Data on crops and cropping systems were collected by survey of the individual farmers and their fields, literatures, statistical reports, survey reports and front-line demonstration reports (FLDs) published by state/district agricultural department. The growth rates for the inputs, area, productivity and yield of crops were worked out in the test districts. The existing crops and cropping systems in the district were analyzed, the yield gap analyzed and the reasons for the yield gap were worked out and the options to narrow down the gap were evaluated. The data were organized in such a way as to link with GIS.

The resource inventory of bio-physical and socio-economic aspects of the 10 selected farmers from each three sample villages have been generated in MS Excel. The data were categorized in the following categories:

- (i) Field data: Farmer's description, latitude, longitude and field area.
- (ii) Soil characteristics: Electrical conductivity, soil organic C content and pH.
- (iii) Crop characteristics: Seed rate, crop duration, yield, date of sowing, and basal doses of N, P and K.
- (iv) Mechanization characteristics: No. of tractors, No. of sprayers, No. of harvesters.

The data requirement also included labor availability, input prices, price of labor and price of produce. Soil samples collected from the sample villages were analyzed in the laboratory of Environmental Science Division, IARI, New Delhi, India for electrical conductivity, soil organic C content and pH.

2.2. Soil Organic Carbon, pH and EC

It is often useful to characterize a soil environment by measuring its organic C content, pH and electrical conductivity (EC). Estimates of total organic carbon are used to assess the amount of organic matter in soils. The determination of soil organic carbon was based on the Walkley and Black chromic acid wet oxidation method [2]. The pH affects the ability of plant roots to absorb nutrients. Calcium, phosphorus, potassium and magnesium are likely to be unavailable to plants in acidic soils, while plants have difficulty absorbing copper, zinc, boron, manganese and iron in basic soils. By managing soil pH, we can create an ideal environment for plants and often discourage plant pests at the same time. Crops need careful pH management to maintain their best quality and appearance. The wrong pH can lock nutrients in the soil, making them unavailable to plant roots. A pH that's too high or low can make disease, insect and weed problems worse.

Electrical conductivity (EC) is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. All the major and minor nutrients important for plant growth take the form of either cations (positively charged ions) or anions (negatively charged ions). These ions that are dissolved in the soil water carry electrical charge and thus determine the EC level of your soil and how much nutrients are available to crops. Knowing soil EC can guide making better farming decisions.

2.3. Geographic Information System (GIS)

In the present study, GIS was used for interpolation and extrapolation of data, which were collected from field or calculated through simulation model. It allows access to large amount of information quickly and efficiently. Any variable that can be located spatially, and increasingly also temporally, can be referenced using a GIS. Locations may be recorded as dates/times of occurrence, and x, y, and z coordinates representing, longitude, latitude, and elevation, respectively. These GIS coordinates may represent other quantified systems of temporal-spatial reference.

ArcGIS is a suite which is consisting of a group of geographic information system (GIS) software products produced by Esri. It is a system for working with maps and geographic information. It can be used for creating and using maps, compiling geographic data, analyzing mapped information, sharing and discovering geographic information in a range of applications and managing geographic information in a database. The system provides an infrastructure for making maps and geographic information available throughout an organization, across a community, and openly on the Web.

Hardware used for mapping was GPS (Global Positioning System) and data collection was on computer. MS Excel was used to create and organize the survey data. Positions from a global navigation satellite system (GNSS) like GPS, a survey tool, are directly entered into a GIS. In our study, data collection and field mapping was carried out directly with field computers (position from GPS). After entering data into a GIS, it required editing to remove errors in further processing. A GIS uses the processing power of the computer to transform digital information, gathered from sources with different projections and/or different coordinate systems, to a common projection and coordinate system. Various themes on major physico-chemical properties of soil such as, pH, EC and OC and fertilizer requirement for N, P and K, which were collected from field and transformed into spatial format where all the layers were geo-referenced and digitized in ArcGIS 9 for land use planning analysis.

3. Results and Discussion

The three sample villages covered under the study area, Panwadi, Bahrala and Ekloata, are located in block Daurala, tehsil Sardhana and district Meerut of Uttar Pradesh state. The growth rates for the inputs, area, productivity and yield of crops were worked out in the test districts. The existing crops and cropping systems in the district were analyzed, the yield gap analyzed and the reasons for the yield gap were worked out and the options to narrow down the gap were evaluated. The data was organized in such a way so as to link with GIS.

The model was applied to evaluate the effects of various agricultural practices on yield and environmental impacts soil in the rice-wheat system of the IGP on 10 farms from 3 villages in district Meerut. Mean annual rainfall of the study area varies from 650 mm to 970 mm, about 80% of which is received during June to September. Minimum and maximum temperatures of the region ranged from 4°C to 46°C. Soils are sandy loam to clay loam in texture and low to medium in organic matter content. Uttar Pradesh is predominantly a rice-wheat-growing state where wheat is grown by broadcasting after 6 to 7 dry-tillage operations and rice seedlings (3-4 weeks old) are transplanted in puddled fields after 2 to 3 dry-tillage and 1 to 2 wet-tillage operations. Data on conventional farmers' practices from farmer participatory trials were used as the model input to calculate the required amounts of fertilizer, irrigation water, biocides, human and machine labor, and seeds as well as N budget, biocide residue, and greenhouse gas emissions in the rice-wheat system under various resource conserving technologies. The climatic data were recorded from the nearest possible weather station.

A variety of themes on physico-chemical properties of soil such as, organic carbon (OC), pH, and electrical conductivity (EC) and fertilizer requirement for N, P and K, collected from the fields were transformed into spatial format. Then, the data were geo-referenced and digitized in ArcGIS for generating maps to enhance effective land utilization. The use of soil based-GIS facilitates the decision making process more precise, automated and efficient. It gives a dynamic product that serves to convert verbal communication into visual, hence prevents information overloading. These maps will help the farmers to improve and update soil and fertilizer information for crop management. Further, the soil based GIS maps will help to assist the planning process and additionally provides comprehensive, accurate and visual information. The users can use these GIS maps for any future land-use planning and to get better crop management in their future agricultural research endeavors. Such GIS maps have also been constructed for other rural areas which also help in decision making process [3, 4, 5]. The maps generated using GIS technique in the course of present investigation is as follows:

1. Organic carbon content in surface soil (0-15 cm) of Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh (Figure 1).
2. Electrical conductivity (EC) of surface soil (0-15 cm) of Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh (Figure 2).
3. pH of surface (0-15 cm) soil of Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh (Figure 3).
4. Application of N fertilizer in Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh (Figure 4).
5. Application of P fertilizer in Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh (Figure 5).
6. Application of K fertilizer in Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh (Figure 6)

4. Conclusion

In conclusion the resource inventory of bio-physical and socio-economic aspects of the 10 selected farmers from each of the three sample villages, Panwadi, Bahrala and Ekloata, located in block Daurala, tehsil Sardhana and district Meerut of Uttar Pradesh state, was generated in MS Excel (Table 1). This dynamic and natural resource based decision support system using GIS enables efficient and environmentally sound land use planning and improved crop management. The data have been categorized in the different categories like Farmer's description, Field data, Soil characteristics, Crop characteristics, Mechanization, Labour availability, etc. The GIS maps generated in this study improve and update the soil and fertilizer information available. The soil based GIS maps helps to assist the planning process to provide comprehensive, accurate and visual information. The users can use these GIS maps for any future land-use planning and to improve crop management in their future agricultural research endeavors.

Figures & Legend

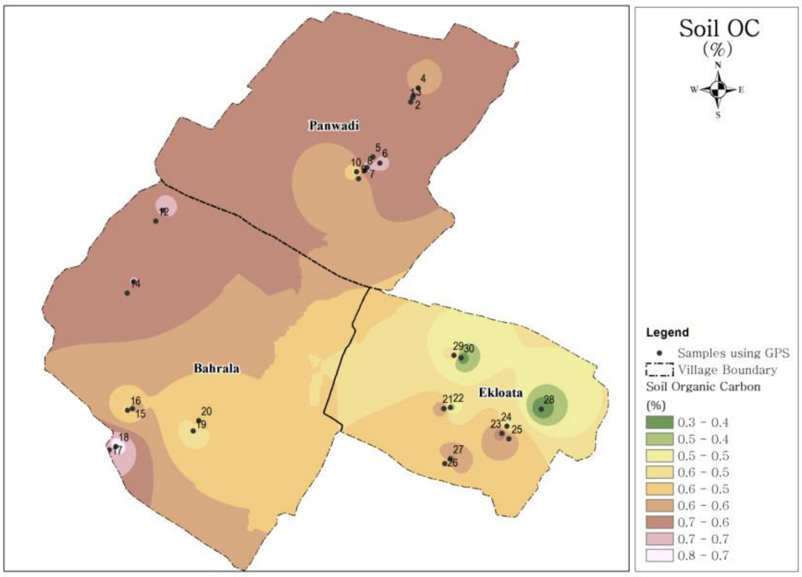

Figure 1: *Organic carbon content in surface soil (0-15 cm) of Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh, India*

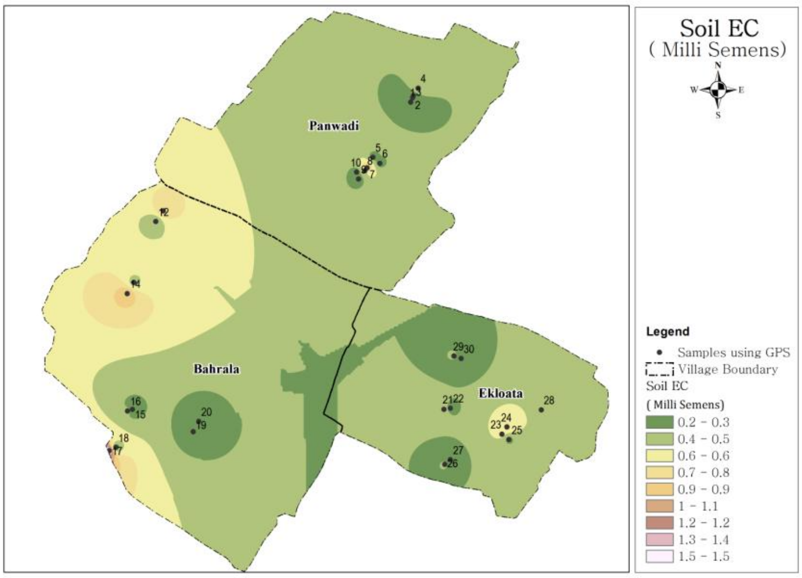

Figure 2: *Electrical conductivity (EC) of surface soil (0-15 cm) of Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh, India*

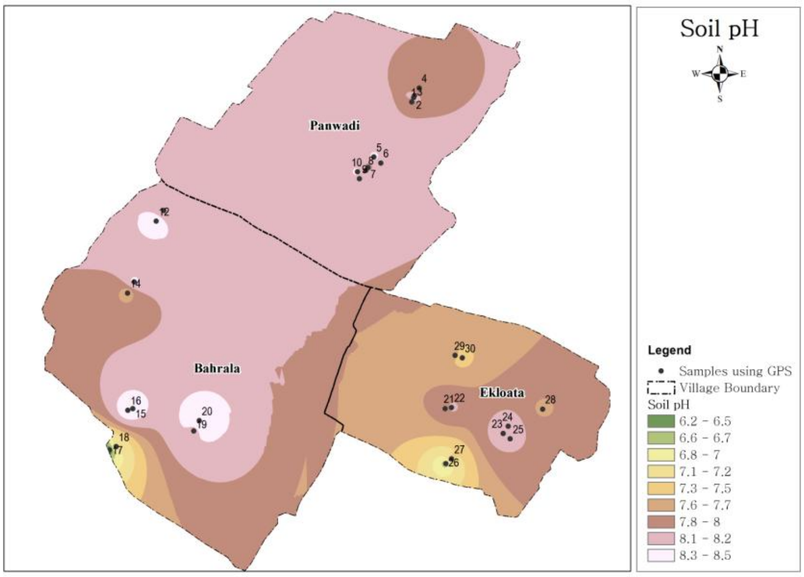

Figure 3: *pH of surface soil (0-15 cm) of Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh, India*

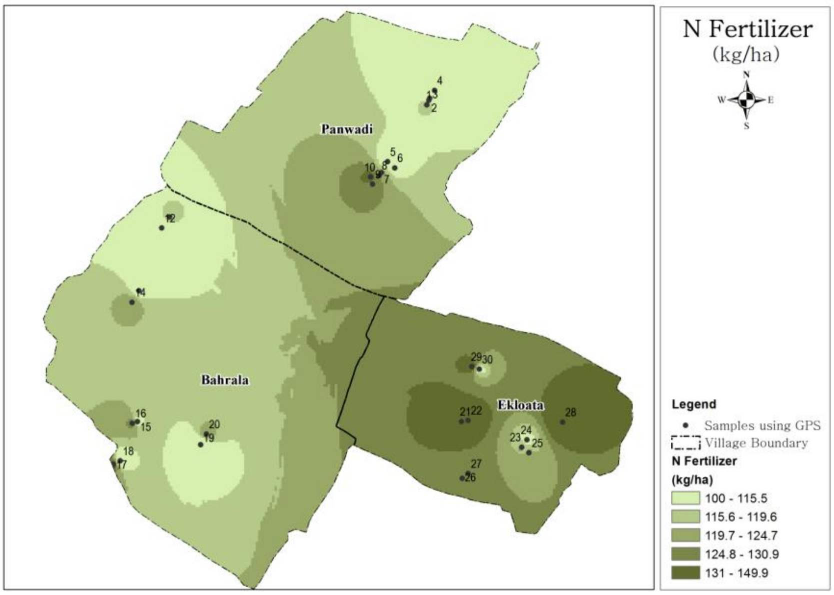

Figure 4: *Application of N fertilizer in Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh, India*

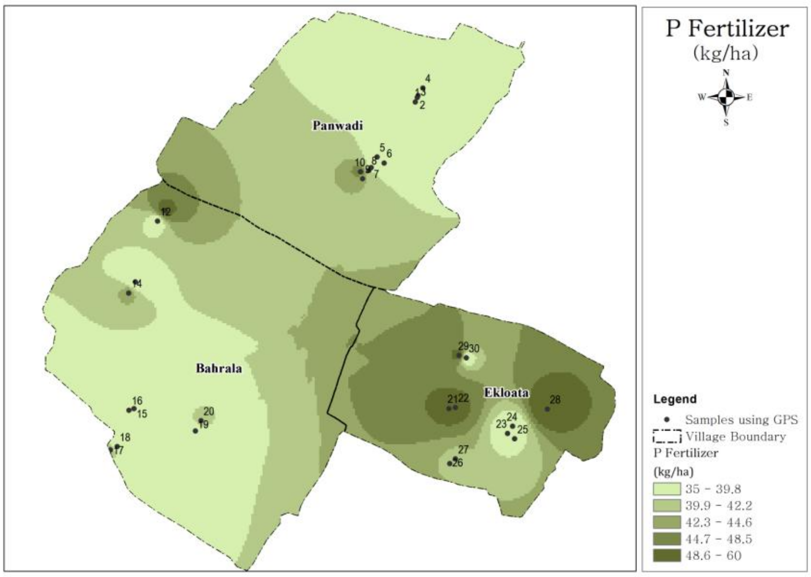

Figure 5: *Application of P fertilizer in Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh, India*

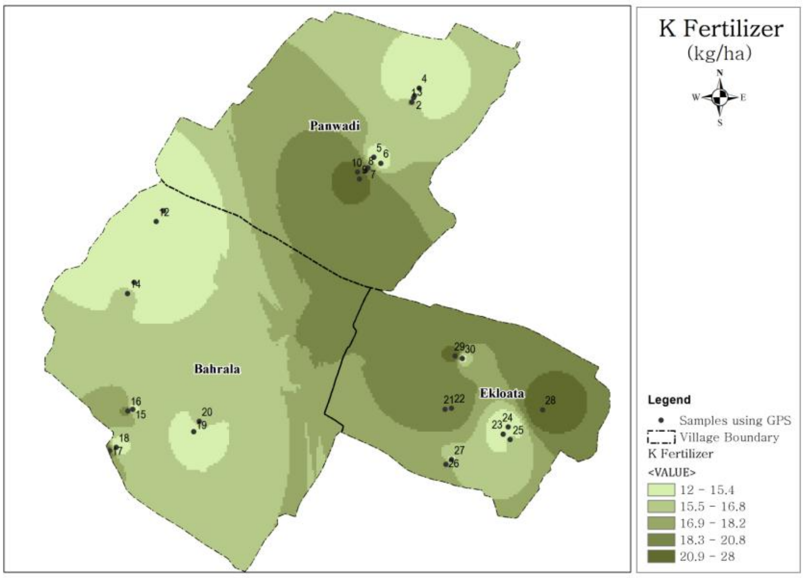

Figure 6: *Application of K fertilizer in Bahrala, Panwadi and Ekloata villages of Meerut, Uttar Pradesh, India*

Table

Table 1: *Input data for model in district Meerut, Uttar Pradesh, India*

S. No	Crop	Village	Field Location		Soil Properties			Fertilizer Requirement		
			Latitude	Longitude	E.C. (dS m^{-1})	Soil OC (%)	pH	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
1	Sugarcane	Panwari	29^o06.680'	77^o44.171'	0.24	0.61	7.9	120	40	18
2	Wheat	Panwari	29^o06.695	77^o44.178'	0.25	0.65	8.1	120	40	15
3	Potato	Panwari	29^o06.702'	77^o44.181'	0.27	0.6	8	100	35	12
4	Rice	Panwari	29^o06.729'	77^o44.197'	0.44	0.55	7.8	110	35	14
5	Potato	Panwari	29^o06.485'	77^o44.037'	0.25	0.62	8.3	100	35	12
6	wheat	Panwari	29^o06.464'	77^o44.061'	0.25	0.66	8.2	110	37	14
7	sugarcane	Panwari	29^o06.448'	77^o44.016'	1.11	0.69	7.8	120	38	18
8	Wheat	Panwari	29^o06.438'	77^o44.008'	0.27	0.63	8.2	125	40	20
9	Potato	Panwari	29^o06.408'	77^o43.985'	0.23	0.56	8.2	130	42	25
10	Sugarcane	Panwari	29^o06.433'	77^o43.978'	0.23	0.45	8.3	140	50	25
11	Rice	Bharala	29^o06.296'	77^o43.291'	0.77	0.65	8	120	52	14
12	Wheat	Bharala	29^o06.258'	77^o43.264'	0.34	0.61	8.4	100	36	12
13	Sugarcane	Bharala	29^o06.043'	77^o43.186'	0.40	0.64	8.3	110	35	14
14	Rice	Bharala	29^o06.004'	77^o43.163'	0.91	0.63	7.6	125	44	16
15	Potato	Bharala	29^o05.596'	77^o43.181'	0.23	0.57	8.4	110	36	14
16	Wheat	Bharala	29^o05.590'	77^o43.164'	0.35	0.48	8.4	130	35	20
17	Sugarcane	Bharala	29^o05.450'	77^o43.099'	1.52	0.63	6.2	140	43	22
18	Sugarcane	Bharala	29^o05.461'	77^o43.122'	0.18	0.73	7.2	100	35	12
19	Rice	Bharala	29^o05.517'	77^o43.397'	0.25	0.47	8.2	100	37	14
20	Potato	Bharala	29^o05.553'	77^o43.417'	0.23	0.52	8.5	125	41	16
21	Rice	Iklauta	29^o05.596'	77^o44.289'	0.40	0.63	7.7	140	52	20
22	Potato	Iklauta	29^o05.600'	77^o44.312'	0.27	0.37	8.1	140	52	20
23	Sugarcane	Iklauta	29^o05.508'	77^o44,495'	0.51	0.66	8.2	120	36	14
24	Wheat	Iklauta	29^o05.533'	77^o44.513'	0.65	0.42	8.1	110	35	12
25	Potato	Iklauta	29^o05.489'	77^o44.520'	0.26	0.57	8	120	40	16
26	Rice	Iklauta	29^o05.401'	77^o44.292	0.34	0.5	6.6	125	42	18
27	Sugarcane	Iklauta	29^o05.418'	77^o44.312'	0.20	0.61	7.3	130	41	15
28	Potato	Iklauta	29^o05.594'	77^o44.635'	0.46	0.33	7.7	150	60	28
29	Wheat	Iklauta	29^o05.784'	77^o44.325'	0.35	0.5	7.5	140	52	24
30	Sugarcane	Iklauta	29^o05.775'	77^o44.350'	0.17	0.32	7.4	110	35	14

References

[1] Environmental Systems Research Institute, Inc., 1999: *Getting to Know ArcView GIS*. 3rd Ed. ESRI, Redlands, California.

[2] Walkley A., et al. *An Examination of the Degtjareff Method for Determining Soil Organic Matter and a Proposed Modification of the Chromic Acid Titration Method.* Soil Sci. 1934. 34; 29-38.

[3] Velmurgan A., et al, 2004: *Remote Sensing and GIS for Optimizing Land Use Based on Fertility Capability Classification*. Proceedings of the Symposium on Geoinformatics Applications for Sustainable Development, IARI, New Delhi, 134-141.

[4] Buol S.W., et al, 1975: *Soil Fertility Capability Classification.* Soil Management In Tropical America, Soil Sci. Dept., North Carolina State University, Raleigh, North Carolina, 23-67.

[5] Sanchez P.A., et al. *The Fertility Capability Soil Classification System: Interpretation, Applicability and Modification.* Geoderma. 1982. 27; 283-309.