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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) FOR SITE SPECIFIC MANAGEMENT OF PADDY PRODUCTION SYSTEMS
A CASE STUDY IN KAMBURUPITIYA DIVISIONAL SECRETARIAT (DS), SRI LANKA

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ABSTRACT

Geographic Information System (GIS) has been known as a powerful tool to analyze spatial data and this technology is recently applied to agricultural sector in Sri Lanka. This study aimed to apply the GIS technology to manage information in efficient way to develop the paddy sector under Kamburupitiya Divisional Secretariat (DS), Sri Lanka. An extensive field survey was conducted to collect 77 soil samples at a depth of 5-20 cm and GPS locations were recorded for each sample. The information related to Machineries used in Paddy production was collected by a survey using a questionnaire. Yield data were collected from Agrarian Services Centers. The pH meter, Walkley & Black rapid titration method and Kjeldhal method were used to determine soil pH, organic carbon and soil nitrogen content respectively. ArcView GIS 3.3 software was used for the spatial analysis and mapping. Results of the study revealed that land areas with suitable pH and soil organic carbon are 3936.96ha and 791.99ha respectively. Soil Nitrogen content was very low. The yield per unit area vary from 1,111.3 to 4,769kg/ha/year. There are considerable usages of machineries for rice cultivation including two wheel tractors, four wheel tractors, threshers, harvesters and sprayers.

***Key words*:** paddy, site specific management, soil nitrogen, soil organic carbon, soil pH

INTRODUCTION

Rice is the staple diet in Sri Lanka and rice yield levels have not been increasing significantly over the last two decades and the country's average yield was lowering while the potential is being far higher (Census and statistics Department 2015). A yield increase of rice in Sri Lanka is essential to feed increasing population in coming years. Expansions of the area of production, yield improvement, or both are the possible avenues for the increasing rice production. It is well known that Sri Lanka does not have additional lands for cultivation and the only possible way is to improve the land productivity for getting higher rice yield. Paddy (*Oryza sativa* L), a semi aquatic cereal, has been originated in the northern region of India. There are three main types of rice cultivars namely Indica, Japonica and Javanica (Datta 1981). Rice is the staple food in Sri Lanka and majority of the world. Almost three billion people in Asia, Africa, and Latin America rely on rice for their main meals (Datta 1981).

In Sri Lanka rice is grown under a wide range of physical environments such as different elevations, soils and hydrological regimes. Rice is grown in all agro ecological regions except in WU1, WU2, WU3 and IU2.If there

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is enough water, almost all kinds of soils could be used for rice cultivation (Panabokke 1996). The total land devoted for paddy is estimated to be about 708,000 ha at present (Anonymous 2015). The total paddy production in Sri Lanka is about 4819 million kg (Anonymous 2015). But still the country is not self-sufficient in rice.

GIS (Geographic Information System) has been known as a powerful tool to analyze spatial data and this technology is recently applied to agricultural sector in Sri Lanka as well. Agriculture is an inherently geographical practice which is a natural application for GIS. GIS and several related technologies Such as Global Positioning System (GPS), continuous yield and soil sensors, and Remote Sensing (RS) instruments and methods are used in site-specific farming systems to collect spatially referenced data which help in performing spatial analysis, decision making and apply variable rate treatment (Usery *et al*. 1995). This technology can be applied to paddy sector in order to sustainable paddy cultivation practices in the country (Sawyer 1994). Classification of soil property variation will guide to site specific crop management and it will pave the way to reduce the cost of production. GIS and methods can be applied to identify the suitable lands for paddy cultivation. Updated databases which contain the information related to a particular sector are essential in decision making process in that particular sector.

This research aims on application of GIS by mapping the status of paddy production in Kamburupitiya DS Division to apply site specific management system.

MATERIALS AND METHODS

Kamburupitiya DS Division (68 km^2 land area) which comprised of 39 Grama Niladhari (GN) Divisions was selected for the study (Figure 1).

The soil samples were collected from 77 sampling sites at 5-20 cm depth. Sampling sites

Figure 1. Map of Kamburupitiya DS Division

were randomly selected to get a good distribution throughout the Kamburupitiya DS division. The GPS reading in local coordinates and other relevant data related to each sampling site were recorded. Samples were analyzed in the laboratory for soil pH, organic Carbon and soil nitrogen. Social data related to paddy production in the Kamburupitiya DS Division was collected using a questionnaire. All the collected information was mapped using Arc View GIS 3.3 software.

Soil organic carbon was determined using Walkley and Black Rapid Titration method (Walkley and Black 1934; Walkley 1947).The 1:2.5 soil water suspensions were used to determine the soil pH (Mclean 1982). Soil nitrogen content was determined by Kjeldhal method (Page 1982).

Spatial distributions of soil pH, organic Carbon and soil nitrogen were mapped. Then suitability analysis was conducted to identify suitable areas for paddy cultivations by using above mentioned soil parameters. The total yield of each GN Divisions and potential yields were mapped. The gap between potential and actual yields was observed. The distribution of available machineries for paddy cultivation was mapped using Arc View GIS 3.3 software.

RESULTS AND DISCUSSION

Distribution pattern of the total Yield of Paddy

The distribution of total paddy Production of each GN Divisions is shown by Figure 02.

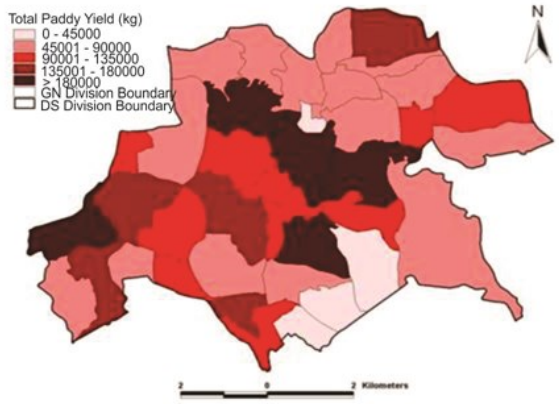

Figure 2. Distribution pattern of total yield of paddy

The total paddy Production in Kamburupitiya Divisional Secretariat Division is 4,057.57 t. Sapugoda (305.04 t), Karagoda Uyangoda 1 west (234.52 t), Kamburupitiya (261.79 t), Ullala East and Mapalana Magin Ihala are in the highest category. Highest paddy production can be seen in Sapugoda GN Division. All the other GN Divisions have a yield lower than 180 t.

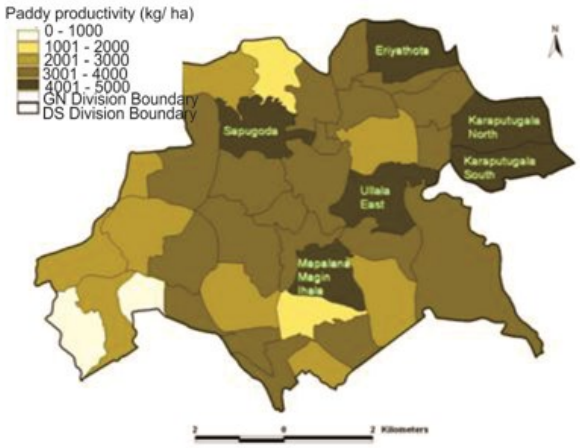

Figure 3. Distribution pattern of paddy land productivity

Distribution Pattern of the Land Productivity of the Paddy Fields

The distribution of Land Productivity of Paddy fields of each GN Divisions was shown in Figure 3. The highest land productivity can be seen in Karaputugala with higher yield (4.8 t/ ha) and the lowest paddy production was observed in Ihala Vitiyala West (0.92 t/ha). The paddy statistics of Census and Statistics Department (2015) reported that average paddy yield as 4.53 t/ha. Paddy yield is lower than average value in 80% of the GN Divisions.

Only five GN divisions achieved the yield level up to 4 t/kg. All other are under yielding area.

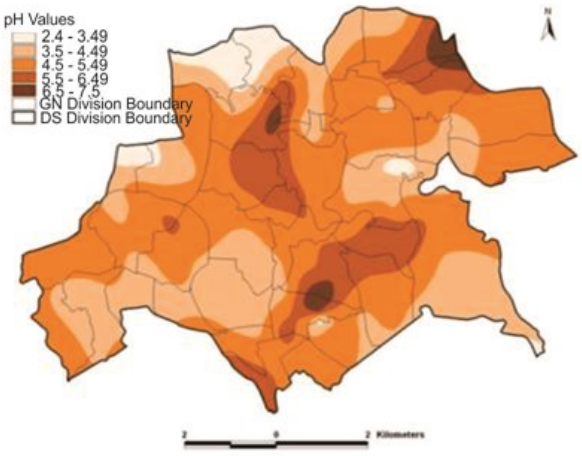

Figure 4. Distribution pattern of soil pH

Distribution of Soil pH

The distribution pattern of Soil pH is shown in Figure 4. Soil pH is varying from 3.1 to 7.3. The pH value range of large area of Kamburupitiya Divisional Secretariat is 4.5-5.5 and slightly acidic. Many species of rice plants can grow well at soil pH range between 5.5 and 6.5 (Yu 1991). Ponnamperuma (1977) further stated that the optimum conditions for nutrient uptake by rice from the soil solution consist of pH of about 6.6. The small area represented the soil pH range higher than 6.5-7.5.

Distribution of Organic carbon and Suitable Organic Carbon Range

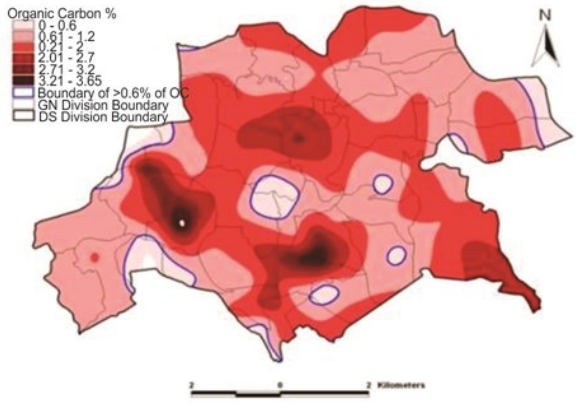

Figure 5. Distribution of soil organic carbon

The distribution pattern of the area with suitable Organic Carbon percentage is shown by Figure 05. The suitable Organic Carbon range for the paddy is more than 0.6% (Bhattacharyya et al. 2013). Many areas of the Kamburupitiya DS Division are contained more than 0.6% organic carbon.

If Soil Organic Carbon percentage lowers than the 0.6%, it is badly affected to the soil aggregation. The relatively lower organic carbon content was observed in Kamburupitiya DS Division.

Distribution of Yield per Unit Area with optimum Organic Carbon and pH range

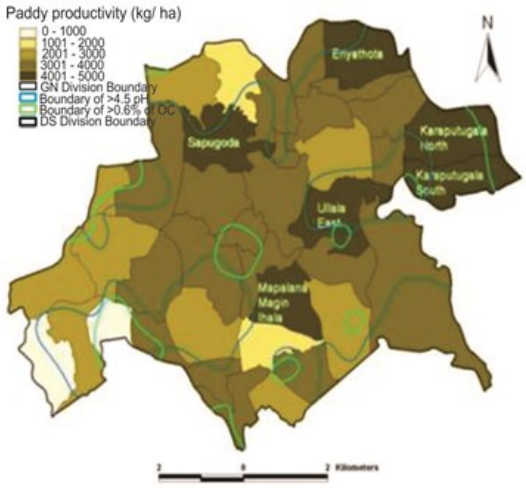

Figure 6. Distribution of Yield per Unit Area with optimum Organic

The Figure 06 shows the boundaries of optimum Organic Carbon and pH with paddy yield per unit area. The intersected area of the optimum pH range and optimum Organic Carbon range is the most suitable for paddy production. The GN Divisions like Karaputugala North, Karaputugala South, Eriyathota, Sapugoda and Mapalana Magin Pahala are in the highest yield category and these areas are situated in the most suitable range for pH and organic carbon. Ullala East is under the highest yield category but some area is unsuitable for pH and organic carbon.

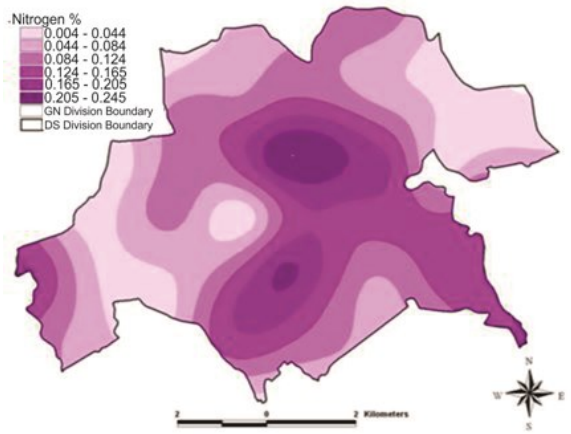

Figure 7. Distribution of soil Nitrogen

Distribution of Soil Nitrogen

The distribution pattern of the area with soil nitrogen content is given in Figure 07. The Nitrogen content of the Soils in Kamburupitiya DS Division is comparatively low. Most

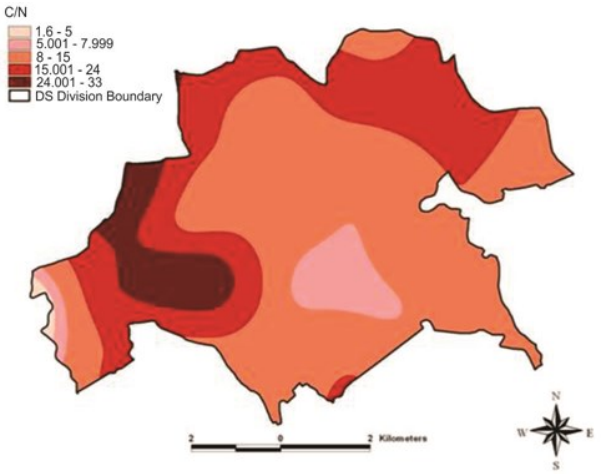

Figure 8. Distribution pattern of soil C/N ratio

part of the area has less than 0.2% nitrogen content. Total Nitrogen content range of paddy soil in many Asian countries is lying between 0.05 to 0.15% (Sehgal *et al*. 1998).

Distribution Pattern of C/N of the Soil

The distribution Pattern of the C/N of the soil is shown by Figure 08. Most part of the area lie on the category of 8-15. Small area with the soil contain lower than 8 is present. The Average C/N ratio in red yellow podzolic soil in study area of Matara district, Sri Lanka was observed as 8-12 (Sehgal *et al*. 1998). This may due to the accumulation of organic matter often takes place in the form of less decomposed organic debris having a high C/N ratio.

Distribution of machineries related to paddy production

The distribution of two wheel tractors, four wheel tractors, harvesters, threshers and rice mills in each GN Divisions is shown in Figure 09 (a), (b), (c), (d) and (e). Two wheel tractor is the major power source for the paddy production in Kamburupitiya Divisional Secretariat Division. Total number of Two Wheel Tractors in Kamburupitiya Divisional Secretariat division is 342. Two Wheel Tractors are distributed well throughout the Kamburupitiya Divisional Secretariat Division. But Urapola West does not have even a single Two Wheel Tractor. Some areas have more than 16 Two Wheel Tractors.

The four wheel tractors are mainly used for the transportation and threshing of paddy in the Kamburupitiya Divisional Secretariat Division. Total number of Four Wheel Tractors in Kamburupitiya Divisional Secretariat Division is 60. Four wheel Tractors are not distributed well throughout the Kamburupitiya Divisional Secretariat Division. Four Wheel Tractors are not available in twelve GN Divisions. Some divisions have more than 5 four wheel tractors.

Combine harvesters are mostly used for harvesting Paddy in the Kamburupitiya Divisional Secretariat. Total number of Harvesters in Kamburupitiya Divisional Secretariat Division

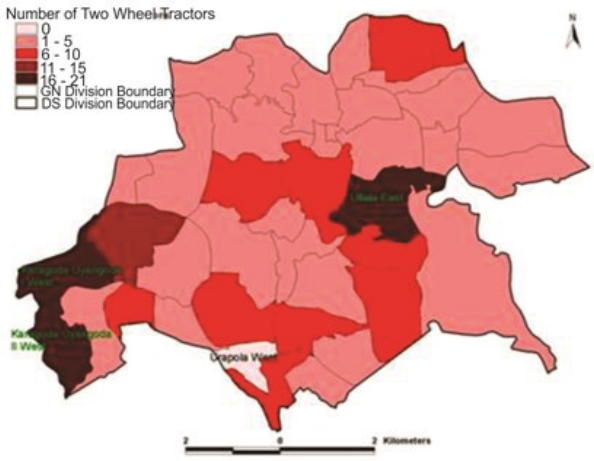

Figure 9 (a) Distribution of two wheeled tractors

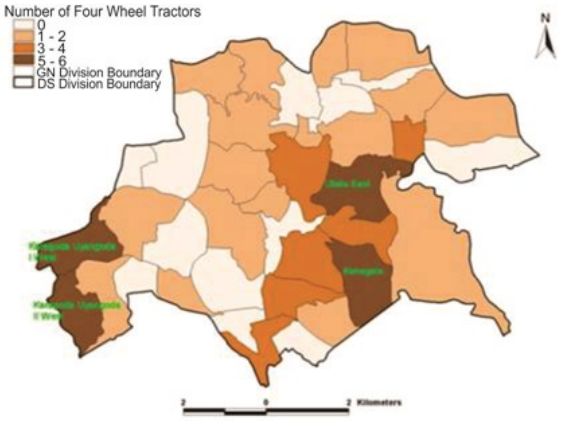

Figure 9 (b) Distribution four wheeled tractors

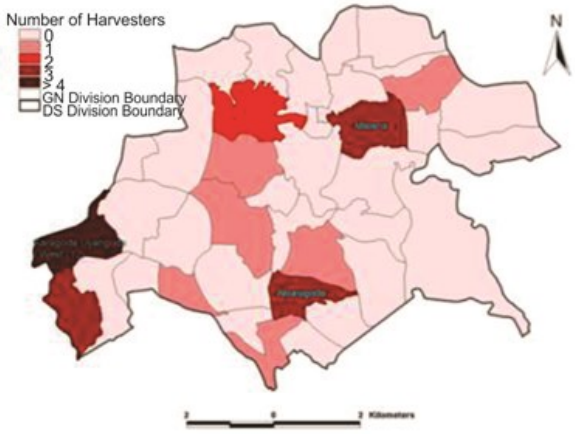

Figure 9 (c) Distribution of harvesters

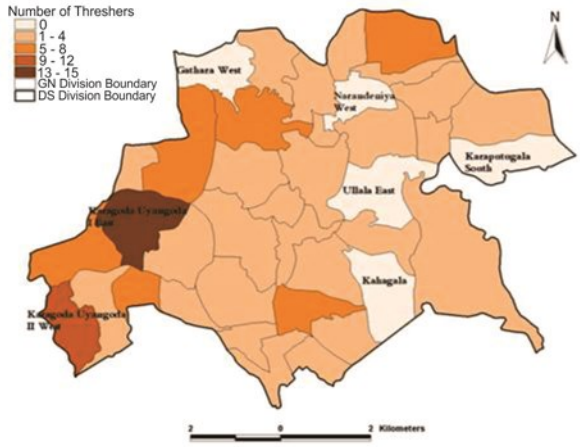

Figure 9 (d) Distribution of threshers

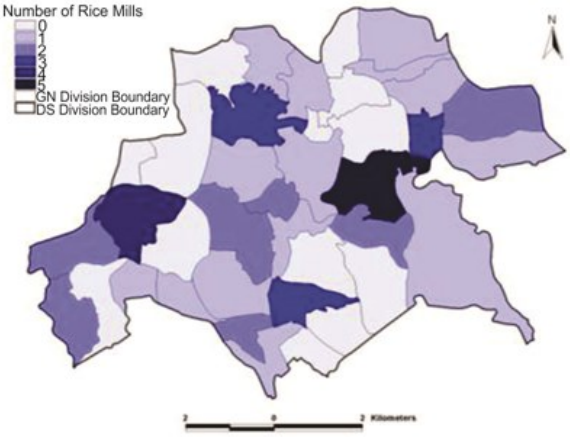

Figure 9 (e) Distribution of rice mills

is 21. Harvesters are not distributed well throughout the Kamburupitiya Divisional Secretariat Division. Harvesters can be found only in eleven GN Divisions.

Total Number of threshers in Kamburupitiya Divisional Secretariat is 100. Western part of the Kamburupitiya Divisional Secretariat division is highly concentrated with threshers. Five GN Divisions do not have even a single thresher.

Rice Mills are absence in thirteen GN Divisions. Ullala East has more than 5 Rice Mills. The divisions Sapugoda, Akurugoda and Thumbe have 3 Rice Mills in each. Total number of Rice Mills in Kamburupitiya Divisional Secretariat division is 36.

CONCLUSION

As the 80% of GN Divisions were observed lower paddy yield compared to the national average value of 4.25 mt/ha, the management decision of paddy cultivation should be addressed to improve land productivity. The suitable pH distribution area of the DS division occupies 3936 ha and it is about 58% of the total land. Organic carbon content of the soil is considerably low. It lies between 0.27-3.64% but the most of the area belongs to the suitable organic carbon content for the paddy. Nitrogen content of the soil is also very low. But there is about 160 ha area with suitable C/N for the paddy cultivation. In case of the mechanization related to the paddy production, the number of machineries is satisfied but the distribution of some machines are not in satisfactory level. Total number of harvesters are 21 which are distributed among 11 GN Divisions but 28 GN divisions do not have a single harvester. Total number of rice mills in the DS division is 36 but 13 GN divisions does not have even a single rice mill.

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