Precision Agriculture using Satellite Technology, Geographic Information System (GIS) and Global Position in System (GPS)

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Introduction

Precision farming or Precision Agriculture (PA) is a technology available for sustainable agricultural production, which enables farm management based on the small-scale spatial variability of soil and crop parameters in the field (Haneklaus *et al.*, 1997). The aims of PA are a better usage of resources and control mechanism so as to improve production efficiency, reduce input costs and reduce environmental impact (Costopoulu and Anagnostou, 1997). Soil as an important component of land should be assessed in terms of their abilities to supply plant need of nutrients. In specifying such plant requirements, it is essential to state them quantitatively and precisely (Tinker and Leigh, 1976). Since mapping is the beginning of PA, yield and soil mapping are often the focus of PA discussion and activities, therefore yield and soil mapping must be accurate in order to get a true measurement of variability and to established the guidelines for PA in particular farm field (Schuller et al., 2001). The most pressing application will be the integration of agronomic and management information in the establishment of a decision support system (DSS) for oil palm management to assist in site specific decision making to individual blocks. Using available data of GIS and GPS should result quickly in improved availability of information for planning, organisation, monitoring and supervision of work (Chew et al., 1997). As a part of this project, the precision farming technique is also applied in wet paddy cultivation to develop a computer-based paddy production by using a GIS for optimum yield increase. Since rice is the third most important crop in Malaysia in terms of land-use after oil palm and rubber. According to the domestic supply of food in Malaysia, the country is only 75% in self-sufficient of its rice consumption whereas rice is the staple food of Malaysia. One of the means to increase rice production is to map within field spatial variation in paddy field using data from soil nutrients and the integration of geographical information system (GIS), global positioning system (GPS) and precision agriculture technique.

Materials and Methods

Soil and plant tissue data collection were conducted using grid sampling by 54m x 30 m in distance. Leaf samples were collected from the 17th frond, which was a representative of plant tissue sample that were taken out during the morning hours. Soil samples were taken out from two different sites, namely at the inter-row and under frond-pile, respectively. An Omni Star Differential Global Positioning System (DGPS) was used to determine the precise location each of sample sites. Collecting of soil samples were conducted by a "soil auger" in two layers (0 to 15 cm and 15-30 cm depth). All the data were mapped by Geostatistic Plus (GS+) software and finally transferred into MapInfo software for spatial analysis. Classic statistics was analysed by SPSS software. The SPOT image taken on March 2000 was acquired from The Malaysian Centre for Remote Sensing (MACRES) and classified using a PCI software available in The Centre for Precision Agriculture and Bioresource Remote Sensing (CPABRS), Institute of Bioscience, Universiti Putra Malaysia. In application of PA technique in paddy cultivation, the locations of the study were Phase 1 of Ladang Merdeka Mulong Lating, which covers an area of 39 ha in the Kota Bharu District of Kelantan and a 40 ha commercial paddy field at Kahang in the Kluang District of Johor (Affandi and Kamaruzaman, 2000; Roy et al., 2001). A database of land information was created with MapInfo GIS software. ESRI's ArcView GIS desktop GIS software was used to view and access the information maintained in a Microsoft's Excel spreadsheet. In this study, three different layers i.e. points, lines and polygons were created by digitizing these spatial data from the map manuscript and by digitizing the information from the computer screen. Soils at 200 points in Kelantan and 162 points in Kahang with specified grid-patterns were collected using an auger within a depth of 0-30 cm. The GPS system was hand-held Trimble's Geo-ExplorerTM II, which was used to record the location points of soil sampling and plot boundaries with proper coordinates. During harvesting, a square frame (1 m x 1 m) was used to collect paddy plants to record grain yields for specified grid-points. Maps of N, P, K and yield for the field was developed using point kriging in the Geostatistics software.

Results and Discussion

In general, total N content of the study area was classified as low level category, except there are a small areas under frond pile (0-15 cm) which were classified as moderate category. Total N content in the soil has a very close relationship with organic carbon (C) content in the soil. Increase of organic C in the soil is usually followed by an increase of total N in the soil. Total N content in plant tissue can be classified as optimum category, although there are small places in the field that can be categorized as excess N. Soil available P varies from low to very high level. Available P in the soil has a very close relationship with soil reaction (pH) in the soil. The amount of total P in plant tissue in the study area is relatively uniform and can be classified into optimum category for oil palm growth. Based on the statistical analysis, correlation between available P in the soil and total P in leaf tissue is not significant.

Exchangeable K in the soil ranges from low level to very high. There is a tendency that the increase of exchangeable K is influenced by an increase of organic matter content in the soil. Total K in leaf tissue was classified as optimum level for palm growth, but there are some areas with total K deficiently for palm growth. There is no significance correlation statistically between FFB with soil nutrient and nutrient content in leaf tissue, except with N content in leaf tissue. Digital SPOT analysis was carried out based on the digital numbers (DN) of each site of the leaf sample points. The results of correlation analysis between DN values of the three bands namely blue (B), green (G) and red (R) with nutrient contents in plant tissue (N, P and K) showed some significant correlation. The G band was correlated with N content in plant tissue, whereas the B band was correlated with K content in plant tissue. There is no significant correlation between R band and nutrient content in plant tissue.

The 2-dimensionals N, P, K and yield distributed maps were made for Kelantan and Kahang paddy fields. Once the variability is known from the nutrient maps, fertilizer application can be adjusted to more closely meet the supplemental nutrient needs for paddy. Optimum fertilizer nutrient use can result in increased yield, reduced cost and reduced potential chemical pollution. It can be implied from the N and P variability maps that almost the total area (light blue and blue color) contains lower N and P (Kamaruzaman and Affandi, 2001). Only small patches representing a moderate rating of P nutrient occurred in the upper portion of the study area. Meanwhile in the upper portion of the K map, the red color polygons represented a high K nutrient. Thus, the correct amount of fertilizer should be applied in these blue and light blue regions. Once, the nutrient maps are drawn in the same scale and same projection (MRSO), it will be easier to manipulate in the GIS with a more systematic decision-making can be made. It can be implied from the yield map that high yield of paddy (more than 6 t/ha) appeared in the upper left and right portion of the map. From the P, K and paddy yield maps, it can be shown that the high yield of paddy existed at the upper portion of the study area, the same location with higher P and K content, where there are red in color. In Kahang paddy field, it was observed that insufficient soil N and P found in both plots where soil K is more than moderate range (Roy et al., 2001). Due to shortage of nutrients especially in the middle area of both plots, yield was also low (below 3.5 t/ha) in the middle area. The paddy yield variation was 1-7 t/ha for Kelantan area and 1-5 t/ha for Johor area. The legend on the map showed the standard rate of soil rating properties in P. Malaysia compiled by soil survey staff, Malaysian Department of Agriculture. There are five ratings of P. Malaysia soil properties i.e. very high, high, moderate, low and very low. Due to the general low N and P contents of the soil, compared to the standard rating for chemical properties of soil in P. Malaysia, it is, therefore, required to apply more N and P fertilizers accordingly to improve soil N and P contents of the paddy field.

Conclusions

In general, soil fertility in the study area is classified as low-level category. Total N in the soil is closely related to organic C, while available P is highly correlated with pH. Total nutrient content in leaf tissue can be classified as optimum category. There is no significant correlation between total N, P and K in the soil and total N, P and K in leaf tissue, respectively. Similarly, no correlation between FFB with soil nutrient and nutrient content in leaf tissue, except with N content in leaf tissue were observed. SPOT image analysis indicated that G band was correlated with N content in plant tissue, whereas B band was correlated with K content in plant tissue. There is no correlation between R band and nutrient content in plant tissue. The introduction of precision agriculture technique in paddy cultivation revealed the spatial variability of macro-nutrients (N, P, and K) and paddy yield, which can be used to define the size of management cells in spatially variable field management. Overall, this study can suggest that implementation of precision farming practices within the area could reveal both difficulties and opportunities with environmentally friendly awareness.

Benefits from the study

This initial research has demonstrated the potential of remote sensing approach using SPOT XS data for obtaining information, in near real-time, will be developed further. Besides a Global Positioning System (GPS) for positioning and navigation in the oil palm fields and integrating remotely sensed data with an Geographic Information System (GIS), studies on the geo-information variability of soil and oil palm fertility parameters and yields were gathered and mapped. Digital image processing of SPOT XS data and the spatial correlation of geocoded data for soil, plant parameter and yields was determined by geostatistical analysis (GS+) on few selected oil palm blocks. Results indicated that remotely sensed, soil analyzed and recorded yield data, when complemented with GIS, GPS, GS+ and MapInfo software could provide a precisie management decision making for the oil palm and paddy production in the near future

Literature cited in the text

Chew, P.S. 1998. Prospects for Precision Plantation practices in oil palm. The Planter, Vol.74, No.873, p.661-684.

Haneklaus, S., Ruehling, I., Schroeder, D. and Schnug, E. 1997. Studies on the variability of soil and crop fertility parameters and yield in different landscape of Northern Germany. *In* J.V. Stafford (ed) Precision Agriculture '97. Vol.II Bioss Scientific Publ. Ltd., Oxford, United Kingdom (1997), p.785-792.

Roy, Swapan Kumar. 2001. Nutrient and yield spatial variability in a commercial Malaysian paddy field. PhD (Precision Agriculture) dissertation, Univeristi Putra Malaysia (UPM), Serdang, Selangor, Malaysia.

Schuller, J.K. 2001. Variable rate technologies. Paper Smart Farming II Workshop on Automation for Agriculture. March 2001, Putra Jaya, Malaysia.

Project Publications in Refereed Journals

Kamaruzaman Jusoff and Swapan Kumar Roy. 2001. Geospatial Application in Mapping of Soil Nutrient Distribution in Malaysia Paddy Field, Precision Agriculture Journal, USA. (In review).

Costopoulou, C.I and M.E. Anagnostou. 1997. Rural area networks for precision agriculture. *J.V. Stafford (ed) Precision Agriculture '97*. .II: 861-868.

Project Publications in Conference Proceedings

Dayang Amenozima and Kamaruzaman Jusoff. 1999. Geospatial Information Technology for Malaysian Agriculture in the Next Millenium. Proc. of PETA-PKD-JPSM Seminar: Repositioning Agriculture Industry in the Next Millenium, 13-14 July 1999, Bilik Persidangan IDEAL, UPM, Serdang, Selangor, Malaysia. Pp: 171-191.

Tamaluddin Syam and Kamaruzaman Jusoff. 1999. Remote Sensing and GIS Technology for Field Implementation in Malaysia. Proc. of PETA-PKD-JPSM Seminar: Repositioning Agriculture Industry in the Next Millenium, 13-14 July 1999, Bilik Persidangan IDEAL, UPM, Serdang, Selangor, Malaysia. Pp: 192-216.

Kamaruzaman Jusoff and Dayang Amenozima Abang Ismail. 1999. Precision Agriculture System: Its Potential in Improving MADA's Rice Production. Proc. Malaysian Science & Technology Congress '98, November 7-9, 1998, Primula Parkroyal Hotel, Kuala Terengganu, Terengganu, Malaysia.pp: 71-78.

Kamaruzaman Jusoff and Tamaluddin Syam. 2001. Soil and leaf nutrients spatial variability of Coastal Oil palm Plantation. Poster Paper presented at the Third International Conference on Geospatial Information in Agriculture and Forestry, Denver, Colorado, 5-7 November 2001.

Swapan Kumar Roy and Kamaruzaman Jusoff. 2001. Interpreting within – field relationship between soil nutrients and paddy yield. Paper presented at Malaysian Science and Technology Congress 2001, Symposium A (Life Science), 24-26 September 2001, Kota Kinabalu, Sabah, Malaysia.

Tamaluddin Syam and Kamaruzaman Jusoff. 2001. Soil nutrients spatial analysis of Coastal Oil palm Plantation in P. Malaysia using GIS. Paper presented at Malaysian Science and Technology Congress 2001, Symposium A (Life Science), 24-26 September 2001, Kota Kinabalu, Sabah, Malaysia.

Kamaruzaman Jusoff. 2001. Digital imagery for precision oil palm management. Invited paper presented at 2001 PORIM International Palm Oil Congress (PIPOC), 20-25 August 2001, Istana and Hilton Hotels, Kuala Lumpur, Malaysia.

Swapan Kumar Roy, Kamaruzaman Jusoff, W. Ishak W. Ismail and Desa Ahmad. 2001. Performance Evaluation of a Combine Harvester in Malaysian Paddy Field. Paper Presented at Asia Pacific Advanced Network (APAN) Penang Meeting, August 20-22, 2001. Universiti Sains Malaysia, Penang. 9p.

Kamaruzaman Jusoff. 2001. Potential of Commercial Paddy Farming in Malaysia. Invited Paper Presented at Asian Strategy & Leadership Institute (ASLI) National AgriFood Conference In Conjunction with FoodPro Asia 2001 Expo and Forum, 27-28 August 2001. Mines Beach Resort & Spa, Seri Kembangan, Selangor. Malaysia. 15 p

Kamaruzaman Jusoff and Affandi Kastor. 2001. Yield and Soil Nutrient Variability Mapping at Ladang Merdeka Mulong, Lating, Kelantan. A Poster Paper Presented at SOILS 2001 Conference 14-17 April 2001 Hotel Promenade, Kota Kinabalu.

Kamaruzaman Jusoff. 2000. Meeting Tomorrow's Need of Malaysian Agriculture with Precision Agriculture. Paper Presented at Seminar on Precision Agriculture, 16 October 2000, Institute for Distance Education And Learning (IDEAL), Universiti Putra Malaysia, Serdang, Selangor, Malaysia. 20p.

Swapan Kumar Roy and Kamaruzaman Jusoff. 2000. Geostatistical Applications in Mapping of Soil Nutrients Distribution in Malaysian Paddy Field. Paper Presented at Malaysian Science and Technology Congress 2000: Research & Development in Science and Technology for the New Era (Symposium C), 18-20 September 2000, Promenade Hotel, Kota Kinabalu, Sabah, Malaysia. 8p.

Affandi Kastor and Kamaruzaman Jusoff. 2000. Soil Nutrient Variability Mapping in Ladang Merdeka Mulong-Lating, Kota Bharu, Kelantan. Paper Presented at Malaysian Science and Technology Congress 2000: Research & Development in Science and Technology for the New Era (Symposium C), 18-20 September 2000, Promenade Hotel, Kota Kinabalu, Sabah, Malaysia. 8p.

Tinker, P.B., and Leigh, R.A. 1976. Nutrient uptake by plant-Efficiency and controle. *In* Bachik and Puspharajah (Ed). International conference on soils and nutrient of perennial crops (ICOSANP). Malay. Soc. of Soil Sci. (1985).Pp.3-18.

Graduate Research

Affandi Kastor. 2002. Precision Agriculture (Paddy) [MS]. Universiti Putra Malaysia.

Swapan Kumar Roy. 2001. Precision Agriculture (Paddy) [PhD]. Universiti Putra Malaysia.

Tamaluddin Syam. 2001. Precision Agriculture (Oil Palm) [PhD]. Universiti Putra Malaysia.

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