Application of Geographic Information Systems in Paddy and Matpe Cultivations of Taungoo University

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Abstract

Development of agriculture technology demand more precise and accurate information for high yield and cost reduction. GIS is a technology that could support above information with minimum cost. Thus, GIS will become a major tool in the modernization of agriculture and subsequent economic development of the nation. This paper introduces some basic applications (mapping and analysis) of GIS in paddy and matpe cultivation of Taungoo University. This technology is available in geography department of many universities. By disseminating this technology to the local people it will contribute to the regional development. Its practical application will also encourage research activities of universities.

Key Words: GIS, Agriculture, Taungoo University Farm

Introduction

Geographic Information Systems (GIS) is "an information system that is designed to work with data referenced by spatial or geographic reference data, as well as a set of operations for working with the data" (Star and Estes, 1990). It is defined as a computer system for capturing, storing, querying, analyzing, and displaying geographically referenced data (Chang, 2006). The word 'geographic' that referred to 'geographically referenced' distinguishes GIS from other information system.

GIS is an integration of a number of geographical branches such as remote sensing, cartography, surveying, and photogrammetry (Chang, 2006). Based on uniform platform (geographically referenced data) every object or information that exists on the earth surface can be located together. Remote sensing and surveying are mainly related to data acquisition techniques, while cartography and photogrammetry are data handling techniques. By using GIS, it is possible to construct a spatial database for particular studying feature and attribute database for its related information and link these two database systems together for analysis and display.

In addition, GIS also has capabilities for data analysis by using statistical techniques. Then, it finally could present the results in both graphical and map forms. Thus, GIS functions could be divided into three sequential parts: mapping (by integration of different information based on geographically referenced data), analyzing (by using statistical and graphical techniques) and presenting (the results in both graphs and maps). Statistical and other spatial analysis functions are widely available in recently developed GIS softwares.

Although GIS was born by integration of some branches of geography it is widely used in other fields for its capabilities of spatial data analysis. Since its development in the 1960s, GIS has been applied in natural resource management including land-use planning, natural hazard assessment, wildlife habit analysis, riparian zone monitoring, and timber management. In more recent years, GIS has been used on crime analysis, emergency planning, land records management, market analysis, and transportation applications. Integration of GIS with global positioning system (GPS), wireless technology, and the Internet has also introduced new applications (Chang, 2006).

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In this paper some practical applications of GIS in agriculture are presented from the case study of Taungoo University farm. Next section concerns with the mapping of farm land and third section of this paper deals with analysis of some farm functions by using GIS. The last section discusses about the possible contributions of GIS to both regional development and university researches.

General Background of Taungoo University Farm

Although academic years of Taungoo University started in 2000-2001, construction works were carried out since 1998 on the 258.85 acres pasture land near Nyaunggaing Village. At that time, some local farmers were cultivating paddy on these pasture land. Although large area of land was used to establish the university, fence was posted only in some interior parts. Land that exists within the partly fenced land is about 200 acres. Thus, the farm lands locating outside the fence was about 58 acres and it was rented to originally working farmer on yearly basis. In addition, some parts of land that was located far away from the building and having suitable characteristics for paddy cultivation were rented to low income university staffs for their convenience up to 2009.

In 2008, about 3 acres of *thetkel* (stalk like long grass) land that exits in front of the university was cultivated for matpe under the fund of government staff welfare. In 2009, this matpe cultivation area and another 4 acres of virgin land (originally reclaimed for football ground) were cultivated for monsoon paddy. Thus, total paddy cultivation area rose to 7acres. Matpe was grown on these 7 acres and another 10 acres of newly reclaimed land in summer of the same year. Topography of newly reclaimed land is generally undulating and large number of small hills, holes and trees are present in the farm. Majority of pits were remains when the ground was excavated to construct main roads within the university. Large perennial trees are to be left as it is for the greening of the campus. Due to presence of hills, different elevation and presence of trees, newly reclaimed farm plots were very small and have irregular shape. Thus, it is very difficult and expensive for measuring and mapping the farm plots by traditional surveying methods (See Fig. 2). In 2010, the lands those were formerly rented to university low income staffs were handed over to university (government staff welfare fund). These lands were also highly fragmented since former rented staffs have not enough money to make systematic land reclamation. They use traditional methods to cultivate on the highly fragmented farm plots.

At present (2010) about 48 acres of land were under paddy cultivation under the fund of government staff welfare fund. Supervision Committee of Taungoo University Farm decided to use modern cultivation methods (System of Rice Intensification (SRI) method) in their farm and intended to become a model for local farmers. Thus, the role of systematic land management and acquisition of correct information become more important in the university farm land.

Mapping of Cultivation Area with GIS

A good GIS could collect data from every source and every form. Based on their nature, available data forms could be broadly divided into two categories: digital (soft copy) and analog (paper form). If derived data are in paper form it is necessary to transform it into digital forms by mean of typing (in case of numerical data) and scanning (in case of map and printed aerial photos). Analog data are mainly derived from existing maps (especially topographic maps), official publications (e.g. Statistical Year Books) and various government departments. Digital data are available from various sources. Among them, recently taken

aerial photos and satellite images are the most efficient and readily available raster (stored data in grid form) digital format. Global Positioning System (GPS) data is available in vector digital format from field surveying of particular study area. Both raster and vector formats data are useful in field mapping.

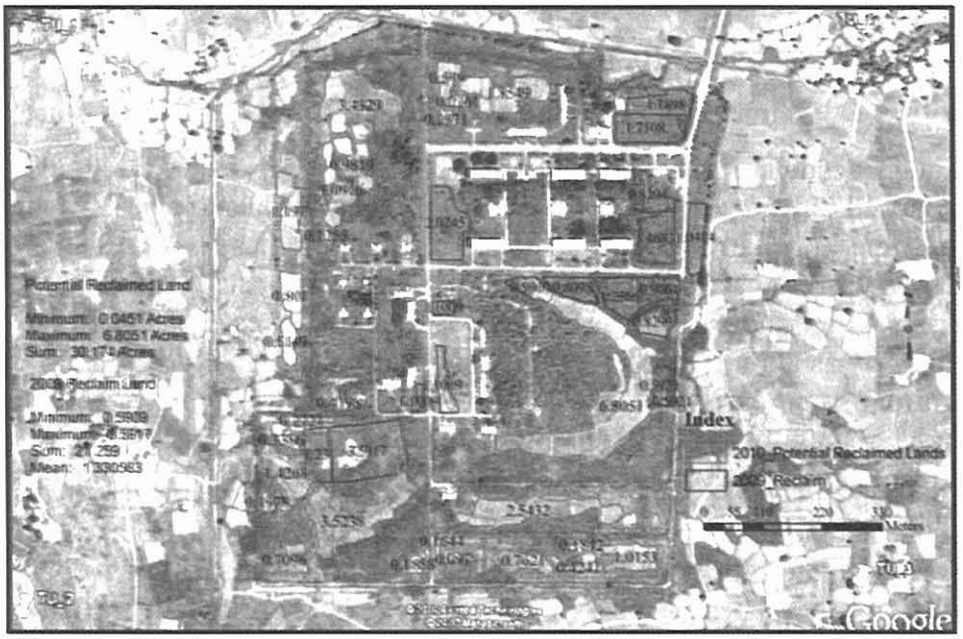

Figure (1) Mapping of potential reclaimed land from satellite image

Satellite image of Taungoo University taken in 7 April 2008 was available from *Google Earth* through Internet. After marking pin-point and typing its latitude and longitude on the four extreme margins of satellite image it was saved as raster image (*.jpeg format). Since saved image includes location of spatial reference points it is ready for geo-referencing. We could geo-reference this image by using GIS software. In case of present study, ArcGIS (ArcMap Version 9.3) was used to register the image. Since GIS software adjusts between registered image and geographical (or projected) location on the globe by using scale factor, we could directly measure actual distance, area and direction, etc. on the registered image. After this step, we could produce satellite image with map scale. In case of Taungoo University farm, we select potential farm sites based on this satellite image map. Based on this map it is possible to construct desired vector information layers by digitizing on the screen. We digitize potential area for expansion of paddy land and calculate these potential areas (Fig. 1).

This map is also used for land-use management of Taungoo University since it can also measure and locate the other spatially distributed activities such as land used for botanical garden and residential areas of university staff. For this purpose, it is necessary to construct vector layers (using point, line, polygon) for particular information derived from the geographically referenced satellite image. Other thematic maps such as map showing field area of fields, plan map of university could produce by combination of different vector data layers (see Fig. 2).

The satellite images, however, have some limitations. If available image resolution is low, detail feature of the earth surface could not be clearly demarcated by using vector layers. In addition, some features that are close or similar tone and texture are sometimes difficult to differentiate based on image alone. Thus, ground checking is necessary before satellite image is effectively utilized. In our case, resolution of available satellite image is not good enough to delineate each field. In addition, acquisition date of satellite image is 2008 and up to date

information is not available from it. Thus, it is necessary to use GPS in that case. We used Trimble GPS attached with palmtop. Through this GPS we could collect vector data and produce maps. Way of map producing is relatively easy and just to work regularly on the embankment of each farm by carrying GPS. As shown in photo (1), this job can be done by women. Only thing is to understand the way of handling and to plan the route of measurement.

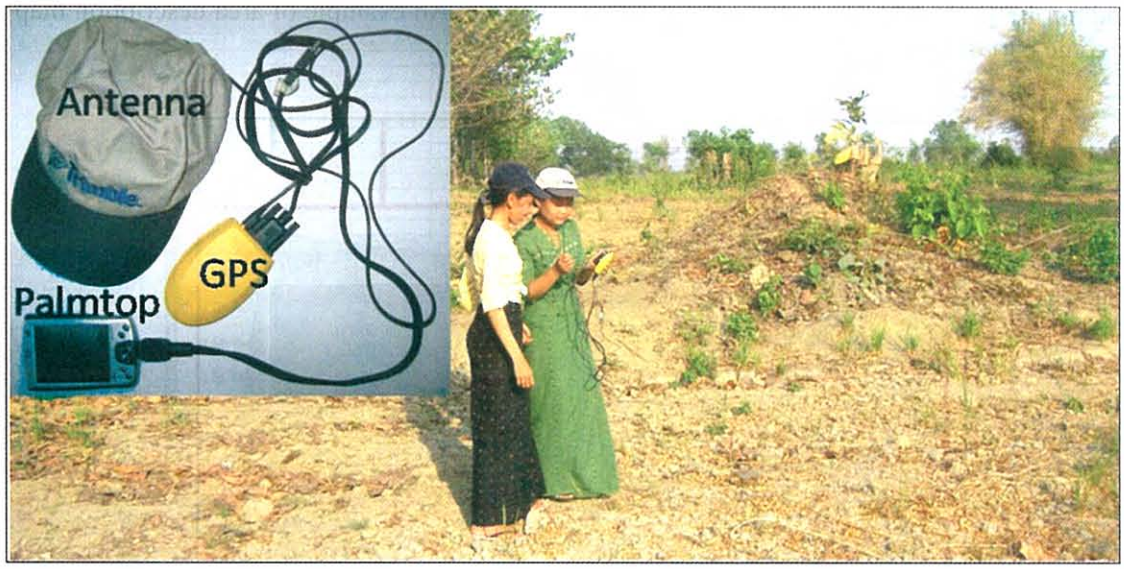

Photo (1) Mapping matpe field by using GPS (upper left photo shows the GPS used in mapping)

Figure (2) Map showing location of farm lands in Taungoo University

After measuring with GPS, it is transformed into shape file (.shp) format within GPS. Derived format is accepted (could retrieve) in majority of GIS software. In our case, we used area of farm plot data to calculate the plowing fee, amount of fertilizer that is necessary to put in a plot and amount of seed that is to be used in nursery. Above results are essential information in land management and scientific agriculture such as SRI. Advantage of GIS is that once data and information are put together in same geo-referencing system we could easily handle it for display and mapping at every required scale. An example of area description map for some part of farm land is shown in Fig. (2) and Fig. (3).

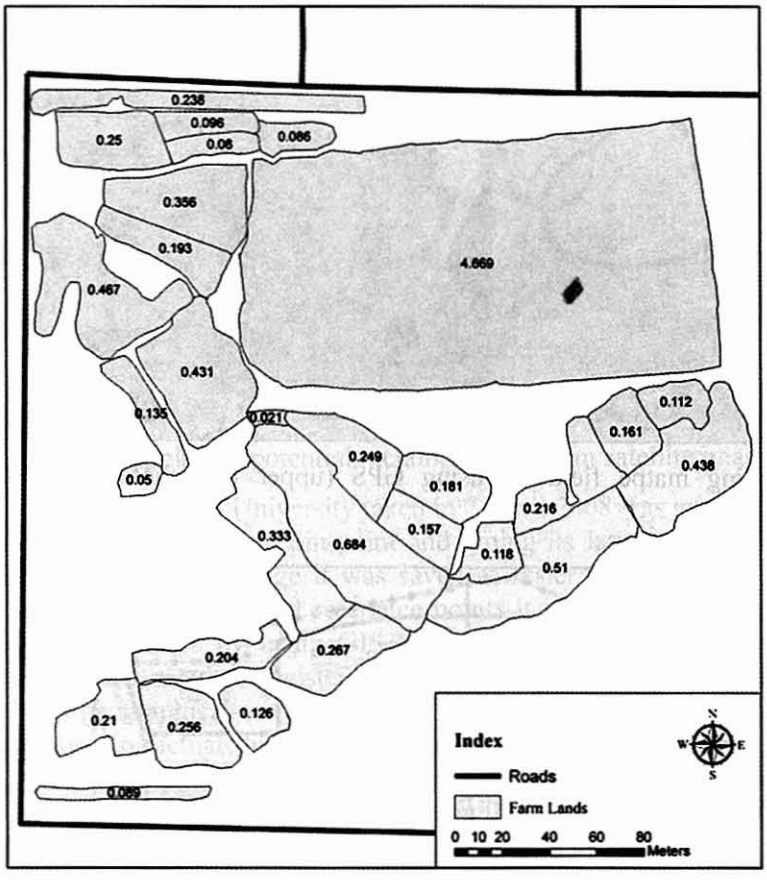

Figure (3) Area description map of farm located in southwestern part of Taungoo University

As one distinguished function of GIS, spatial database is already attached to every objects, those representing features on the earth surface by point, line, polygon (as objects) on the computer screen. Another function of GIS is that attribute information could be recorded separately and attached to spatial database before performing calculations and analysis. Ground distance and area related to digitized object are already recorded in the attached table (in case of Geodatabase file format) of spatial database and automatically update when objects are modified. Thus, spatial information related to recorded feature could be directly derived from GIS. Other collected information such as amount of fertilizer inputs, date of transplanting, yield, etc. are recorded in attribute table and attached to each object by GIS software (Fig. 4).

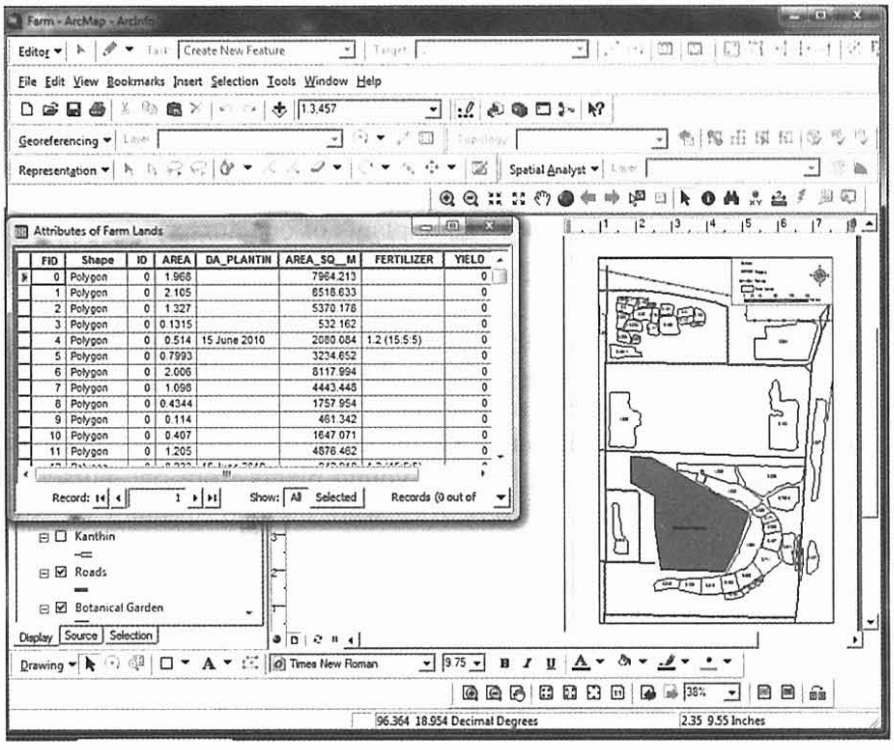

Figure (4) Attribute table attached to objects on the map

Analysis of Farm Functions by Using GIS

Analysis is second step in GIS application. It is conducted based on the data derived from first step (mapping and other field observations). Thus, it is necessary to conduct first step accurately to get correct answer in analysis. Two types of analysis were presented in this paper. First analysis is concerned with the choice of appropriate locations for nursery. And second analysis is related to soil treatment.

Finding appropriate nursery site locations

New rice cultivation method (SRI) used in the university is different in some aspects from traditional rice cultivation method. In traditional method, nursery period takes about (30) days while SRI method takes only 8 to 12 days. Thus, young plants are too small and it is necessary to be handled with care in SRI method. In addition, the distance between nearest plants is 10 inches in SRI method while traditional method used 8 inches by 6 inches distances. Number and young plant grows in one place also differ in the two methods. Traditional one uses 3 to 5 plants while new one use only one plant. Thus, the role of transplanted young plant is very important and directly related to the final yield in SRI method. Accordingly, nursery should be closely located to the transplanting fields. By reducing carrying distance it is possible to reduce the injuries of young plants.

Another important point in selection of nursery is carrying cost. In traditional method, young plants are pulled out from the nursery and carried to the transplanting field after bundling. In case of SRI, young plants are dug to include its roots and carried with pans to the transplanting field. Then, young plants were carefully separated from each plant together with their roots in the transplanting field before transplant. As a result, number of young plant that could be carried in each trip is relatively lower in SRI method than traditional method. Thus,

the distance between nursery and transplanting filed should be close to reduce the carrying cost.

Based on overall required situations following points were considered in the analysis of appropriate nursery location.

1. Young plants carrying distance should not be more than 100 meter distance
2. Each farm plot should be grown by young plants of one nursery
3. Should be minimum trip of young plants carrying

Analysis started by finding geometric center (centriod) of each farm plot under paddy cultivation (see southwestern part of Fig. 5 for example). Then 100 meter radius circles were depicted in appropriate location (requirement 1). In some case, circles are overlapping to reduce the young plants carrying distance. Centriod points were considered in division of nursery zone and let each farm plot totally used young plants from one nursery (requirement 2). Then, farm plot including in each nursery zone were defined. In that case, some large and separately located farm plots were considered as particular nursery zones. Finally, (20) nursery zones were recorded. Each zone includes different size of farm plot in different distance. Thus, it is necessary to calculate a point that could give the minimum distance for young plants carrying to all farm plots in one nursery zone (requirement 3). Weighted mean center (weighted spatial mean) method is appropriate for this analysis. It is calculated by using each centriod included in one nursery zone weighted by area of farm plot. Here, areas of farm plot were used as weighted value since number of young plant to carry is directly proportional to the area of farm plot. The resulted potential nursery sites were shown in Fig. (5). Southwestern part of this map revealed the centriod of each farm plots used in calculation of weighted mean center. Area covered by each nursery also given in the map to understand the amount of seed to be sown in nursery.

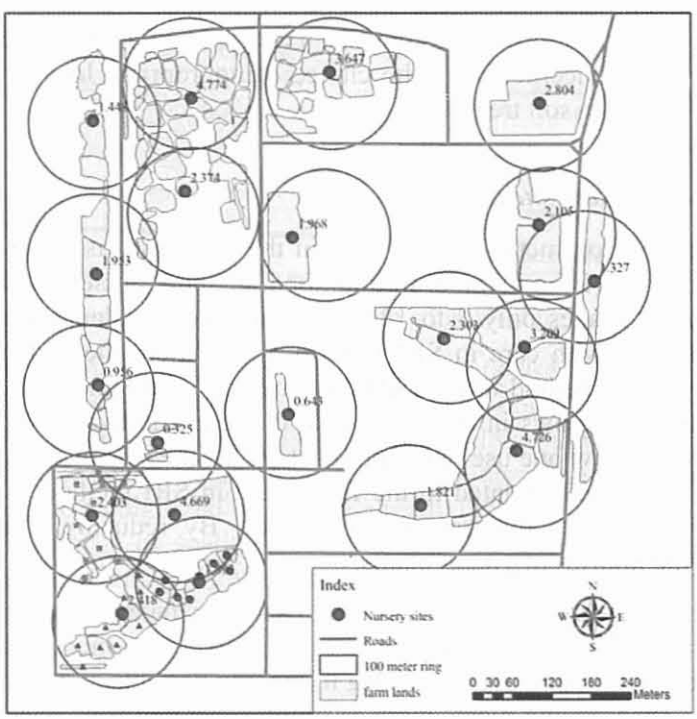

Figure (5) Location of potential nursery sites

Analysis on soil treatment

There are variations in any large farm plot in term of pH and nutrient values (especially, nitrogen, potassium, phosphorus). By knowing the exact spatial variation of each nutrient value it is possible to treat the soil by less costly and more effectively. To carry out this function it is necessary to know the spatial variation of nutrient values in the farm plot by taking proper sampling method. It can be easily done by using soil tester that can measure pH and nutrient values and GPS. Soil tests were carried out in selecting sample point and measure the location. Then, these points were transferred to the (.shp) format by using GIS software. By linking attribute table (results of pH and nutrient values) to these points it is possible to reveal these points on the map by its values. Then isolines showing distribution pattern of soil pH values could be generated by using interpolation function (contour).

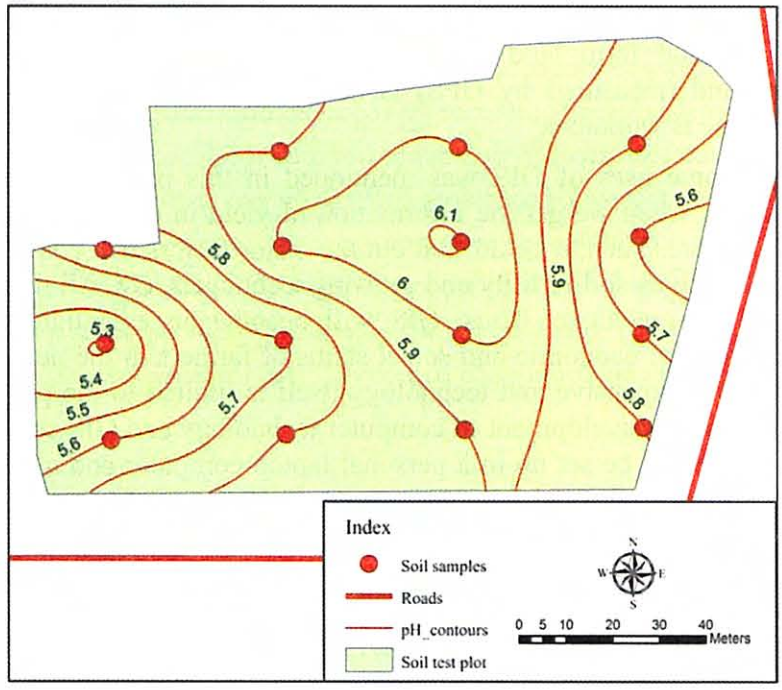

Figure (6) Example of soil pH analysis in farm plot

Figure (6) shows hypothetical pH distribution in the farm plot located in the front of University. We used systematic sampling method to collect pH values. Results revealed that western part of the farm plot has lowest pH value and central part has highest values while eastern part has moderate values. From this map we could understand that western part of the farm plot needs some treatments like adding of limestone powder to reduce its acidity. By knowing exact location that needs treatment we could reduce the amount of lime and labor cost more than half. In addition, by selective treatment we could avoid possible excess of alkalinity (high pH value) in the central part. Other nutrient values also could be measured and produce map for selective treatment.

Conclusions

Using of advanced agriculture techniques demand precise and accurate farm information for both high yield and cost reduction. In the case of old farms, land measurements and mapping were made for one time and could be used for many purposes. In newly reclaimed farm land demarcation of farm plots are ever changing and farm plot itself is very irregular to be able to measure by traditional surveying method. To measure all farm plots used in this analysis will take nearly one month with large amount of labour by traditional method. By using GPS and GIS, however, it can be made within three days by one surveyor. In addition to surveying and mapping of existing farm land, GIS has the ability to measure potential farmlands by using satellite image. This measurement of potential farmland could be easily made from satellite image with some ground checks. Thus, it is very cost effective. In our case, two areas of potential farm land (only use geo-referenced satellite image) and actually reclaimed farm land (measured by GPS) is nearly the same. Thus, for land management, satellite image alone is workable.

Although some uses of GIS was mentioned in this paper, its actual usage is much wider. For example, when we get the information of yield in each farm plot, it is possible to calculate yield per acre. Then, it could find out the major factors that control the yield by using other information such as soil fertility and growing techniques, etc. All these analysis could be done with GIS software alone. Thus, GIS will become an essential tool to boost paddy production and lifting of economic and social status of farmers in the near future. Equipments used in GIS are very expensive and technology itself is limited to the professionals up to the late 1990s. But with the development of computer technology and GIS softwares these barriers were reduced. GIS could be set up in a personal laptop computer and a GPS could be bought with lower price than a personal computer or could be rented for particular use from other person or departments. Satellite images are also available free from Internet. In addition, GIS is widely used in geography department of many universities. Distribution of this technology to local people and application of this technology in their respective regional area could upgrade not only academic field but also local economy.

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