Remote Sensing (RS) and Geographic Information System (GIS) in Precision Farming

การสำรวจระยะไกล (RS) และระบบสารสนเทศทางภูมิศาสตร์ (GIS) ในการทำเกษตรแม่นยำ

Received: May 05, 2022
Revised: July 17, 2022
Accepted: August 04, 2022

Kataya Mahachanawong Suvarnaphaet[1] and Phisit Suvarnaphaet[2]
กตญู มหาชนะวงศ์ สุวรรณแพทย์ และพิสิษฐ์ สุวรรณแพทย์

ABSTRACT

Agriculture provides food and fiber, which are two of humanity's most fundamental requirements. Precision agriculture is a revolutionary method of agricultural management that is revolutionizing how farmers operate. It is built on information technology, which helps farmers collecting data and knowledge in order to make better decisions. In addition, it entails using geographic data to better understand field variability, minimize input consumption, and increase crop output (yield). Over expanding area of land, soil types, moisture content, nutrient availability, and other variables change considerably. Farmers may more accurately decide what inputs to place where and in what quantities by using remote sensing (RS), geographic information systems (GIS), and global positioning systems (GPS). With this knowledge, farmers can make better use of costly resources like fertilizers, insecticides, and herbicides, as well as water supplies.

Keywords: Precision Agriculture, Remote Sensing, Geographic Information System

---

[1] Lecturer, Faculty of Animal Sciences and Agricultural Technology, Silpakorn University, Phetchaburi IT Campus; Email: suvarnaphaet_k@silpakorn.edu.

[2] Lecturer, Department of Agricultural Leadership and Communications, Faculty of Animal Sciences and Agricultural Technology, Silpakorn University, Phetchaburi IT Campus; Email: suvarnaphaet_p@silpakorn.edu.

บทคัดย่อ

ด้วยอาหารและเส้นใยทางการเกษตรนั้นคือ 2 สิ่งหลักที่มนุษยชาติมีความต้องการมากที่สุด เกษตรแม่นยำเป็นการปฏิวัติการจัดการทางการเกษตรเพื่อปฏิวัติวิธีการทำงานของเกษตรกร การทำการเกษตรที่มีความแม่นยำสูงด้วยระบบเทคโนโลยีสารสนเทศจะช่วยให้เกษตรกรสามารถรวบรวมข้อมูลและองค์ความรู้ต่าง ๆ เพื่อการตัดสินใจได้ดียิ่งขึ้น นอกจากนี้เกษตรแม่นยำเกี่ยวข้องกับการใช้ข้อมูลทางภูมิศาสตร์เพื่อทำความเข้าใจความแปรปรวนในการทำงานภาคสนามได้ดียิ่งขึ้น ลดการใช้ปัจจัยการผลิต และเพิ่มผลผลิตทางการเกษตร ด้วยพื้นที่ทำการเกษตรที่มีขนาดใหญ่ ประเภทดิน ปริมาณความชื้น ความพร้อมของธาตุอาหาร และตัวแปรอื่น ๆ ที่เปลี่ยนแปลงเน้นเกษตรกรอาจตัดสินใจได้อย่างแม่นยำยิ่งขึ้นว่าปัจจัยการผลิตใดควรจะใส่ที่ใดและในปริมาณเท่าไรโดยใช้การตรวจจับระยะไกล (RS) ระบบสารสนเทศทางภูมิศาสตร์ (GIS) และระบบระบุตำแหน่งทั่วโลก (GPS) ด้วยความรู้นี้เกษตรกรสามารถ ใช้ทรัพยากรที่มีค่าใช้จ่ายสูงเช่นปุ๋ยยาฆ่าแมลงและสารกำจัดวัชพืชรวมถึงการจัดการน้ำได้อย่างมีประสิทธิภาพยิ่งขึ้น

คำสำคัญ: เกษตรแม่นยำ การสำรวจระยะไกล ระบบสารสนเทศทางภูมิศาสตร์

Introduction

One of the most creative and technically sophisticated kinds of farming is precision farming of sustainable agriculture to emerge in the twenty-first century. Precision farming aims to increase agricultural output while also improving environmental quality (Abhilash Joseph, Abdul Hakkim, & Sajeena, 2020). Precision agriculture is a word that catches the imagination of those concerned with the production of food, feed, and fiber (Landa & Feller, 2010). Precision agriculture has the ability to boost output while simultaneously lowering production costs and their impact on the environment. Precision agriculture evokes visions of farmers facing the elements with computerized gear that is flawlessly controlled by satellites and local sensors as well as crop planning software that accurately predicts crop development. The term "future of agriculture" has been applied to this photograph (Tayari, Jamshid, & Goodarzi, 2015). Precision Farming (PF), as well known as Precision Agriculture (PA) or site-specific crop management (SSCM), is a farming system that integrates information and production to improve long-term, site-specific, and whole-farm production efficiency, productivity, and profitability while minimizing unintended effects on wildlife and the environment (Alemaw & Agegnehu, 2019).

Precision farming offers numerous advantages, technology can make farm planning and managing easier however it is more challenging to apply it effectively. This does not occur when a farmer buys a GPS unit or a yield monitor. It happens gradually when the farmer has a better understanding of precision farming technology and realizes that precision farming is more than simply about increasing yields (Lencsés, Takács, & Takács-György, 2014). The first step for a farmer to be successful in precision farming is having knowledge of his natural resources in the field. This includes a greater grasp of soil types, hydrology, microclimates, and aerial photography. Before purchasing a yield map, a farmer must understand the several factors that influence crop productivity in the field (Andreo, 2013).

According to Liaghat and Balasundram (2010) the PA database contains:

• Crop information such as growth stage, health, and nutritional requirements.

• Consider soil depth, texture, nutritional status, salinity, and toxicity as well as soil temperature and potential productivity.

•Microclimate data such as canopy temperature, wind direction and speed, and humidity were collected seasonally and daily.

• The current state of surface and subsurface drainage, irrigation infrastructure, water supply, and other input plans.

The purpose of this article is to present content and material about precision agriculture using remote sensing (RS) and geographic information system (GIS) as follows: 1) Geographical Information Systems (GIS), 2) Interpolation, 3) Spatial Econometrics, 4) Spatial Econometrics Importance, 5) Precision farming currently employs GIS software, and 6) Remote Sensing (RS).

Geographical Information Systems (GIS)

The Geographical Information System is an important tool for analyzing and managing agricultural resources (GIS). GIS, a core tool for decision support systems, is critical in the development of expert systems across a wide range of agricultural industries (Tayari et al., 2015). A geographical information system (GIS) is a database system that collects, stores, retrieves, manipulates, analyzes, and displays spatially connected data on maps. It is a combination of cartography, statistical analysis, and database technology in its most basic form. There are interactive GIS maps available. Map users may scan a GIS map in any direction, zoom in or out, and alter information types displayed on the computer screen. The ability to balance inputs and outputs in precision farming is critical to long-term success and profitability. GIS capability to analyze and show agricultural settings and processes has proven to be extremely beneficial to farmers (Maguire, 1991).

In precision farming vehicles, GIS serves two purposes. First, it has various simulation models that farmers can utilize such as water flow, crop development, soil erosion, and nutrient and pesticide leaching. GIS facilitates the integration of geographical data on a wide range of issues, including soil, crop, weather, and field history (Lu, Daughtry, Hart, & Watkins, 1997). Second, farmers can analyze research findings from GIS assisting features to optimize solutions for usage on farms. GIS can help with this research data and findings by providing a strong foundation for storing base data, simple modeling, presenting findings, creating a user interface, and managing farm movement using GPS. A decision support system for the deployment of precision farming at the farm level may be developed using GIS (Ray, Panigrahy, & Parihar, 2008).

Yield monitors are devices that measure agricultural yields and are mounted to harvesting machines. At regular intervals, the monitor's yield data as well as the GPS unit's position data, are gathered and recorded (of time or distance). They also keep track of information such as distance and bushels per load as well as the number of loads and fields. Yield maps can be created using GIS software (Fulton, Hawkins, & Taylor, 2018).

In recent years there have seen the development of many approaches for statistically assessing spatial relationships within and across environmental data. These approaches allow for the quantitative determination of whether a particular variable has a geographical trend or pattern, and whether it is connected to others, and therefore describes and/or forecasts the same growth and productivity actions of the plants. The capacity to comprehend or anticipate probable connections between, for instance, environmental factors and yield, is impacted by a simple visual depiction of data. We can't determine if such relationships are relevant or if they're hidden by numerous kinds of inaccuracy or stochasticity. As a result, statistical analysis is essential for quantifying and numerically defining the geographical connections found in the field.

At present, GIS technology is becoming more advanced. It is possible to use the precision farming applications for analysis and to develop the product obtained from cultivation effectively in order to farm well in the long run and get rewarding returns. Farming for good productivity has many related factors. Let us start with the soil quality of the area used in cultivation. The location of land-climate cultivated plants have to meet the needs of the market. As mentioned above, in each factor, GIS technology can be used for analysis and development in agriculture at any stage to increase productivity.

In the authors' view, using GIS technology in precision agriculture analysis is a great choice in improving, developing, and predicting the expected outcomes of farming. Yet the data needed in the analysis is quite subtle, and the data analyzer must have knowledge and understanding of GIS technology. It will be an ideal choice for certain agencies, however, it will be challenging for farmers who do not have much knowledge of the GIS technology.

Farmers can utilize Geographic Information Systems (GIS), Global Positioning Systems (GPS), or Remote Sensing (RS) separately or they can apply these technologies together, resulting in increased efficiency and geo-informatics technology has been applied and planned to make decisions on various subjects accurately, quickly, and efficiently. The author presents remote sensing (RS) content in the final section.

Interpolation

We must fill in the gaps using estimated or interpolated data to reflect the variables of interest. For interpolation to still be credible, the information of a variable should have a geographical pattern; i.e. locations nearer in geographic space should have more comparable values than those farther away. It is called "spatial autocorrelation". Interpolation is only possible if this association exists. To determine whether a variable exhibits spatial autocorrelation, a variety of indices can be employed (Mendez, Labrador, & Ramachandran, 2013). The letters "G" (Geary index) and "I" are the most often used (Moran index). Following confirmation that the values of the variable under inquiry have autocorrelation, to produce a surface map of a variable, an interpolation method is used to simulate it (Fu, Jiang, Zhou, & Zhao, 2014).

Geostatistics

All of the interpolation methods discussed above make no assumptions about the data's parametric distribution. Geostatistics is another technique assuming that variable values in a field's geographic space are distributed in a continuous and normal manner. An effective measure is mapping the variables gathered using geostatistical methods and a reference grid (raster or surface map) (Wani, 2019).

Spatial Econometrics

As the use of GIS grows, a methodology for managing spatial models and autocorrelation has emerged. According to Wani (2019), spatial econometrics is a set of approaches that deal with the idiosyncrasies caused by space in statistical modeling. The fundamental ideas of this approach differ from those of geostatistics. Geostatistics assumes continuous geographical variation. Covariance, according to spatial econometry, is the result of distinct things interacting with one another. This premise necessitates the development of a spatial weight matrix to describe a geographic stochastic process.

Precision farming is currently using GIS software.

Aside from the well-known proprietary GIS software (such as ArcGIS, MapInfo) that has produced specialized plug-ins or modules for PF applications, there seems to be a booming demand for GIS expressly built on PF. The much more widely utilized programs include Farm Works, SST Toolbox software, GeoAgro GIS, Map Shots, and other similar products. Some software come with applications for smartphones and tablets, as well as internet connectivity. Some examples of open-source software that provides wide and specialized GIS applications for PF include GeoDa (which also contains geostatistical analytical techniques), QGIS, GRASS GIS, and R (Namgyal, Bahar, Mehdi, Saxena, Dorjey, & Gupta, 2021). They are mostly used in academic settings.

Remote Sensing (RS)

Precision farming necessitates an understanding of the characteristics of small, usually homogeneous management zones. Soil tests for nutrients, yield monitors for crop production, soil samples such as organic matter content, data on soil maps, and ground conductivity meters indicating soil moisture can all provide these meaningful features. A manual sampling of fields along a regular grid is common, and the obtained data is interpolated using geostatistical methods (Georgi, Spengler, Itzerott, & Kleinschmit, 2018). Variability in soil, water, and crops geostatistical modeling entails taking a large number of samples at regular intervals across an agricultural area. These types of samples are both expensive and time-consuming. Several studies have demonstrated the importance of using remote sensing technologies to collect geographically and temporally diverse data for precision farming. To obtain PF remote sensing imagery, satellite-based sensors or CIR video digital cameras mounted on small aircraft can be used (Ray et al., 2008).

Remote sensing (RS) is the science of obtaining and analyzing data at a distance using sensors that are not in direct contact with the object being viewed (Aggarwal, 2004). The science of remote sensing entails aerial, satellite, and spacecraft studies of the surfaces and atmospheres of our solar system planets, with the Earth being the most frequently studied. In general, RS is limited to methods for detecting and measuring electromagnetic energy as it interacts with surface materials and the environment, including visible and non-visible radiation (Praveen & Sharma, 2020).

The use of RS and GIS technology in natural resource planning has been demonstrated to be extremely useful at the national, state, and district levels. Because of substantial advancements in the spatial, temporal, spectral, and radiometric resolutions of space-borne RS satellites, the application of these technologies in natural resource management is expanding rapidly (Patil,Maru, Shashidhara, & Shanwad, 2002).

There are several significant advantages of remote sensing (Patil & Chetan, 2017):

- Remote sensing (RS) is well-known for acquiring non-destructive data about the earth's characteristics.
- Rather than relying on single point measurements, RS data can be collected regularly across exceedingly large geographical areas.
- RS data can disclose information about unreachable areas to people.
- To reduce sample bias in RS, systematic data collection (raster) can be utilized.
- RS can give basic biophysical data that may be used in a wide range of applications.
- RS does not rely on data created elsewhere, in contrast to other mapping disciplines such as cartography and geographic information systems (GIS).

Remote sensing, or remote sensing technology, is a tool used to store space based on light waves in different wavelengths and electromagnetic waves in various forms, such as radar, microwave, and radio. Those perception devices are usually installed on aircraft or satellites. The most commonly used agencies are government and military units. In the past, even though the technology was used in agriculture, it was used at the policy level by government organizations and seldom used in the company or on a farm because of the expensive price. Remote sensing technology nowadays is much cheaper and easier to use. Farm owners can use it by ordering services from private satellites or public information available for download on the Internet, however, since data from remote sensing covers a wide area of data, the data will be inaccurate if it is used for smaller areas on the farm. The raw data obtained from remote sensing is primarily spectra of electromagnetic waves or light waves. This requires interpretation into useful information, such as the size and diversity of agricultural land, the types of crops cultivated, and soil moisture. In recent years, remote sensing technology is popular again. It has been introduced with an affordable flying drone. Middle-class farmers can buy drone-based remote sensing technology with low cost.

Conclusion

Precision agriculture is essential for improving output while minimizing environmental impact. Better management of the world's agricultural resources is necessary, given growing population demands and increased agricultural productivity. To do so, detailed data on the many sorts of resources, as well as their quality, amount, and position, must first be gathered. Data collecting and production systems, satellite or aerial-based RS technologies will be critical to improve present agriculture and natural resources.

Satellite image data should be analyzed rapidly by GIS software, and data acquired from experiment location should be used to increase satellite image data accuracy. Pest and disaster prevention, crop estimation, and plant growth monitoring can be exploited with satellite data, reducing negative environmental consequences and smoothing the way to a sustainable, environmentally friendly, and dynamic agriculture development.

Geoinformatics technology is an important technology for precision agriculture. It is a state-of-the-art technology to collect, manage, analyze, and obtain spatial data in both remote sensing (RS) and geographic information system (GIS) to effectively apply to precision agriculture by knowing about geography in geoinformatics technology to understand the phenomena that occur in nature concerning humans. Geoinformatics technology and knowledge are used to describe the interactions that take place. Geoinformatics technology is used in geographical processes, including the use of

RS and GIS. In data management and analysis, it is possible to summarize and use it in systematic planning and decision-making, such as studying and tracking changes in the environment by using high-resolution satellite imagery data to analyze and apply geographic information systems in agricultural data management.

Adopting cutting-edge technologies and innovations for precision agriculture (PA), such as geographic information system (GIS), Global Positioning System (GPS), and remote sensing (RS), will increase productivity, help to create the same soil fertility in the whole area, plant and manage water and fertilizers as needed, and can increase productivity or maintain the same level of yield as traditional farmers.

Reference

Abhilash Joseph, E., Abdul Hakkim, V. M., & Sajeena, S. (2020). Precision Farming for Sustainable Agriculture. *International Journal of agriculture innovations and research, 8*(16), 543-553.

Aggarwal, S. (2004). Principles of remote sensing. *Satellite remote sensing and GIS applications in agricultural meteorology*, *23*(2), 23-28.

Alemaw, G., & Agegnehu, G. (2019). Precision Agriculture and the Need to Introduce in Ethiopia. *Ethiopian Journal of Agricultural Sciences, 29*(3), 139-158.

Andreo, V. (2013). Remote sensing and geographic information systems in precision farming. *Instituto de Altos Estudios Espaciales "Mario Gulich"-CONAE/UNC Facultad de Matematica. Astronomia y Física–UNC*.

Fu, W. J., Jiang, P. K., Zhou, G. M., & Zhao, K. L. (2014). Using Moran's I and GIS to study the spatial pattern of forest litter carbon density in a subtropical region of southeastern China. *Biogeosciences, 11*(8), 2401-2409.

Fulton, J., Hawkins, E., Taylor, R., & Franzen, A. (2018). Yield monitoring and mapping. In Shanon, K. D., Clay, D. E., & Kitchen, N. R. (Eds.), *Precision Agriculture Basics* (pp. 63-78). ASA, CSSA, SSSA.

Georgi, C., Spengler, D., Itzerott, S., & Kleinschmit, B. (2018). Automatic delineation algorithm for site-specific management zones based on satellite remote sensing data. *Precision Agriculture, 19*(4), 684-707.

Landa, E. R., & Feller, C. (Eds.). (2010). *Soil and culture.* Springer Science & Business Media.

Lencsés, E., Takács, I., & Takács-György, K. (2014). Farmers' perception of precision farming technology among Hungarian farmers. *Sustainability, 6*(12), 8452-8465.

Liaghat, S., & Balasundram, S. K. (2010). A review: The role of remote sensing in precision agriculture. *American journal of agricultural and biological sciences, 5*(1), 50-55.

Lu, Y. C., Daughtry, C., Hart, G., & Watkins, B. (1997). The current state of precision farming. *Food reviews international, 13*(2), 141-162.

Maguire, D. J. (1991). An overview and definition of GIS. *Geographical information systems: Principles and applications, 1*(1), 9-20.

Mendez, D., Labrador, M., & Ramachandran, K. (2013). Data interpolation for participatory sensing systems. *Pervasive and Mobile Computing, 9*(1), 132-148.

Namgyal, D., Bahar, F. A., Mehdi, S., Saxena, A., Dorjey, S., & Gupta, V. (2021). Remote sensing (RS) and geographical indication system (GIS) techniques in precision agriculture. *The Pharma Innovation Journal, 10*(8), 1220-1222.

Patil, V. C., Maru, A., Shashidhara, G. B., & Shanwad, U. K. (2002, October). Remote Sensing, Geographical Information System and precision farming in India: opportunities and challenges. In *Proceedings of the Third Asian Conference for Information Technology in Agriculture* (pp. 26-28).

Patil B, Chetan HT. (2017). Role of remote sensing in precision agriculture, *Marumegh, 2*(4), 34-37.

Praveen, B., & Sharma, P. (2020). A review: The role of geospatial technology in precision agriculture. *Journal of Public Affairs, 20*(1), e1968.

Ray, S. S., Panigrahy, S., & Parihar, J. S. (2008). Precision Farming in. *Extension of Technologies: From Labs to Farms,* 307.

Tayari, E., Jamshid, A. R., & Goodarzi, H. R. (2015). Role of GPS and GIS in precision agriculture. *Journal of Scientific Research and Development, 2*(3), 157-162.

Wani, M. A. (2019). 15 Remote Sensing and GIS. *Agricultural Impacts of Climate Change [Volume 1],* 263.