The Role of Remote Sensing Technology (Latest Geospatial) for Agriculture in Indonesia

Rizatus Shofiyati [1,*]

[1] *Indonesian Center of Agricultural Land Resources Research and Development (ICALRD) - MoA*
[*]*Corresponding author. Email: rshofiyati@gmail.com*

ABSTRACT
Remote sensing has several capabilities to be used in agriculture, which plays a significant role in crop classification, crop monitoring and yield assessment. In Indonesia, use of remote sensing divided into 3 eras: non-satellite (1970s - 1981), transition (1982 - 2004), digital satellite (2005 - now). Research on digital remote sensing for agriculture has been started since 1997/98. However, operational use of remote sensing in agriculture started in mid-2014 and its use has been increasing to date. Remote sensing is an important tool in timely monitoring and provides an accurate picture of agricultural sector with a high revisit frequency and accuracy. A sustainable agricultural management needs a spatio-temporal based technology analyzes. Combination between remote sensing and other advanced techniques such as global positioning systems and geographic information systems plays a major role in assessment and management of agricultural activities. Taking advantage of remote sensing capabilities, Indonesian Agency of Agricultural Research and Development (IAARD), the Ministry of Agriculture (MoA) has not only used for agricultural land resources mapping, but also developed a remote sensing based information system of Standing Crop (SISCrop) and Smart Soil Sensing Kit. Using the latest satellite data (such as Sentinel-1 and 2, SPOT 6/7, Landsat 8, and MODIS), MoA can estimate crop area, monitor plant growth, evaluate soil fertility, detect crop stress, monitor drought and flood condition, estimate yield, implement precision agriculture, and support crop insurance assessment. These implementation can improve efficiency and effectiveness of agricultural land management and maintain the sustainability of agricultural system.

Keywords: *Spatio-temporal, Satellite data, Standing Crop, SISCrop.*

1. INTRODUCTION

Currently, remote sensing technology (sensing) and sensors have developed very rapidly. The specifications of remote sensing data are very diverse. The ability of sensory technology that can detect and monitor remotely without touching the object being observed can be utilized for various purposes. Therefore, the senses can monitor a wide area even in locations that are difficult to reach from land. Recording that can be done periodically, both historically and in real time is also an advantage of this technology. The ability of these sensory technologies can be utilized by filling the gap in the availability of technology that is not yet adequate to support agriculture. Sensing applications can be strengthened especially in supporting precision agriculture. Some of the information obtained from satellite imagery, can help manage agricultural land more effectively and efficiently in the management and planning of agricultural land.

Remote sensing technology can be used in precision agriculture. Precision farming systems are based on satellite navigation systems or terrestrial systems for geographic information and sensors located within farm plots or equipment. This system is done by collecting information that is used to make decisions with more precision and optimize crop yields. This allows saving or reducing the fertilizer used. This means that precision agriculture can reduce costs and optimize farmland, reducing environmental impact by optimizing the use of water, pesticides and engine fuels; thus, greater production is obtained with fewer resources [1].

This paper describes several applications of remote sensing and sensor technology for agriculture, which have been implemented by the ministry of agriculture in Indonesia.

2. REMOTE SENSING FOR AGRICULTURE IN INDONESIA

2.1. Why agriculture needs remote sensing?

Currently, agriculture faces problems of Anthropogenic decreases in soil fertility, soil sickness, environmental pollution, wide yield gap, GHG emission, More unpredictable weather due to climate change, Increased intensity of pest and diseases, Water use inefficiency. Using remote sensing and spatial data analysis can create recommendation of strategies for narrowing yield gap, climate smart agricultural practices, cropping calendar, and increase more grain per drop.

Remote sensing has been the most useful tool to acquire spatial and temporal information, therefore it has several advantages for agronomical research. Remote sensing plays a significant role in crop classification, crop monitoring, and yield assessment. The monitoring of the agricultural production system follows strong seasonal patterns in relation to the biological life cycle of crops. All these factors are highly variable in space and time dimensions. Moreover, agricultural productivity can change within short time periods, due to unfavorable growing conditions. Agricultural systems should be monitored periodically. Remote sensing is an important tool for time series monitoring and giving an accurate picture of agricultural condition. It has high revisit frequency and high accuracy. For sustainable agricultural management, all influenced factor need to be analyzed based on a spatio-temporal [2].

Remote sensing combines with global positioning systems and geographical information systems are playing a major role in assessment and management of agricultural activities. Some application of these technologies in the field of agriculture are crop acreage estimation, crop growth monitoring, yield estimation, soil moisture estimation, soil fertility evaluation, crop stress detection, detection of diseases and pest infestation, drought and flood condition monitoring, weather forecasting, crop insurance, precision agriculture for maintaining the sustainability of the agricultural systems and improving effectiveness agriculture management [3].

2.2. Applications Remote Sensing in Agriculture

Development of the use of remote sensing for agriculture in Indonesia is divided into 3 periods, non-satellite era (1970s - 1981), transition era (1982 - 2004), digital satellite era (2005 - now) (Figure 1). Utilization of remote sensing using aerial photos has only been intensively used from 1970 to 2004. Between that period, namely 1982, satellite imagery was used. However, digital interpretation only started in 1997/98.

2.2.1. Soil and Land Agricultural Mapping

Agricultural land resource maps are very diverse, ranging from land maps as basic data to thematic maps derived from them. In the 1980s, for the purposes of surveying and compiling land maps, aerial photographs were interpreted manually using a three-dimensional stereoscope against overlapping aerial photographs (mosaic). Land use and cover in aerial photographs can be used as a marker of soil formation and soil type. Technological advances have produced a variety of images with varying detail and accuracy, ranging from Landsat images suitable for review scale map preparation (1:250,000 scale) or SPOT images for more detailed scale (1:50,000 scale or greater) [4]. Satellite images used are presented in Table 1.

Various maps can be made from soil maps, such as land suitability map, commodity recommendation map, agroecological zone (AEZ) map, commodity zoning map, land management recommendation map and so on. In addition, satellite images are used to create maps of paddy fields and other land uses, such as oil palm, coconut, sugar cane, cocoa plantations. It can also identify land availability map, swamp land maps types and agriculture land conversion.

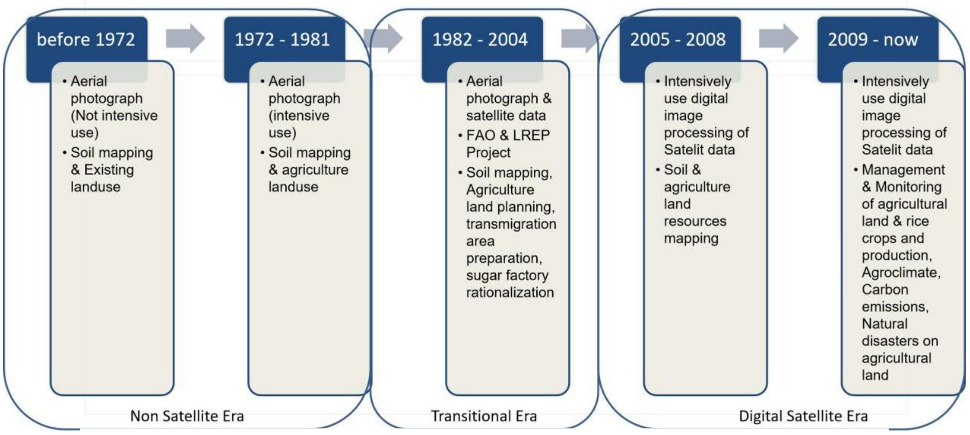

Figure 1 Three periods of satellite data utility in agriculture.

Table 1. Types of satellite imagery used for land mapping

Scale	Remote Sensing Data	Remarks
1:1,000,000 Exploration map	Satellite data (Landsat TM) Contour maps US navigation maps	Joint operation graphics
1:250,000 Reconnaiss-ance map	Satellite data (Landsat 7/8) Digital elevation (SRTM, DEM) CRST: IKONOS, Quick bird, World View	Land cover, landform, surface wetness (for peat soil mapping)
>1:50,000 semi-detailed to detailed map	Satellite data (Landsat, SPOT) Very high-resolution satellite data: IKONOS, Quickbird, World View Aerial photographs	Land form

Integration of remote sensing, land resource maps and paddy field maps, can be used to identify the potential of swamp land as a food supplier during a long dry season. The results of both analyzes can provide information on land that has potential for a large planting area. Satellite images can detect receded area in swamp areas by using tasseled cap, wetness, greenness and brightness and other methods, such as Land Surface Temperature and Vegetation indexes [5, 6].

2.2.2. Crop Monitoring

Standing Crop is information on the growth phase of rice plants obtained from analysis of satellite images that can be presented either spatial, tabular, or graphic. Standing Crop analysis is performed automatically which is built from a model based on satellite imagery [7]. The development of standing crop from time to time is presented in Figure 1, where research on the identification of the rice phase or so-called standing crop has been started since 1997/98. However, it was only at the end of 2014 that the model was used operationally by the Ministry of Agriculture in assisting its policy making [8].

The data can be derived into various information, such as identification of rice planting index, irrigation water regulation, estimation of production input needs (seeds, fertilizers, pesticides), area estimation, rice production and harvest time. So that it can be known when rice plants in an area are ready to be harvested and in which areas. So that the supplying action for production inputs to areas that need to be carried out.

Anticipation in management can also be done by combining Standing crop information with weather. This information can be used for management recommendations tailored to rainfall conditions, such as early planting or cropping patterns following the rainfall pattern. Likewise, the use of varieties or types of plants is adjusted to the prediction of rainfall in the next 1-2 months. Thus the need for the number and types of seeds, fertilizers, and pesticides, as well as water supply at that phase can be calculated more precisely [9].

The agricultural crop monitoring information system is a WebGIS-based information system that provides information on the growing phase (standing crop) of rice in spatial and tabular form interactively. The data displayed is the result of satellite data analysis. The standing crop information system, which is currently called SISCrop, has been developed since 2015 and has been renamed several times, a) Land Resources and Agricultural Crops (SI-SDLTP), SI-PETANI (2016), and SI MANTAP (2017-2019).

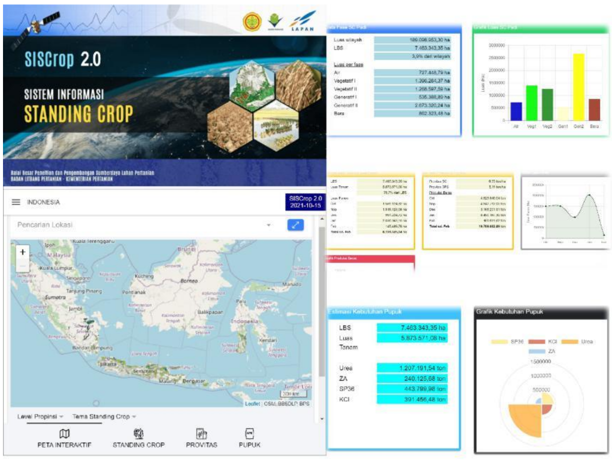

Figure 2 Display of SISCrop 2.0 [10]

How can remote sensing technology detect shifts in planting groups in a wider area, where we can see the diversity of production, region by region. Water can be used efficiently so that not much is wasted. For this reason, regular arrangements for the provision of water are needed so that the provision of water is in accordance with the real plants planted in the field. The implementation of cropping pattern maps from year to year that utilizes Standing Crop analysis can be used to monitor shifts in cropping patterns and suitability of application of the rules that apply to distribution of irrigation water in Irrigation Area [11].

Daily images, such as MODIS, combined with standing crop data, can provide information on areas affected by floods and agronomic droughts [12, 13]. Even with a temporal analysis of flood events frequency in an area, it can provide information on flood endemic areas [14]. With this data, government can prepare anticipation for these areas. Thus, remote sensing can assist field officers or loss adjusters in accelerating the checking of crop damage due to floods and droughts in agricultural insurance programs [15].

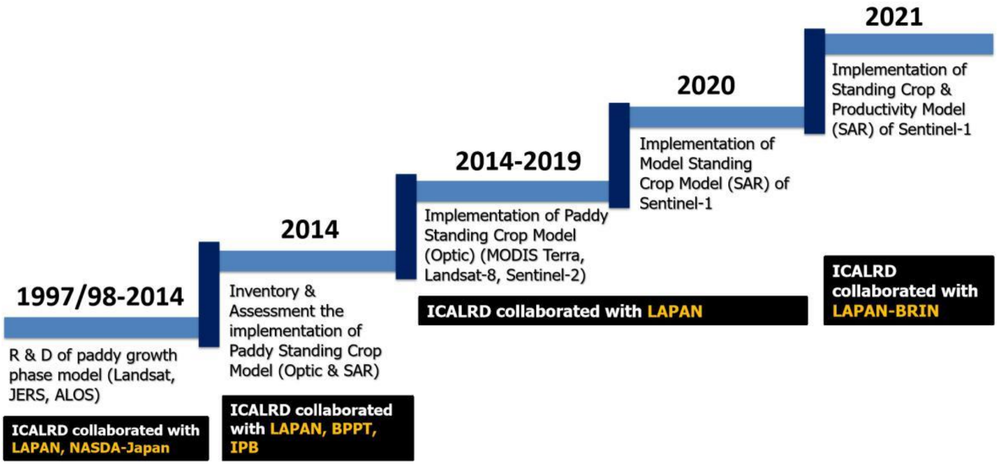

Figure 3 Development of standing crop over time

2.2.3. Smart Soil Sensor kit

The Smart Soil Sensor kit (S3K) is a soil fertility detection tool developed by the Soil Research Institute. S3K can be used to monitor and analyze soil fertility in real-time, fast and affordable. Hartatik in Indonesia Agency of Agricultural Research and Development (IAARD) [16] report that, The development of this tool by utilizing the Far Infrared (FIR), Middle Infrared (MIR) and Near Infrared (NIR) spectrum. They can be used as sensors to detect soil properties. The spectrum commonly used in the laboratory, in principle, can be carried out in the field but in the right spectrum range of wavelengths.

Infrared light waves can predict some soil properties such as nitrate (NO3-). Some NIR spectrometers have different wavelengths. The price of a nutrient detector sensor that has a wide wavelength range is quite expensive when compared to a sensor that has a narrow wavelength range.

S3K is an advanced technological innovation to determine soil chemical properties using an Infrared Sensor (NIR) with a wavelength of 1300 – 2600 nm so that the process of determining soil properties is faster, soil properties data are quantitative, and more practical to use in rooms and fields. S3K is equipped with decision support to provide fertilizer recommendations according to soil properties and nutrient needs of rice, corn and soybeans. Parameters of soil chemical properties measured were pH, C-organic, N-total, P2O5 and K2O 25% HCl extract, P Bray I extract, P Olsen extract, K Morgan extract, cation exchange (Ca, Mg, K and Na), cation exchange capacity, base saturation and soil texture.

3. CHALLENGES AND INNOVATIVE IDEA OF REMOTE SENSING IN AGRICULTURE

3.1. Challenges for Future Use of Remote Sensing

For future use of remote sensing has some challenges. They are :

- Continuity of availability of satellite image data and tools that still depend on other countries
- The model and results of remote sensing analysis are still in doubt or there are concerns that it will be publicly known by the general public
- Expensive initial investment (infrastructure, equipment and human resources).

3.2. Remote Sensing Based Innovative Idea

Innovative technology breakthroughs based on remote sensing and sensors that need to be developed:

- Identify the potential of swamp land as a food supplier
- Food system early warning
- Irrigation management using satellite imagery
- Development of soil condition detectors integrated with agricultural machinery, tillage, planting tools and fertilization applicators.
- Cooperation with various parties for development and mass production

4. CLOSING REMARKS

Various types of images can be used, one of which is to identify land cover and use in an area. Up-to-date land cover and use maps can answer many questions regarding the availability and reserves of agricultural land.

There is a new awareness that remote sensing is very important and can be properly utilized by the private sector to answer the rapid reaction costs of what is happening in the field. Sensory data informs the actual condition, as it is. Therefore, the sense-based model and the results of its analysis can also be utilized and implemented optimally in the field by policy makers.

The sophistication and advancement of remote sensing and sensor technology is no doubt, but its utilization is not optimal. Now is the time to voice this out. The formal reference to the National Medium-Term Development Plan (RPJMN) Sustainable Development Goals (SDGs) digital transformation must be to realize digital agriculture, advanced independent and modern agriculture. SISCrop is a corporate product of the Ministry of Agriculture. Strategic information, how does this information link with various technical directorates. There is empirical data from a large study of economic benefits, market opportunities, insurance claims, which are reinforcements so that they can be echoed even better.

ACKNOWLEDGMENTS

We would like to acknowledge institutions that supported through providing funding for remote sensing research activities and expertise guidance. They were Indonesian Agency of Agriculture Researc and Development (IAARD), Indonesian Ministry of Agriculture, and Indonesian National Institute of Aeronautics and Space (LAPAN-BRIN). Their eagerness to contribute to the research and development models were highly appreciated.

REFERENCES

[1] Baseca, C.C., S. Sendra, J. Lloret and J. Tomas. A Smart Decision System for Digital Farming. Agronomy 2019, 9(5). 2019. pp 216.

[2] P. Shanmugapriya, S. Rathika, T. Ramesh and P. Janaki, Applications of Remote Sensing in Agriculture - A Review, International Journal of Current Microbiology and Applied Sciences ISSN: 2319-7706 Volume 8 Number 01, 2019, pp 2270-2238, https://doi.org/10.20546/ijcmas.2019.801.238.

[3] S. Khanal, K.C. Kushal, J.P. Fulton, S. Shearer and E. Ozkan, Remote Sensing in Agriculture—Accomplishments, Limitations, and Opportunities, Remote Sens. 2020, 12, 3783; doi:10.3390/rs12223783

[4] R. Shofiyati, A. Mulyani, W. Hartatik, Husnain, F. Djufry, Pengembangan Integrated Intelligent System Dalam Pengelolaan Sumberdaya Lahan Mendukung Pertanian Presisi, IAARD Press, 2021. pp 399 - 433.

[5] U. Avdan, G. Jovanovska, Algorithm for automated mapping of land surface temperature using LANDSAT 8 satellite data, Journal of Sensors, 2016, 2016

[6] J. Muro, S. Heinmann, A. Strauch, G. Menz, editors. Land surface temperature retrieval in wetlands using normalized difference vegetation index-emissivity estimation and ASTER emissivity product. In: Living Planet Symposium; 2016

[7] R. Shofiyati, Eye in the sky Memantau Standing Crop dari Satelit. Warta Penelitian dan Pengembangan Pertanian Volume 39 No. 4, 2017. ISSN 0216-4427. pp 7 - 8.

[8] R. Shofiyati, APRSAF Space Applications Working Group Best Practices Case Studies Agriculture, Water Resources and Related Fields: Integrating Space-Based Data and Field-Based Information Systems, JAXA, Symbios Communications, 2020, pp 18-19.

[9] Y. Apriyana, E. Surmaini, W. Estiningtyas, A. Pramudia, F. Ramadhani, S. Suciantini, E. Susanti, R. Purnamayani, and H. Syahbuddin, The Integrated Cropping Calendar Information System: A Coping Mechanism to Climate Variability for Sustainable Agriculture in Indonesia, Sustainability 2021, 13(11), 6495; https://doi.org/10.3390/su13116495.

[10] Indonesian Center of Agricultural Land Resources Research and Development (ICALRD), Sistem Informasi Standing Crop (SISCrop) 2.0, http://scs1.litbang.pertanian.go.id, 2021.

[11] R. Shofiyati, Uchida, S., Ismullah, I.H., dan Sarwani, M, Change Detection of Cropping Pattern in Paddy Field Using Multi Spectral Satellite Data for Estimating Irrigation Water Needed. Agrivita Journal of Agricultural Science (AJAS), 34, No. 3. 2012, SK DIKTI No.65a/DIKTI/Kep./2008 (B).

[12] R. Shofiyati, W. Takeuchi, P. Sofan, Soni Darmawan, Awaluddin and W. Supriatna, Indonesian drought monitoring from space. A report of SAFE activity: Assessment of drought impact on rice production in Indonesia by satellite remote sensing and dissemination with web-GIS, IOP Conference Series: Earth and Environmental Science, Volume 648, 2014, pp 1-10. doi:10.1088/1755-1315/20/1/012048.

[13] S. Darmawan, W. Takeuchi, R. Shofiyati, Estimation of Rice Production and Forecasting of Agricultural Drought in Indonesia Based on MODIS Data (Case Study in Indonesia). Proceedings of 34th Asian Conference on Remote Sensing, Vol. 1, Curran Associates, Inc., 2014, pp 2861 – 2865.

[14] R Shofiyati, W Takeuchi, S M Pasaribu and Y R Irawan, Space-based drought analysis to support

agricultural insurance facing climate change, 1st International Conference on Sustainable Tropical Land Management 16 - 18 September 2020, Bogor, Indonesia, 2021. pp 1-11, doi:10.1088/1755-1315/648/1/012130.

[15] R. Shofiyati, Haryono, dan S.M. Pasaribu, Pemanfaatan Teknologi Penginderaan Jauh untuk Pertanian di Era Industri 4.0, IAARD Press, 2019, pp 161-180.

[16] Indonesian Center of Agricultural Land Resources Research and Development (ICALRD), Smart Soil Sensing Kit, Terobosan 4.0 Deteksi Cepat Hara Tanah, https://www.litbang.pertanian.go.id/info-teknologi/4209/, 2019.