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Multi Sensor Satellite Data for Rice Production Estimation in an Effort to Support National Food Security

Rizatus Shofiyati[1*], Ishak Hanafiah Ismullah[2], and Hidayat Pawitan[3]

[1]Indonesian Center for Agricultural Land Resources Research and Development (ICALRD), Indonesian Ministry of Agriculture, Bogor.
[2]Bandung Institute of Technology (ITB), Bandung.
[3]Faculty of Mathematics and Natural Sciences, Bogor Agricultural University (IPB), Bogor. (Indonesia)

ABSTRACT

Rice is a staple food for Indonesia. For some time, a food availability approach was used for based of Indonesia's food security program. Monitoring and early warning systems is one of inherent components in the implementation of food security paradigm. Spatial information about paddy plated area and production is an important element for monitoring in agriculture. Further, the data spatially and time series, both historically and in real time, is required for consideration in the planning management and development of agricultural land. Purpose of his study is to assess spectral character of ALOS satellite imagery and combination of multi-sensors SAR and Optic to identify paddy planting area in paddy field. Research has conducted on Subang District area, West Java Province. Data used is PALSAR for analyzing of backscatter and soil moisture content and ALOS AVNIR-2 is for analyzing of NDVI and checking of land cover visually, with acquisition date on 10 May 2007. Research result shows that multi resolution data can produce a more detailed distribution map of paddy planting area of Subang. However, validation of the method used remains to be done. Multi-sensor data provides an opportunity to obtain better information and can contribute in agricultural land planning and influence to better agricultural development policies. The information can be used for policy maker for food security planning and management in Indonesia.

Keywords: Paddy planting area, multi sensor, PALSAR, AVNIR-2.

1. INTRODUCTION

Rice is a staple food for Indonesia, so that, agricultural land has a strategic function as the primary food provider for people in Indonesia. Rice self-sufficiency is very important for food security program. Monitoring and early warning systems is one of inherent components in the implementation of food security paradigm. Spatial information about paddy plated area and production is an important element for monitoring in agriculture. Dealing with the existing methods of food production estimation, the reliability of data and information is varying. It is obvious that the government has to maintain food security for the country, as the demand for food is significantly increasing. Usually at the time of famine, there was turmoil on the availability of rice as the national food. It is an indication of an error in the decision-making, due to misinformation.

Currently, different methods of data collection, resulting in differences information in rice production estimation. To this point, agricultural monitoring techniques using appropriate tools are very important. Remote sensing data offers the advantage of a wide spectral coverage. In addition, to its temporal acquisition provides data record periodically. It can be used as an alternative to study land use change, such as the growing period of paddy field. Wide coverage of satellite data allows giving information about condition of agricultural land even in remote areas. Further analysis on such data and information would be incorporated in the current agricultural development planning.

The Subang area, West Java Province, was selected as research sites. This area has contribution to national rice production with large agricultural land, both irrigated and rained. The analysis has been done by using a combination of characteristics of multi spectral satellite data (optical) and SAR (radar). The capability of SAR data can fill the lack of optical data. It is not depend on sunlight and can penetrate of clouds and fog. The combination of both allows producing better information for identification of rice plant. Satellite data used is data that was used until the current stage is the ALOS PALSAR and ALOS AVNIR-2 date of acquisition May 10, 2007. The variation of the growth period of rice plants using a variety of paddy field conditions represented each of periods of paddy growing stage in one scene data.

The research result shows the possibility to use multi sensor SAR and Optic data for analyzing paddy planting area. However, the

***Corresponding Author**: Rizatus Shofiyati, Indonesian Center for Agricultural Land Resources Research and Development (ICALRD), Indonesian Ministry of Agriculture, Bogor.. E-mail: rshofiyati@litbang.deptan.go.id

validation of the method used remains to be done. Combination of Soil Moisture Volume calculated from backscatter of ALOS PALSAR and NDVI derived from ALOS AVNIR-2 show a specific pattern. Based on this analyzes, a map of distribution of paddy planting area of Subang Area has been produced. The results of this study is expected to provide better information and can contribute in agricultural land planning and influence to better agricultural development policies. The information can be used for policy maker for food security planning and management in Indonesia.

2. MATERIALS AND METHODS

2.1. Study Area and Data Used

The Subang area, West Java Province, Indonesia was selected as research sites. The location is situated between coordinates 106°22’ - 107°55’ East and 5°55’ - 6°31’ South.

ALOS PALSAR and AVNIR-2 have been used for this study. ALOS PALSAR has been analyzed to get water content data and ALOS AVNIR-2 to get NDVI value. AVNIR-2 is also used for visually comparison. The description of data used is in Table 1. Date of acquisition of both data is 10 May, 2007, while analysis of NDVI was obtained from two acquisition dates of ALOS AVNIR-2 (10 May 2007, and 15 May 2009). Map of research location and area coverage of overlapped data is presented in Figure 1.

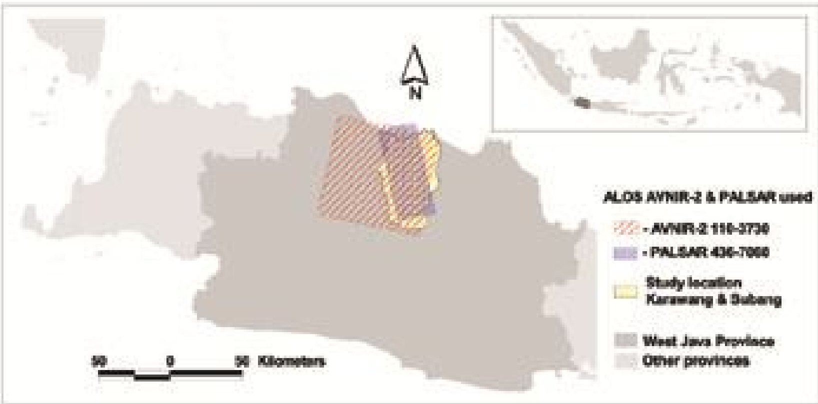

Figure 1. Map of study area

Table 1 Description of ALOS images used

No.	Scene ID	Path	Frame	Mode	Orbit Direction	Off Nadir	Resolution	Polarization/ Cloud cover
1.	ALPSRP068787060	432	7060	PLS	Ascending	21,5°	25 m	HH, HV, VV, VH
2.	ALAV2A068713730	110	3730	OBS	Descending		10 m	11-20%
3.	ALAV2A176073730	110	3730	OBS	Descending		10 m	3-10%

Note: Date acquisition of No. 1 and 2 is 10 May 2007, and No. 3 is 15 May 2009.

2.2. RESEARCH METHOD

The vegetation index (VI) can be used to determine pixels that have the densest, greenest and darkest vegetation in image. Vegetation indices has been used is Normalized Difference Vegetation Index (NDVI), which is calculated by using NIR and Red, as follows

NDVI = (Near Infrared - Red) / (Near Infrared + Red) .... (1)

Where: NDVI values calculated using band 4 for NIR and band 3 for Red of ALOS AVNIR-2 data. Backscatter value of ALOS PALSAR data were obtained by using the following calculation [1]:

$\sigma^0 = 10 * \log_{10} [DN^2] + CF$………………..….(2)

where : σ^0 = backscatter coefficient (dB); DN = digital number of PALSAR image; CF = factor calibration = −83.0 dB (st.dev 0.64 dB).

To calculate soil water content of backscatter (dB) used a simple linear equation refers some research results [2][3][4] as follows:

VSM = a σ^0 + b …..……………………. (3)

A study conducted by Kim *et al.* (1007), on relatively plain lowland areas, value of a is 0.99 and b is 43.8, so the equation obtained is:

VSM = 0 99 σ^0 + 43,8 ………………… (4)

While for not flat area, value of a is 1.37 and b is 29.1, so equation used is as follows:

VSM = 1.37 $\Delta\sigma^0$ + 29,1 ………………. (5)

Where: VSM = volume soil moisture (%); a and b = coefficient that is depended on backscatter and polarization; σ^0 = backscatter coefficient; $\Delta\sigma^0$ = backscatter coefficient that has reduced by roughness effect. The study site that is located in northern coastal area has large lowland paddy fields. Assuming that the study site is flat area, equation 5 is used for calculation of moisture content.

Based on water content of soil sample was taken during field visit, correction of VMS calculation is used an equation as follows:

VMS_{cor} = $0.0287VMS^2 - 2.7852VMS + 91.937$ …………………………………... (6)

3. RESULTS AND DISCUSSION

3.1. Analysis of ALOS data for paddy identification

a. Character of Spectral and NDVI of ALOS AVNIR-2 (Optic data)

The results of spectral analysis showed specific character of each band of ALOS AVNIR-2 on different condition of paddy growth periods. Figure 2 shows different patterns of each paddy growth period. In vegetated land, infrared band is reflected more than red band. In flooding conditions (planting period) and fallow or bear (after harvest), value of infrared band is lower and red band is higher than other land cover conditions. The value of infrared and red bands on fallow or bare condition is higher than at time of land inundated or wet (during planting period). Infrared band is transmitted on the condition of land flooded.

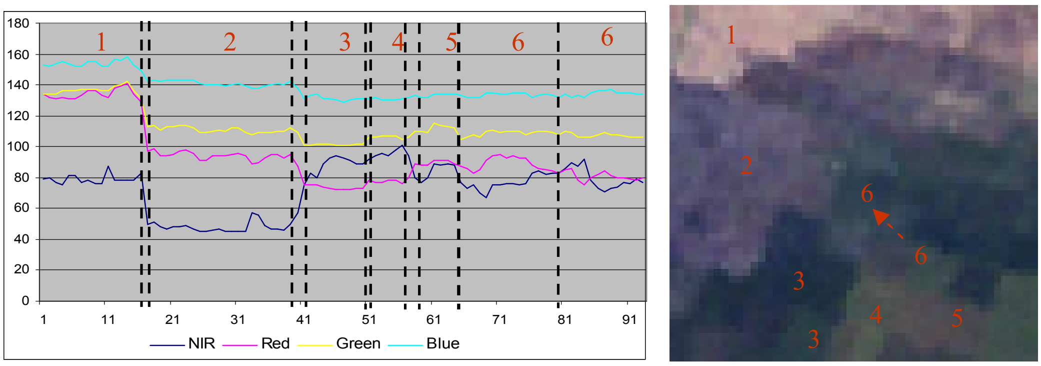

Figure 2 spectral pattern of VNIR band of ALOS AVNIR-2 on different land cover conditions in paddy fields

NDVI values calculated by equation 1 at different rice growth period can be seen in Figure 3. The analysis was obtained from two acquisition dates of ALOS AVNIR-2.

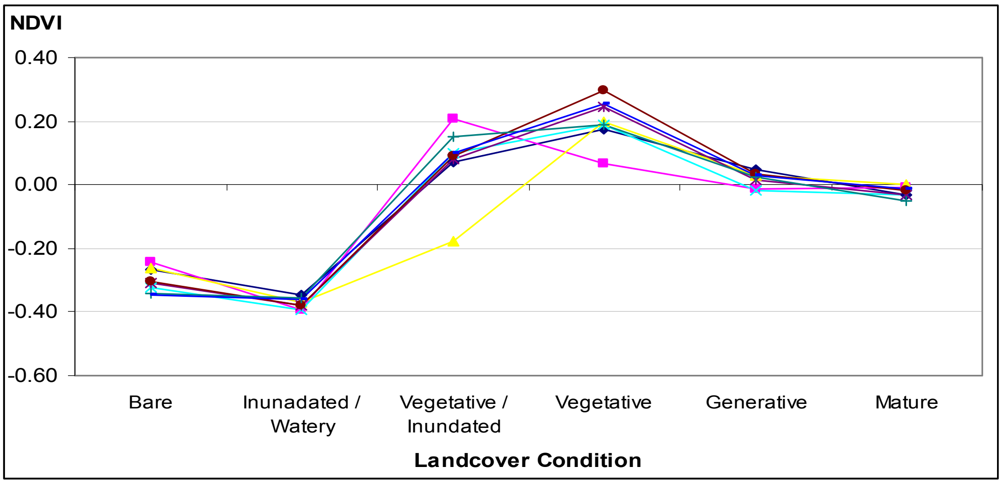

Figure 3. NDVI Pattern of paddy growing period

Vegetation generally has low reflectance and low transmittance in the visible part of spectrum. This is mainly due to plant pigments absorbing visible light; chlorophyll pigments absorb violet-blue and red- light for photosynthetic energy. Green light is not absorbed for photosynthesis and therefore most plant appears green. Plants generally also reflect radiation highly in the near infrared region. This is mainly due to the high air/cell interface area within leaves. As the water fills the air gaps, there is a decrease of multiple scattering and a decrease in near infrared reflectance. Nearly any near infrared radiation that is not reflected by a plant leaf will be transmitted. However, a second, or a third layer of leaves will reflect some of the transmitted near infrared radiation. Soil reflectivity appears to be low in red and violet wavelengths, and higher in central wavelengths. Water reflects primarily in blue wavelengths and somewhat less in all other wavelengths. Near infrared reflectance is very low for water and moderate for soil.

b. Character of Backscatter and Volume of Soil Moisture of ALOS PALSAR (SAR data)

Study conducted by Shofiyati and Uchida [in 5], rice growing stages as well secondary crops on rice-fields of the study area can be also detected by this NDVI and Wetness scatter diagram (NDVI-Wetness Scatter diagram) of Landsat TM. Based on the study, this research has combine 2 multi sensor of ALOS data, to get information of wetness from ALOS PALSAR data.

The research result shows a specific scatter pattern of NDVI of ALOS AVNIR-2 (x axis) and Volume of Soil Moisture or backscatter of ALOS PALSAR (y axis). The diagram is presented in Figure 4. The scatter pattern of planting or flooding phase has low NDVI value (negative) and high wetness value. The values of NDVI increased during vegetative to flowering and heading phase, while the wetness value decreased. After heading1 phase, the scatter turned into the opposite, which both the value of NDVI and Wetness decreased. During maturity process and harvesting, the NDVI is around 0 and Wetness has negative value. While the scatter pattern of secondary crops, such as maize, cassava, soybean etc. has no flooding phase. The values of NDVI is similar with paddy pattern, it increased during seeds growing to flowering and turned back during maturity process. But Wetness value has different pattern. Secondary crops always have low value of Wetness. Interpretation based on the scatter diagram can be used to identify the distribution of cropping type in May 2007.

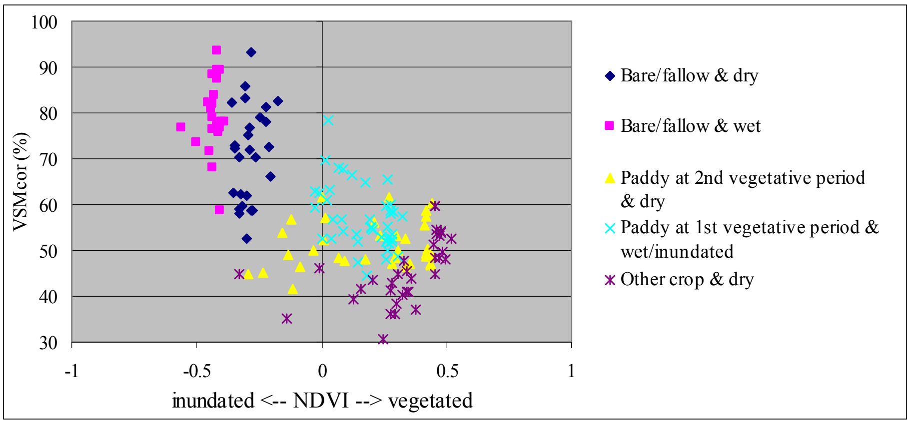

Figure 4. Scatter diagram of NDVI of ALOS AVNIR-2 and VMS of ALOS PALSAR of some land cover types

3.2. Paddy Planted Area

Estimation of paddy panted area can be done using multi sensor ALOS PALSAR and AVNIR-2. Estimation of rice acreage is done by analyzing of water content of soil or land derived from ALOS PALSAR data, and NDVI from ALOS AVNIR-2. Analysis result produces a distribution map of rice planted area in Subang, West Java Province (Figure 5).

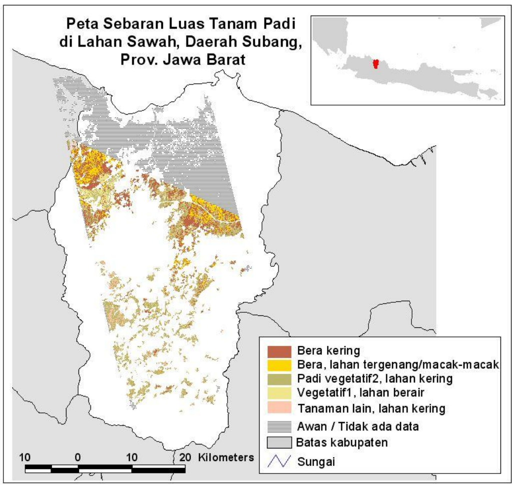

Figure 5. Map of paddy planted area distribution in Subang, West Java Province derived from Multi Sensor ALOS PALSAR and AVNIR-2 data analysis

Study conducted by Shofiyati *et al.* [in 5], analysis using a single sensor (ALOS PALSAR) can produce map of paddy planted area. However, use of multi sensor of ALOS data can produce more detailed information of paddy planted area map. Comparison of analysis results on location which covered by ALOS AVNIR-2 and PALSAR data overlapped is presented in Table 5a and b.

Table 5a Paddy planted area on the study area in May 2007 derived from Multi Sensor of ALOS AVNIR-2 and PALSAR data.

No	Land cover condition of paddy field	Area (Ha)
1	Bare or fallow, dry condition	7.829,3
2	Bare or fallow, inundated or wet condition	3.523,0
3	Paddy at 2nd vegetative period, dry condition	11.747,6
4	Paddy at 1st vegetative period (inundated)	3.460,1
5	Other crop, dry condition	2.974,5

Table 5b Paddy planted area on the study area in May 2007 derived from single sensor of ALOS PALSAR data.

No.	Land cover condition of paddy field	Area (Ha)
1.	Bare or fallow	11,351.3
2.	Paddy at 2nd vegetative period	14,722.1
3.	Paddy at 1st vegetative period (inundated)	3,460.1

Estimated paddy planted area at 2nd period of growing stage at the next 2 months and vegetative 1 between 1 and 1.5 months (25-40 days). While the growth period of rice (lowlands) from planting to harvest about 105 days [6][7]. In areas covered by overlapping data of ALOS AVNIR-2 and PALSAR based on area presented in Table 5a, an estimated 1.5 - 2 months ahead of harvest area is about 18,182.2 ha, and if the bare land is planted by paddy in May, three months in advance it will be harvested around 14,873, 3 ha, and other covering area of 2,974.5 ha is planted with other crops.

Assuming that productivity of paddy is 4.5 / ha, referred to national productivity average [8][9], estimated that rice production in the study area at next 2 months is 81,819.9 tons and 66,929.8 tons for next 3 months. Estimated conditions of rice plants is done by visually comparing of appearance of the ALOS satellite data AVNIR-2 and experience of researchers in analyzing satellite data for food crops, especially paddy.

For multi-sensor analysis, Optical and SAR satellite data used should have same acquisition date, or at least acquired in same period of paddy growth. The multi sensor analysis required a free cloud covered optical satellite data.

3.3. Practical Implementation of Paddy Production Estimation Using Remote Sensing Data for Supporting Food Security

For some time, Indonesia's food security program was based on a food availability approach with twin strategies: price stability and rice self-sufficiency. Recently the government implemented the sustainable food security paradigm (SFSP) with four primary dimensions (Simatupang, 1999, in [10]): availability, accessibility, vulnerability (stability and reliability), and sustainability. Monitoring and early warning systems is one of inherent components in the implementation of the paradigm.

An enormous leap in technologies that allows for accurate collection and prediction of agricultural information is needed to support information for monitoring and early warning systems. The end user, such as communities, farmers, and policy and decision makers need accurate, up-to-date and spatially referenced of agricultural information. This need coincides with major advances in technologies of remote sensing for acquiring agricultural information.

Remote sensing technology can provide food production information. The information can be used for policy maker for food security planning and management in Indonesia. Information about an area distribution of paddy planted and harvested is essential for planning and management of food security, water resource and agricultural production facility. Paddy has specific characteristics throughout paddy life time, which is mix proportionally in accordance with its age, between water, soil, and paddy vegetation. On the other hand, satellite data have multiple benefits, i.e good spatial, spectral, and temporal resolution. Paired of two components, paddy specific characters and multi benefits of satellite imagery can be used to obtain information for paddy growth monitoring and production estimation. Utilization of remote sensing data for supporting food security is shown in Figure 6.

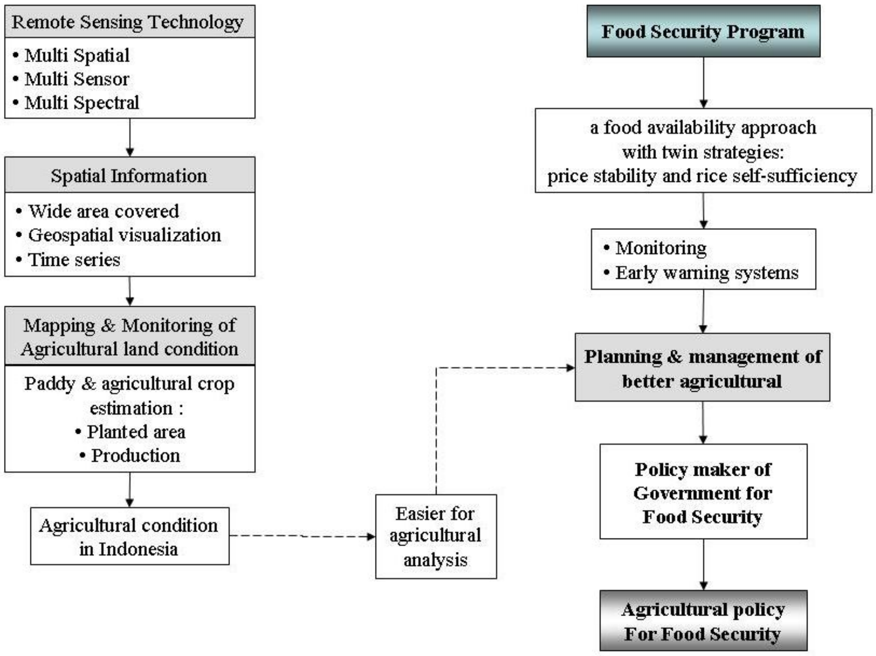

Figure 6 The Utilization of Remote Sensing for Supporting Food Security

Based on this information combined with information gathered by other concern departments, the policy makers can fix the target of import/export and purchasing policy of food grains well in advance to maintain the food security of Indonesia. Considering all these information it appears that remote sensing technology has been playing a very effective role in this country in providing valuable information on seasonal agricultural crops in addition to many other applications. This way has contributed to the development of national agricultural system information. Its ability to provide spatial information can optimize data utilization for supporting policy and decision maker to make recommendations of agricultural planning and management. Recommendations can be obtained by combining with the legal aspects, socio-economic and institutional aspect. However, still there are scopes to extend the utility of satellite-based information acquisition technology in Indonesia and some institutions have been continuing the research to maximize the benefit from such advanced technology.

4. Conclusion

Multi sensor of satellite data of ALOS AVNIR-2 and PALSAR can derive more detailed information of paddy growth period. The method can produce a map of paddy planted area distribution that give promising solution to get better information of paddy production estimation. To obtain more appropriate value of VMS, the VMS calculations need to be corrected with empirical data obtained from laboratory analysis of soil water content of samples taken from the field. The information of paddy production of remote sensing data has contributed to the development of national agricultural system information. The information gathered by other concern departments, the policy makers can fix the target of import/export and purchasing policy of food grains well in advance to maintain the food security of Indonesia.

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