VERIFICATION OF LAND MOISTURE ESTIMATION MODEL BASED ON MODIS REFLECTANCES IN AGRICULTURAL LAND

DEDF. DIRGAHAYU[1] AND PARWATI SOFAN'

Abstract

From this research, it is found thai reflectances in the 1". 2nd, and 6lh channels (RI.R2.R6) of MODIS have high correlations with surface soil moisture (% weight) at 0 - 20 cm depth. An index called Land Moisture Index (LMI) was created from the linicr combination of R! (%). R2 (%), and R6 (%)

The MODIS reflectances and field soil moisture in paddy field taken from the Central and East Java during July September 2005 are applied into the previous model which have been generated from data during July - September 2004. The result showed that there was a high correlation between Land'Soil Moisture (SM) which was measured from field survey, and 1 Ml. which was generated from the MODIS rcfcctances. The best model equation between SM and LMI is the power regression model, which has the coefficient of determination of 88%. It is implied that soil moisture condition can be obtained from the MODIS data using Land Moisture Index. Therefore, the spatial information of drought condition analysed through! the soil moisture in the agricultural land can be provided from the MODIS data.

Keywords: Land Moisture Index, Soil Moisture Estimation, spatial information, drought

I. Introduction

a. Background

Soil moisture condition is one of important parameters which has to be well known by farmers or agriculturist for arranging, monitoring, and supporting crop growth in any stage. The soil moisture can be derived by direct and indirect measurement. The direct measurement of soil moisture is conducted through ground survey with equipments, such as the gravimetric technique, tensiomelcr, and neutron probe. The conventional method can provide give very accurate information, but costs a lot of budget to measure very wide area. The indirect measurement of soil moisture can be made using the satellite remote sending technique. The satellite remote sensing data can cover a wide area at once and monitor the fluctuation of soil moisture condition became of their temporal resolution. Therefore, the limitation in the conventional method to monitor soil moisture condition can be resolve using satellite remote sensing data.

Researcher, Remote Sensing Application and Technology Development Center, National Institute of Aeronautic and Space of Indonesia (LAPAN)
Phone/Fax: 062-21-8710274 / 8722733; e-mail: dede_dirgahayu03fgyahoo.com

Study of estimating soil moisture using satellite data among others were conducted by Takeuchi and Yasuoka (2004) and Wang (2005). The soil moisture estimation is developed by Landsal Thematic Mapper (TM> and MODIS data, which were different in spatial and temporal resolution. Dirgahayu (1997) derived soil moisture estimation from Soil Brightness Index (SB!) using Landsat TM in the plantation area of sugar cane in Jatitujuh, West Java. The principal component analysis of 2^{nJ} to 5' bands Landsat TM was developed to estimate SBI. The correlation between SBI and soil moisture is high. However, Landsat ETM 7 data with has 30 m spatial resolution can only cover at certain area and at certain time, and only has temporal resolution of 16 days. In addition, they have SLC off problem since 2003. Meanwhile, Takeuchi and Yasuoka (2004), and Wang (2005) investigated the indices of vegetation, soil and water using MODIS near infrared, visible and short wave infrared speclrums. Although MODIS spatial resolution of 250 m and 500 m is lower than Landsat TM, it can provide daily information. This information is urgently necessary for as an early warning for drought condition.

b. Objective

This research is performed to estimate soil moisture condition in the agricultural land, especially in paddy field based on reflectance combination of the MODIS Terra Aqua satellite data implementing the Stepu ise Regression to select 3 best reflectances of the MODIS data.

II. .Methodology

a. Data

The daily MODIS reflectance data for June September 2004 and July September 2005 are ased in this study. The location of Uus research is in Central Java and East Java. The field measurements of soil moisture were obtained by ground truth at the same period with MODIS data. They were analyzed at the Soil Physic Laboratory' using the gravimetric method.

b. MODIS Data Processing

b.l. Corrected Reflectance

The corrected reflectance from the atmosphere effect in each channels of MODIS Level IB data was produced by level 2 processing. Furthermore, the data arc conducted the advance processing to improve and repair data quality, i.e. Bow-Tic and Geometric Correction to make reflectances data in 250 m (Rl, R2) and 500 m (R3 - R7) spatial resolution.

b.2. Statistical Value Extraction of Reflectances

Statistical value of the minimum, maximum, mean, median and standard deviations for each reflectance of MODIS data was made in training area of ground survey point under the homogenity consideration. Training sample must be considered to composite RGB 6.2,1 image.

c Analysis

The correlation and regression analysis are made to know the relation between MODIS data reflectances and land moisture, especially to the soil moisture of less than 75%. The Stepwise regression is applied to select 2 or 3 best reflectances for estimating surface soil moisture. Principle component transformation is conducted if there are significant correlations among the reflectances. The result of the multiply linier regression or the first principle component analysis is used to create a new index herein after referred to as Land Vloisture Index (LMI) with equation:

$$LMI=c + bI*Xl + b2*X2 + b3*X3 \quad (I)$$

where:

c is constant which is added for making positive value in LMI

XI, X2, and X3 are reflectances selected;

M,b2,b3 are regression coeficients or vector eigen coefficients.

The simulation model in non linear form (power, exponential, or logarithmic) between LMI and soil moisture are then conducted for obtaining the best estimation model which has the highest determination coefficient (R^2) and the smallest of Standard Error (SE).

III. Results and Discussion

a. Spectral Responses of MODIS Reflectances

The MODIS reflectances (Rl to R7) and soil moisture from the field measurement in East Java are shown in Table 1. The scatter plot between the soil moisture and each MODIS reflectance, and the trend analysis for both soil moisture and each MODIS reflectance are shown in Figure 1 until Figure 7.

Table 1. Mean Reflectance of MODIS on Location Where Soil Sample Intake During July - September 2004 in East Java.

No	Rl	R2	R3	R4	R5	R6	R7	SM
1	28.2	39.3	22.0	25.8	46.1	40.6	28.7	4.6
2	18.7	31.4	15.0	16.6	30.8	24.5	15.5	10.2
3	12.8	21.5	10.1	10.7	21.7	21.1	14.7	14.1
4	10.7	18.7	11.6	11.6	21.2	18.4	11.6	12.4
5	9.8	20.1	10.2	10.4	22.2	197	12.0	27.6
6	12.4	27.9	7.8	10.0	26.8	21.8	12.6	24.7
7	8.9	20.9	8.2	'9.1	22.3	19.0	11.2	31.9
8	9.0	22.5	7.2	9.2	18.8	16.4	9.2	37.9
9	9.2	24.4	6.7	9.0	22.1	20.1	10.8	43.0
10	10.0	29.0	97	11.8	30.7	22.9	13.3	34.2
11	9.8	28.7	8.5	10.5	36.5	19.4	10.4	52.0
12	11.3	33.4	8.1	11.3	32.6	25.1	15.1	36.6
13	10.1	32.2	6.9	10.6	35.5	28.0	16.2	36.6
14	7.9	25.7	8.7	9.2	24.0	17.6	9.5	35.9
15	74	24.2	8.2	8.7	24.2	16.3	7.9	49.4
16	7.9	26.7	8.7	9.3	25.1	19.5	11.5	33.5
17	7.7	27 7	8.0	9.6	32.9	24.2	11.3	62.4
18	6.5	25.1	5.7	7.4	21.9	14.5	8.3	61.4
19	6.5	25.7	7.3	7.8	21.1	15.4	8.5	66.7
20	6.2	34.5	7.4	8.5	25.3	18.7	10.0	73.8
21	5.3	35.7	5.9	7.5	29.0	18.4	7.9	72.8

Notes:

R1-R7 Reflectances of red,NIR, blue, green,middle IR and MIR (middle infra red) in %

SM Soil Moisture (gr water/dry soil) in %

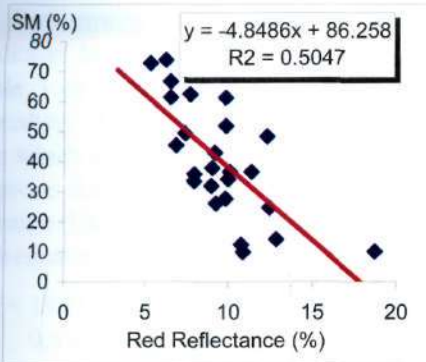

Fig. 1. Response of Red Reflectance (R1) vs Soil Moisture

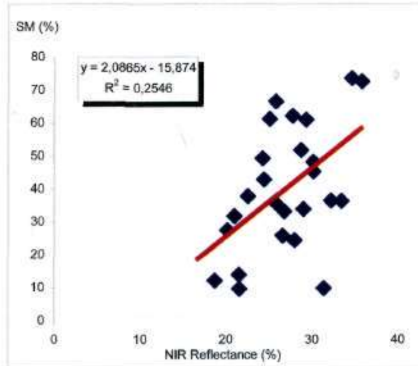

Fig. 2. Response of NIR Reflectance (R2) vs Soil Moisture

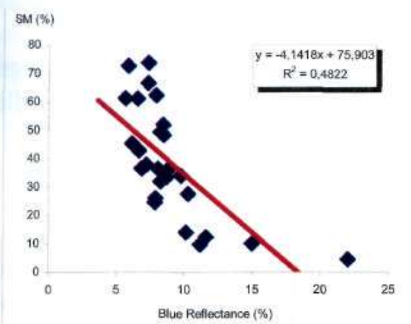

Fig. 3. Response of Blue Reflectance (R3) vs Soil Moisture

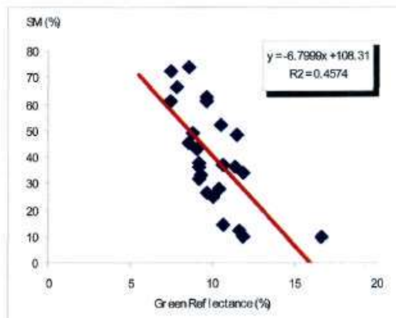

Fig. 4.Response of Green Reflectance (R4) vs Soil Moisture

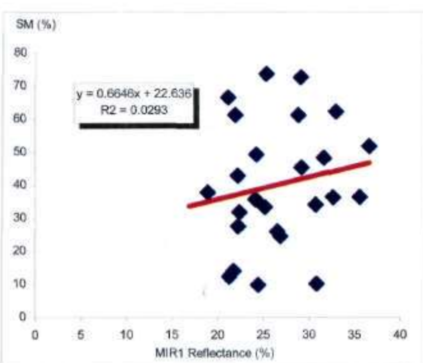

Fig. 5. Response of MIR 1 Reflectance (R5) vs Soil Moisture

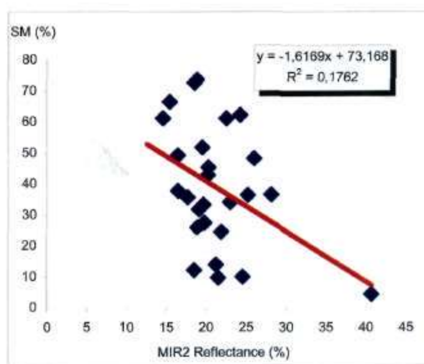

Fig 6. Response of MIR 2 Reflectance (R6) vs Soil Moisture

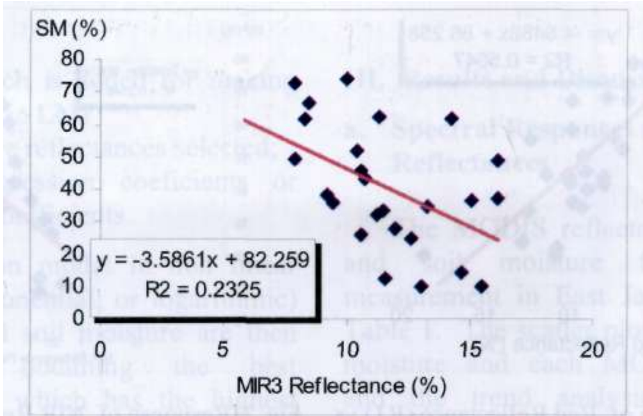

Fig. 7 Response of MIR 3 Reflectance (R7) vs Soil Moisture

Based on those figures, it can be showed that the relationship between soil moisture and it spectral response of NIR (Fig. 2) has positive correlation, whereas with other reflectances have negative correlations. These condition explain that land with densed canopy vegetation has more water content than those with less vegetation or bare land. Land which has vegetation with dense canopy has high reflectance response in NIR. That condition can be represented by vegetation index or NDVI (Normalize Difference Vegetation Index) as:

$$NDVI = (NIR - Red)/(NIR + Red) \quad (2)$$

The result from the regression analysis (include T-test and Probability) among all MODIS reflectances (R) and soil moisture can be shown on Table 2.

Table 2. The Regression Analysis Result among MODIS Reflectances (R) and Soil Moisture

Predictor	Coef	SE Coef	T	P
Constant	26.717	17.392	1.536	0.142
Rl	-3.312	2.697	-1.228	0.235
R2	2.112	0.824	2.562	0.020
R3	-1.717	4.171	-0.412	0.686
R4	1.508	6.839	0.221	0.828
R5	0.326	1.089	0.300	0.768
R6	-1.441	2.658	-0.542	0.594
R7	0.731	3.350	0.218	0.830

Furthermore, we can select 2 or 3 best predictors based on the regression result in Table 3 or trough the Stepwise Regression Procedure. Three reflectance's of MODIS data which have been selected based on the Stepwise Regression (see Table 3) for land moisture (LM) estimation are Rl, R2, and R6 with equation:

$$LM = 19.85-3.414*R1+2.347*R2-0.492*R6 \quad (3)$$

with $R^2 = 0.74$; Se= 10.88

Although T-test value of R6 is not significant, but decided to select, because it can detect thermal effect of land condition caused by drought.

b. Land Moisture Index

Based on results mention above, we have done a modification of expression (3) in order to make positive value of Land Moisture Index (LMI). The result of modification can be used as new index with equation:

$$LMI = 40-3.414*Rl+2.347*R2-0.492*R6 \quad (4)$$

Scatter plot result between LMI and Soil Moisture (SM) in Figure 8 shows positive relationship, where increasing of SM is also followed by increasing of LMI.

Table 3. The Stepwise Regression Result to Select 3 Best Predictors of Reflectances to estimate Soil Moisture

Predictor	Coef	SE Coef	T	P
Constant	19.849	12.262	1.619	0.120
Rl	-3.414	0.929	-3.677	0.001
R2	2.347	0.571	4.113	0.000
R6	-0.492	0.967	-0.509	0.616

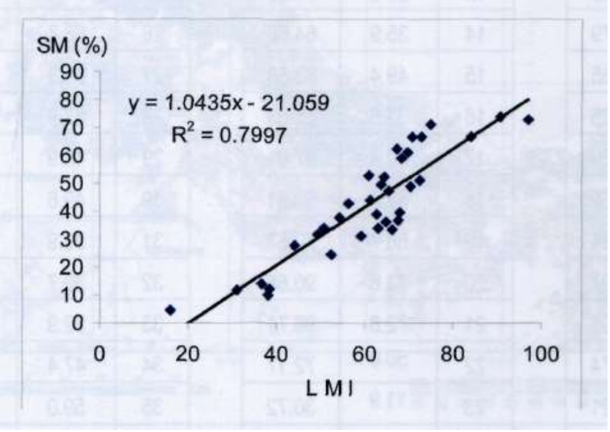

Fig. 8. Scatter plot and Trend between Soil Moisture and Land Moisture Index

c. The Best Estimation Model and Implementation

The best estimation model for estimating soil, moisture from LMI can be obtained by running some simulations of non linier regression model. To get the optimum result, dependent or independent variable can be transformed into new variable by using mathematical operation. Comparison among type of regression result can be seen on Table 4.

Finally, the best model is developed to estimate soil moisture (SM) condition for the agricultural land, i.e., the power model equation. From Table 4, it is shown that the power model is better than that of the exponential model, because the power model has higher R^2 and smaller SE, with equation:

$$SM = 0.0282\ LMI^{17656} \qquad (5)$$

The scatter plot result between SM and LMI based on Table 5 is shown on Fig. 9.

Table 4. Regression Type Results between Soil Moisture (y) and LMI (x)

No	Type	Expression	R^2
1	Linier	$y=1.0435x- 21.059$	0.7997
2	Logarithmic	$y = 47.539Ln(x) - 150.72$	0.7129
3	Exponential	$y = 4.2763e^{00354x}$	0.8229
4	Power	$y = 0.0282x^{17656}$	0.8817
5	Polynomial	$y = 0.0011x2 + 0.9168x - 17.755$	0.8003

Table 5. Soil Moisture (SM) and Land Moisture Index (LMI) of MODIS Data on Test Location

No	SM	LMI	No	SM	LMI	No	SM	LMI
1	4.6	15.95	13	36.6	67.35	25	71 1	74.58
2	10.2	37.79	14	35.9	64.68	26	66.7	83.72
3	14.1	36.35	15	49.4	63.58	27	31.3	59.11
4	12.4	38.25	16	33.5	66.03	28	33.9	50.38
5	27.6	43.99	17	62.4	67.01	29	48.9	70.23
6	24.7	52.39	18	61.4	69.51	30	49.6	63.45
7	31.9	49.24	19	66.7	70.67	31	38.9	62.56
8	37.9	53.97	20	73.8	90.65	32	39.7	67.58
9	43.0	56.01	21	72.8	96.71	33	52.9	60.63
10	342	62.74	22	50.9	72.17	34	47.4	65.26
11	52.0	64.21	23	11.9	30.72	35	59.0	68.15
12	36.6	67.24	24	44.0	61.01	36	66.5	72.71

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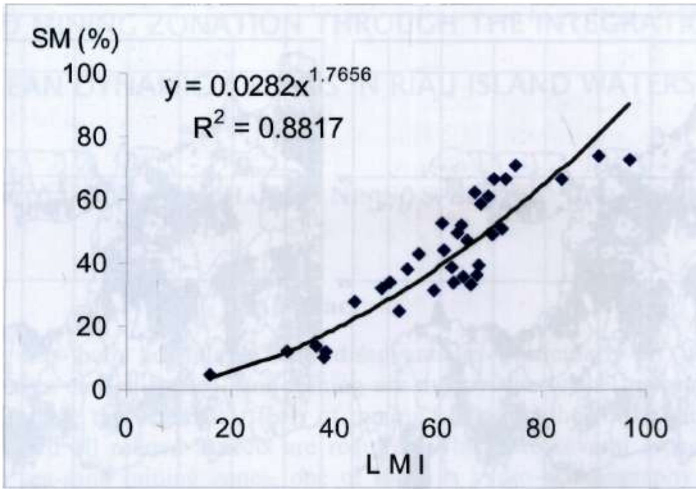

Fig. 9. The Relationship between Soil Moisture and LMI MODIS

The above model can is then implemented to create the spatial soil moisture distribution at paddy field up to the district level using MODIS data (Figure 10). For the provincial level, it is shown at Figure 11. Afterwards, the potential drought can be predicted based on soil moisture. We assume that the drought condition in a planting area has soil moisture, not less than 30%, or the early growing season has more than 30% of soil moisture.

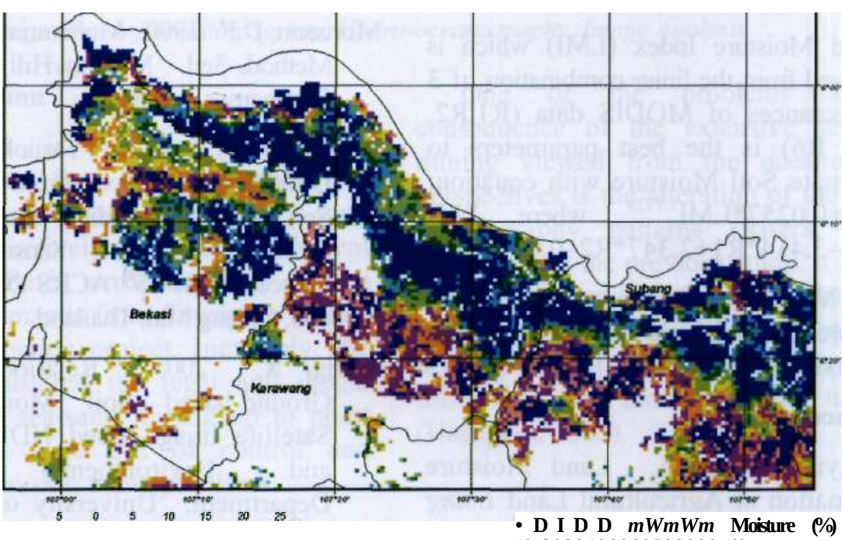

Fig. 10. Spatial Distribution of Land Moisture on 2nd Weekly of August 2005 at Bekasi, Karawang District, West Java

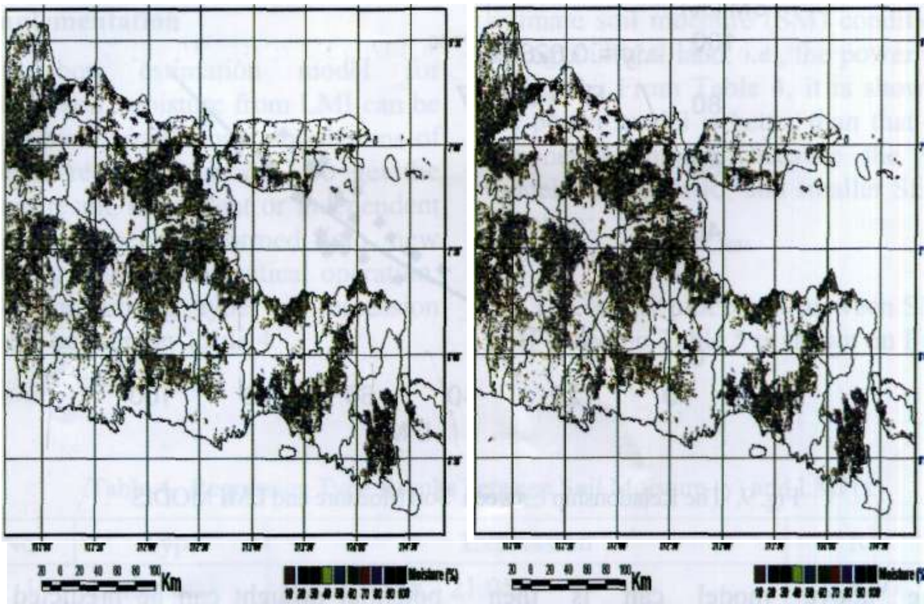

Fig. 11 Spatial Distribution of Land Moisture on 2nd Weekly of August 2005 at East Java Province

IV. Conclusion

Finally we can conclude following results through our study.

1. Land Moisture Index (LMI) which is derived from the linier combination of 3 reflectances of MODIS data (R1,R2, and R6) is the best parameters to estimate Soil Moisture with equation: $SM=0.0257*LMI^{17729}$ where $LMI=40-3.414*Rl+2.347*R2-0.492*R6$.
2. Soil Moisture can be used as one indicator to predict of drought and early growing season.

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