A Study toward the Evaluation of ALOS Images for LAI Estimation in Rice Fields

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ABSTRACT:

For expanding and managing agricultural sources, satellite data have a key role in determining required information about different factors in plants Including Leaf Area Index (LAI).This paper has studied the potential of spectral indices in estimating rice canopy LAI in Amol city as one of the main sources of rice production in Iran. Due to its importance in provision of food and calorie of a major portion of population, rice product was chosen for study. A field campaign was conducted when rice was in the max growth stage (late of June). Also, two satellite images from ALOS-AVNIR-2 were used (simultaneous with conducted field works) to extract and determine vegetation indices. Then the Regression between measured data and vegetation indices, derived from combination of different bands, was evaluated and after that suitable vegetation indices were realized. Finally, statistics and calculations for introduction of a suitable model were presented. After examination of models, the results showed that RDVI and SAVI2, by determination coefficient and RMSE of 0.12 – 0.59 and 0.24-0.62, have more accuracy in LAI estimation. Results of present study demonstrated the potential of ALOS images, for LAI estimation and their significant role in monitoring and managing the rice plant.

1. INTRODUCTION

The ratio of leaf surface area to unit ground surface area, called leaf area index (LAI) (Breda, 2003). Mapping and monitoring of LAI is mandatory for spatially distributed modeling of surface energy balance, vegetation productivity, water and CO2 exchange, Crop modeling and Photosynthesis monitoring. In addition, LAI is an important variable in climatic, ecological and agronomical research studies (Soltani and Galeshi, 2002; Lockwood, 1999; Ewert, 2004; Chen et al., 2002).

Measuring LAI on fields is time consuming and requires a great amount of labor and hence cost. For these reasons, many studies have sought to discover relationships between LAI and remote sensing data for its cost-effective, rapid, reliable and objective estimation.

Rice is regarded as a strategic and applicable product, after wheat, in food regime of people around the world and Iran. Since rice product industry create many occupations and profits in national level, it has a remarkable impact in economic and social perspectives. Rice widely planted in northern part of Iran. Rapid population growth, demands more rice production, while agricultural lands are gradually being reduced with urban expansion. The importance of this product caused remote sensing researches to focus on the monitoring of rice production, especially in the countries where rice is the main food.

LAI estimation, by new remote sensing methodologies, for estimating the amount and quality of product, biomass, damage and many other determining parameters of rice is so profitable. Therefore this study is aiming to analyze and to evaluate AVNIR-2 images for estimating the rice LAI.

Using the method of inversions of canopy Radiative Transfer Models (RTM) (Fang et al., 2003; Knyazikhin et al., 1998a, 1998b; Weiss et al., 1999) and empirical or semi-empirical relationships between spectral vegetation indices (VIs) and LAI method (Chen and Cihlar, 1996; Curran, 1983; Jordan, 1969; Myneni et al., 1997; Wiegand et al., 1979) are two main methods used in LAI estimation. Regarding that it is difficult to obtain optimal parameterized solutions for RMT inversions (Fang et al., 2003) and RTMs are often restricted to specific ideal conditions of plants and environment (Gobron et al., 1997), it is difficult to apply this method to agricultural practices.

Whilst VI methodologies are more usual because of their convenience and easy application. In this approach, initially, by using field measurements, a relation is defined between LAI and spectral data. Next, by applying such relation for other areas under studies, LAI is determined by vegetation indices (Curran, 1983; Asrar et al., 1985; Wiegand et al., 1990; Turner et al., 1999; Vaesen et al., 2001).VI consist of combinations and proportions of bands which is used more in plants (plants has high reflectance in near infrared and low reflectance in red). As a matter of fact, these VIs are recruited for extracting that information which are related to vegetation characteristics but under the condition of environment are not possible to be shown on bands. The advantage of VI is minimizing the effects of external factors such as atmospheric conditions (Myneni and Asrar, 1994), soil optical properties (Huete, 1989), illumination geometry (Shibayama et al., 1986), canopy morphology (e.g., leaf angle distribution) and leaf physiological properties (e.g., pigment content) (Haboudane et al., 2004) and for these reasons remote sensing data have been transformed and combined into various VI.

LAI generalization from small scales (regional) and for special species to large ones and different spices is not robust. But for generalization from leaf to global levels of a special species like rice, good results have been obtained (Boegh et al., 2002; Broge and Mortensen,2002; Clevers, 1989; Colombo et al., 2003; Curran, 1983a, b; Xiao et al., 2002) .
According to presented material, the goal of this study is presentation of optimized indices for LAI estimation using regression analysis and investigation AVNIR-2 image capability in LAI estimation.

2. DATA AND STUDY AREA

2.1 .Ground Data

In summer 2010(simultaneous with satellite pass) a field campaign was conducted in Amol, Northern part of Iran, when most of the rice crops were in grain-filling stage. Sixty plots of 30m by 30m were chosen by adopting stratified random sampling. To eliminate GPS errors, considering the spatial resolution of applied images (10 meter), the dimensions of filed samples were chosen by multiple of 3 in pixel size (30 meters) then the coordinates of determined points were regarded as the center of plots on ground.

Depending on the homogeneity of the sample plot, few sub-plots were selected and targeted for LAI measurements. LAI was determined by measuring the surface of the clipped shrubs using the LI-3100 scanning planimeter and dividing it by the surface area of the sub-plots. The plot LAI was then calculated by averaging the LAI of subplots. In next step two images of ALOS-AVNIR-2 were processed.

Figure 1. Ground Data Measurement

2.2 Remot sensing data

Since rice fields have small dimentions and their species are diverse, it was necessary to use high resolution images to segregate the fileds and increase the accuracy. Therefore, AVNIR2 images of ALOS satellite were used. This sensor is able to image in blue, red, green, and near infrared band with 10 m apatial resolution.Also it is equipped with a PROSMA camera for stereo mappig and PALSAR. In order to determin a suitable time for providing satellite images, primarily phenology information of rice was ontained. Then according to available data, planting time, SPAD peak and the harvest date was determine. Finally two images on 20 June 2010 and 7 July 2010(SPAD peak time) were provided.

2.3. Study Area

Study area is located in Amol city which is one of main rice producers in Iran. The approximate area of location is about 385 square kilometers and is between 36°25′13″ N, 36°38′51″ N latitudes and 52°11′ 17″ E, 52°20′50″ E longitides. In Figure 2 the position of area is demonstarted. Area of study is located in a low level (Above sea) sedimentary plain where near shore line is below Mean Sea Level. Climate of this area is humid, according to De Martine classification.

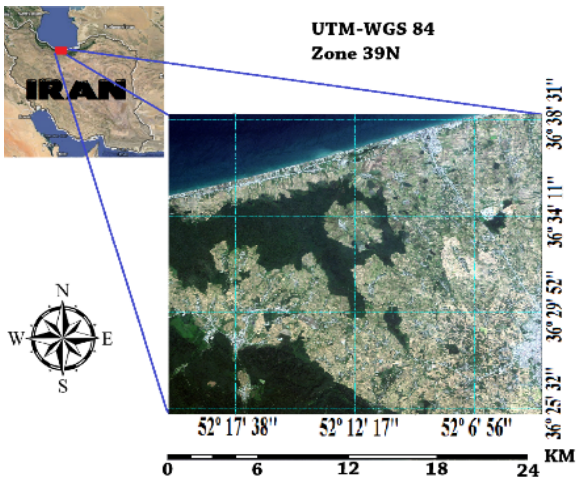

Figure 2. Study area

3. DATA PROCESSING

Because no processing had been carried out on images, it was imperative to conduct geometrical and atmospheric correction on images. To these ends, geometrical correction was done using 19 distributed points in 1:25000 scale maps with 0.29 and 0.25 accuracy for two images respectively. Next, by using 2th order polynomial equations, resampling were done with nearest neighbor method. Also for increasing the accuracy, ground control points from ground measurements were recruited. Due to the presence of water vapor in this area an atmospheric correction model was applied to reduce the effect of atmosphere. In this paper FLAASH module, which is based on MODTRAN4 (Matthew, 2000), from ENVI 4.7 software was used.

4. METHOD

Vegtation indices which were developed initially in early 1970s for monitoring land perspectives, were applied for estimation of vegetation cover, primary product and some process such as evapotranspirtaion(Anser,1998).Vegetation indices are implemented on all pixels on aspecifc time and location regardless of land condition. Generally to assess biophisical parameters of plants (Biomass and leaf area index) by remote sensing physical and statistical approaches are used.

Among statistical aproaches, use of spectral indices is common due their ease of application and relation to physical variables (Baret, And Guyot, 1991:5, Baret, 1992:7). Ofcoarse, all spectral indices are not related to LAI. In this paper, it was tried to use most frequent applied indices for LAI estimation and are computable by AVNIR-2 images. As a matter of fact, 24 indices were chosen which were listed in Table 1. In this table α shows soil line, and β intercept. In this research, as well as vegetation indices, reflectances of four bands of sensor were used. After comparison of results, the most appropriate index for LAI estimation was selected.

Index Formulation	
$MSAVI = 0.5 + R_N - \sqrt{(R_N + 0.5)^2 - 2(R_N - R_R)}$	$TSAVI = \frac{\alpha(R_N - \alpha R_R - \beta)}{\alpha R_N + R_R + \alpha\beta + X(1+\alpha^2)}$
$GNDVI = \frac{R_N - R_G}{R_N + R_G}$	$MSR = \frac{R_N}{R_R} - 1 \Big/ \sqrt{\frac{R_N}{R_R} + 1}$
$BNDVI = \frac{R_N - R_B}{R_N + R_B}$	$SAVI = \frac{(R_N - R_R)(1 + L)}{R_N + R_R + L}$
$GBNDVI = \frac{R_N - R_B - R_G}{R_N + R_B + R_G}$	$SAVI2 = R_N \Big/ R_R + \frac{\beta}{\alpha}$
$GRNDVI = \frac{R_N - R_R - R_G}{R_N + R_R + R_G}$	$OSAVI = 1.6 \frac{R_N - R_R}{R_N + R_R + 0.6}$
$ARVI = \frac{R_N - R_{RB}}{R_N + R_{RB}}$	$NDVI = \frac{R_N - R_R}{R_N + R_R}$
$RDVI = \sqrt{NDVI \cdot DVI}$	$TVI = \sqrt{NDVI + 0.5}$
$WDVI = R_N - \alpha \cdot R_R$	$RVI = R_R \big/ R_N$
$GEMI = \frac{\alpha(1 - 0.25\alpha) - (R_R - 0.125)}{1 - R_R}$	$IPVI = \frac{R_N}{R_R + R_N}$
$SARVI = \frac{R_N - R_{RB}(1 + L)}{R_N + R_{RB} + L}$	$DVI = R_N - R_R$
$NRVI = \frac{0.2R_N - R_R}{0.2R_N + R_R}$	$SARVI2 = \frac{2.5(R_N - R_R)}{1 + R_N + 6R_R - 7.5/R_B}$
$EVI = 2.4 \frac{R_N - R_R}{R_N + R_R + 1}$	$PVI = \frac{R_N - \alpha R_R - \beta}{\sqrt{\alpha^2 + 1}}$

Table 1: Index Formulation

5. RESULTS

For introducing proper regression models, between LAI value and satellite data Regresion analysis and RMSE computations were done. Based on Average statistics of measured data (sampled points) LAI is introduced as dependent variable (Y) and values of vegetation indices as independent variable (X). In order to find the relationship of dependent and independent variables and model fitness, linear regression was used (Table 2).

Index	R^2	RMSE	Index	R^2	RMSE
NDVI	0.56	0.57	RVI	0.59	0.57
GNDVI	0.64	0.45	MSR	0.59	0.58
BNDVI	0.54	1.11	SAVI	0.63	0.37
GBNDVI	0.64	0.34	**SAVI2**	**0.62**	**0.24**
GRNDVI	0.64	0.80	OSAVI2	0.58	0.57
ARVI	0.45	1.35	MSAVI	0.55	0.57
RDVI	**0.59**	**0.12**	TVI	0.56	0.57
WDVI	0.59	0.94	**TSAVI**	**0.59**	**0.25**
GEMI	**0.63**	**0.27**	IPVI	0.56	0.57
SARVI	0.62	0.90	DVI	0.59	0.97
NRVI	0.59	0.57	SARVI2	0.58	0.58
EVI	0.43	1.23	PVI	0.57	0.46

Table 2. Regression Results

The results of this study showed that among analysed indices, RDVI and SAVI2 were the most proper indices for LAI estimation in study area. The best RMSE value for available data was 0.12 and 0.24. Also in continuance, it was demonstrated that TSAVI and GEMI has more acceptable accuracies in contrast to others. Existence of red and near infrared bands in most of indices indicates express the relation of these bands with LAI.

SAVI index, by imposing the values of slope and intercept of soil line strongly reduce effects of background reflectance, is very appropriate for LAI index (Broge, N. H. and Leblanc, E, 2000). RDVI index, by using magnifying the differences in red and near infrared bands along with their sum, and decreasing the amount of saturation in NDVI, is a proper LAI estimator (Figure 4).

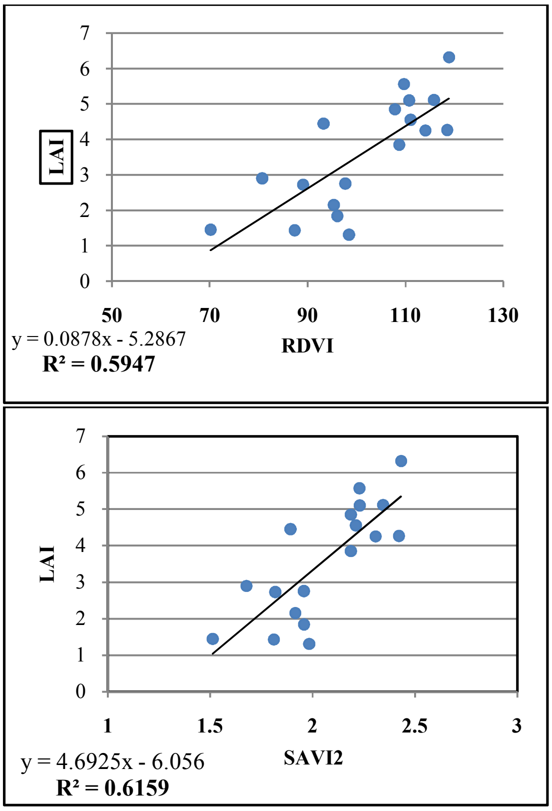

Figure 3. SAVI2 and RDVI relations with LAI

In red region of Electromagnetic spectrum, due to absorption of light through chlorophyll pigments, reflectance intensity decreases but in near infrared bands (because of structural characteristics of plant) the intensity of reflectance increases. Most of vegetation indices use the produced contrast between these two bands to estimate vegetation cover and physical parameters of plants.

One of the most applied vegetation indices which is used commonly in vegetation studies, is NDVI. But the use of this index in this study was confronted with low accuracy. As last studies showed (Trucker, 1979,:7, Sellers, 1985:4, 1998:, Gao et al, 2000:6), NDVI index in vegetated areas is saturated and cannot be regarded as an efficient index.

Considering that in the time of this research, rice was on its max growth, NDVI could not provide suitable accuracy in LAI estimation. Saturation of NDVI in high LAI was shown in figure 4.

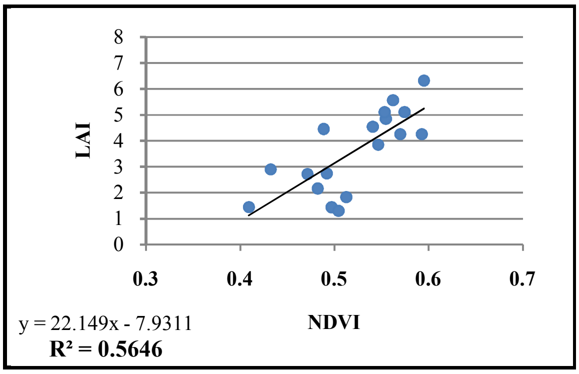

Figure 4. NDVI and LAI Relation

6. CONCLUSION AND DISCUSSION

In this research reflectance values in four bands of AVNIR-2 sensor were used, as well as spectral indices. Among bands under study, infrared band could show the best result with determination of coefficient $R^{\wedge 2}$=0.59. In this part no absorption is occurred by chlorophyll but if the plant leaves grow, which consequently it is possible to reach more minerals, the reflectance reaches maximum in this band. This result is in agreement with last studies (Thenkabail et al, 2004; Latifur, 2011).

As mentioned above, the time of field work was done during the max growth of rice and as a result, regarding that the soil surface is covered, indexes like OSAVI (for the reduction of background reflectance) could not reach a higher accuracy than NDVI (Table 2).

In the present study two atmospheric reduction indices SARVI and ARVI were used. The results indicate that these indices are not efficient after atmospheric corrections and their use after this correction caused some error. Notably, multiplying, subtracting, dividing, and summing of a constant number (except 0) in any index, does not change RMSE and R^2 and just change the values linearly.

For WDRVI and TVI it was observed that NDVI is multiplied with a constant number in their structure, so it is expected that the value of R^2 be equal in all these three indices (Table 2).

Results demonstrated that those indices which show better the differences of red and infrared bands, in contrast with other indices which by giving coefficients to bands reduce such a difference, has more accuracy. Also, due to the high density coverage of area, indices which use soil line adjusting factor L could not increase the accuracy of estimations very well.

It is recommended that for increasing the accuracy, in other regions, measurements be done simultaneously as much as possible, because the change of environmental changes in different times of day can affect the results. The more near the time of imaging to the reproductive phase of rice, the less is the background effects and the more accurate results of LAI estimation. Our results demonstrated the potential of AVNIR-2 and images confirmed that they contain relevant information for LAI estimation and can play a significant role in monitoring and managing the rice plant.

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