ESTIMATION OF POTATO YIELD IN AND AROUND MUNSHIGONJ USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

Monitoring of crop growth and forecasting its yield well before harvest is very important for crop and food management. Remote sensing images are capable of identifying crop health as well as predicting its yield. Normalized Difference Vegetation Index (NDVI) calculated from remote sensing images has been widely used to monitor crop growth and relate to crop yield. This study used 16-days Terra MODIS data for 2006 to estimate the yield of potato in Munshigonj area of Bangladesh. This satellie data has been validate using ground truthing in 50 farmers field and phenological growth of potato has been studied using NDVI metrics. Regression model was developed between NDVI and field level potato yield collected from Depertment Agriculture Extension (DAE) for 6 upazillas of Munshigonj during 2006. The results showed that there is significant correlation (R^2=0.76) between remotely sensed NDVI and field level potato yield. Hence, remotely sensed NDVI data may be an effective tool for early prediction of potato yield.

Keywords: *NDVI, NDVI Metrics, Potato yield, Terra MODIS, Upazilla*

1. INTRODUCTION

Remote sensing images provide access to spatial information at global scale; of features and phenomena on earth on an almost real-time basis. They have the potential not only in identifying crop classes but also of estimating crop yield (Mohd et al. 1994); they can identify and provide information on spatial variability and permit more efficiency in field scouting (Schuler 2002). Remote sensing could therefore be used for crop growth monitoring and yield estimation.In Bangladesh rice is the dominant crop. At present, cultivation of potato in Bangladesh is increasing. The area and production under potato cultivation in 1989-90 were 0.12 million ha and 1.07 million metric tons respectively, while in 1993-94 they rose to 0.13 million ha and 1.4 million metric tons respectively (BBS, 1996). The area irrigated under potato cultivation was 0.07 million ha in 1983-84. The future prospect of cultivation of potato in Bangladesh is quite bright. Forecasting crop yield well before harvest is very important. Early yield prediction together with monitoring of crop development and its growth are generally important. Conventional techniques for crop yield estimation in many countries are based on data collection for crop and yield estimation is done based on ground-based field visits and reports. These are often subjective, costly, time consuming and generally bear large errors for incomplete ground observations (Reynolds et al. 2000). Moreover, yield computed thus are available too late for decision makers for taking appropriate actions on food situation of the country creating problems.

Remote sensing has been used extensively as a tool to assess and monitor vegetation parameters, crop vigour and yield estimation. Most studies have established that there is correlation between Normalized Difference Vegetation Index (NDVI) calculated from remote sensing images and the green biomass as well as yield. Therefore, NDVI can be used to estimate yield before harvesting (Gat et al. 2000, Groten 1993, Liu & Kogan, 2002, Rasmussen 1997). The potential of regression models to estimate crop yield more accurately under variable management conditions was clearly established (Haig L.A. 2003). However, no study on the relationship between remote sensed data and crop yield of potato have been conducted in Bangladesh.Therefore, this research was conducted to estimate potato yield in and around Munshigonj district using TERRA MODIS 16-days NDVI data. Spatial and temporal pattern of the potato productivity in and around Munshigonj district was also studied and h a relationship was established between NDVI of potato crop and yield of potato.

2. DATA AND METHODOLOGY

2.1 Map of Study Area

The field study area is located at Munshigonj sadar between 90°28´ E to 90°36´ E and 23°36´ N to 23°22´ N [Figure 1(a)], while the study was conducted covering the whole Munshigonj district of Bangladesh. The area is covered with different soils. As per soil structure, three types of soil are in the Munshiogonj district. Figure 1(b) shows the soil group of the study area. Heavy loamy soil prevails over the major part of the study area. Heavy clayey soil occupies the second position in the Munshigonj area, while light clayey soil prevails over a smaller area. Agriculture is the main activity in the study area. The area is characterised by two growing seasons. The main growing season (potato) starts in November and ends in April (Rabi).

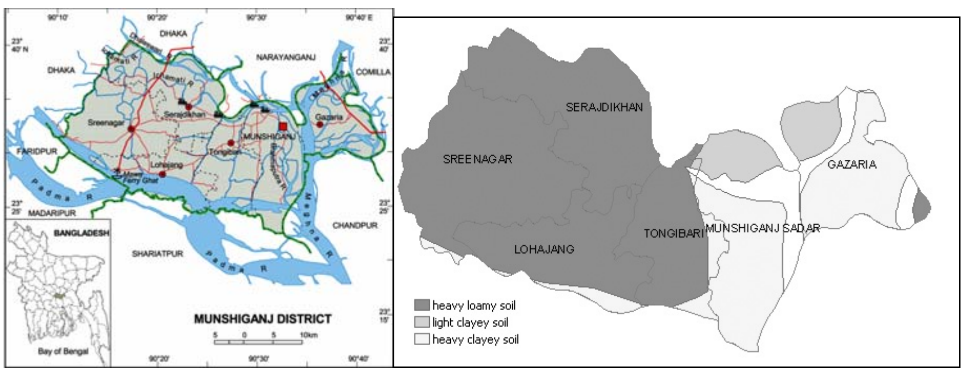

Figure 1: (a) location map and (b) soil classification map of the study area (Munshigonj district)

2.2 Satellite , Field and Secondary Data

Satellite images used for this study include MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid images taken from 3rd December 2005 to 6th March 2006 in total 9 images. The image is the input for product generation for several of the land products including Vegetation Indices (VIs), Normalized Ddifference Vegetation Index (NDVI) and Leaf Area Index (LAI). The image is a composite using sixteen consecutive daily images. The "best" observation during each sixteen day period, for every cell in the image, is retained. Data on crop information was collected from Department of Agricultural Extension (DAE) at Munshigonj Upazila sadar from 1993 to 2006. GPS was used for positioning and receiving data from satellite for on field digitizing and truthing. Fifty numbers of farmer's fields were digitized using Hand GPS to collect primary data. Selection of farmer's field was made in three remote ends of the study field (Munshigonj sadar) during 2005–2006. The phenological growth stage of potato was ascertained through these ground measurements.

2.3 Tools and Techniques

ERDAS Imagine 8.4 and ArcGIS 9.0 software were used for image processing and spatial analyzing. Tera MODIS images are not geo-referenced and provided in a rectangular gird. Using ERDAS imagine, Terra MODIS images were geo-referenced to Lambert Conformal Conic projections with GCS_Indian (Bangladesh) reference system. Finally, geo-referenced data has been re-sampling using nearest neighbour method. Each cell value of the image represents a 16-day average Normalized Difference Vegetation Index, or NDVI. The difference between the near-infrared (Band2) and the visible – red (Band1) bands, over their sum is called NDVI. Value of band 1for Terra MODIS vary from 0.62-0.67 µm, while for band2 from 0.841-0.876 µm. The formula for computing NDVI is as follows:

$$\text{NDVI} = (\text{Band 2}\ \ \text{Band 1})/(\text{Band 2} + \text{Band 1}) \qquad (1)$$

NDVI value of zero means no green vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves. Finally this processed NDVI data are analysed spatially using ArcGIS spatial analysis tool (Zonal Statistics, Extractions, Condition, etc.).

3. RESULT AND DISCUSSION

3.1 Phenological Development of Potato in the Cropping Season

Plantation of potato begins in the study area from the middle of November and harvesting ends at the end of February. During that time eight Terra MODIS images were available and processed for this study. Average value of NDVI was calculated for each of fifty farmers' fields. An NDVI profile was developed from the average values of NDVI and shown in Figure 2. This profile indicates the phenological stage (life cycle of potato) of potato for the growing during 2005-2006 season. This profile was further analysed to derive basic metrics as per method of Reed et al. (1994) and supplementary metrics as per Hill et al. (2003).

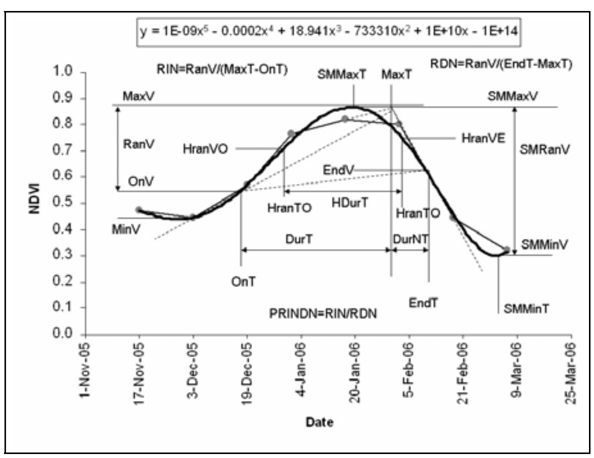

Figure2: The phenological curve of potato and diagrm showing its life metrics

The phenological curve of potato was analysed and life metrics of potato in the study area were presented in Table 1.The first twelve metrics are basic life metrics of potato and others are supplementary. It provides sensitivity and better seasonal environment of growing phenomenon of potato. Result represents a significant amplitude and distinct response period of NDVI. The potato growing season is not dampened or disturbed by the modalities like forests, water-bodies, rivers, settlements etc. The life metrics of potato also provide normal and possible range of values of starting dates, ending dates, maximum values, etc.

Table 1: Description of NDVI metrics of potato for the Munshigonj area

Index	**Value**	**Definition**	**Metric**
OnT	27 days	Intersection of forward lag and smooth curve	Starting date of NDVI high period
OnV	0.53	Value of NDVI at forwards intersection	NDVI at start of high period
EndT	87 days	Intersection of backwards lag and smooth curve	End date of NDVI high period
EndV	0.6	Value of NDVI at backwards intersection	NDVI at end of high period
MaxT	75 days	Time of maximum raw corrected NDVI	Date of maximum NDVI
MaxV	0.88	Maximum value of corrected raw NDVI	Maximum NDVI
DurT	47 days	Time from forwards to backwards intersections	Length of NDVI high period
RanV	0.35	Difference between minimum and maximum value of smooth curve	Amplitude of season
RIN	0.01	Slope of line from forwards intersection to raw maximum	Rate of NDVI increase
RDN	0.03	Slope of line from raw maximum value to backwards intersection	Rate of NDVI decrease
TINDVI	25 days	Integrated area under smooth NDVI curve	'Magnitude'' of season
DurNT	13 days	Time from backwards to forwards intersection	Length of NDVI low period
RRINDN	0.33	Rate of increase/rate of decrease	''Quality'' of season
HRanTO	42 days	Time of half range value at onset—equals OnV+(RanV/2) when rising	Start of active growing season
HRanVO	0.7	Half range value at onset—OnV+(RanV/2)	NDVI at start of active growing season
HRanTE	79 days	Time of half range value at end—equals EndV+(RanV/2) when falling	End of active growing season
HRanVE	0.73	Half range value at end—EndV+(RanV/2)	NDVI at end of active growing season
HDurT	36days	Duration of period from HRanTO to HRanTE	Duration of active growing season
SMMaxT	64 days	Time of maximum smooth NDVI curve	Date of peak of season
SMMaxV	0.86	Maximum value of smooth NDVI curve	Value at peak of season
SMMinT	106 days	Time of minimum smooth NDVI curve	Date of season minimum
SMMinV	0.3	Minimum value of smooth NDVI curve	Value of season minimum

3.2 NDVI for Supervised and Unsupervised Images: Case Study for Jan-17-2006

MODIS images are unsupervised with negative and positive values of NDVI. Unsupervised images were converted into supervised by deducting a value of 0.4 which is the lower level of phonological curve (see Figure 2). The MODIS image for January 17, 2006, representing the near maximum growth of potato, was taken for supervised and unsupervised condition as a case study (Figure 3).

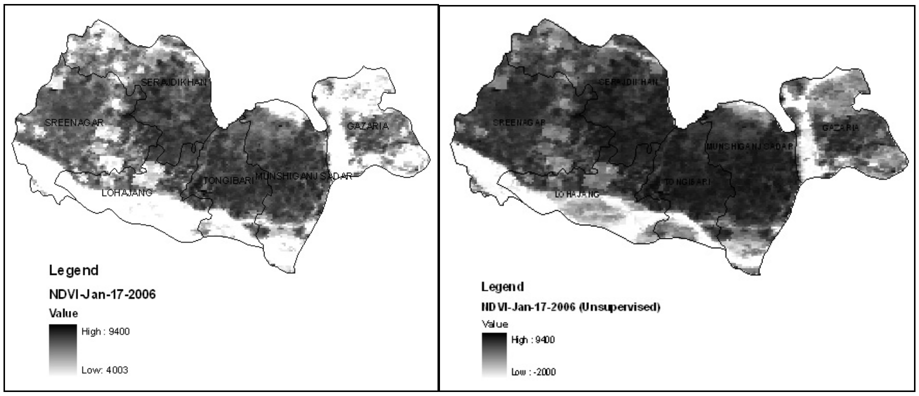

Figure 3: Spatial distribution of mean NDVI of potato on Janusry 17, 2006 for a) supervised condition and b) unsupervised condition in the study area of Munshiogonj

The values of NDVI mean for supervised and unsupervised condition and their differences along with average yield are shown in the Table 2 for different administrative units (Upazilla) of Munshigonj district. The difference in supervised and unsupervised NDVI is high for Louhajong and Gazarial Upazilla. This difference is caused by the vegetation and plants other than potato in the flood planes of the surrounding major rivers.

Table 2: Mean NDVI near maximum growth of potato on January 17, 2007 of (a) supervised and (b) unsupervised condition

Upazila	**Yield**	**Supervised $NDVI_{mean}$**	**Unsupervised $NDVI_{mean}$**	**Difference of $NDVI_{mean}$**
Serajdikhan	29.00	0.726	0.7104	0.0156
Sreenagar	29.00	0.714	0.6243	0.0897
Gazaria	23.04	0.606	0.4754	0.1306
Munshigonj	26.99	0.752	0.6832	0.0688
Tongibari	28.24	0.775	0.7086	0.0664
Louhajong	26.16	0.673	0.4323	0.2407

Regression analysis was carried out with yield data and NDVI mean for supervised and unsupervised condition and they are shown in Figure 4. The correlation coefficient for supervised condition is higher (R^2=0.67) than unsupervised condition (R^2=0.55). Therefore, all other analysis of this study uses NDVI values of supervised condition.

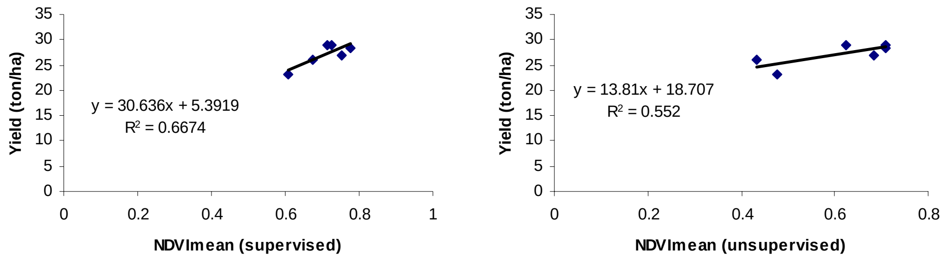

Figure 4: Comparing Yield versus NDVI $_{mean}$ of potato in (a) supervised and (b) unsupervised condition

3.3 MODIS NDVI Map

Spatial distribution pattern of NDVI of potato over Munshigonj district during 2005-2006 season was studied (Figure 5). Spatial distribution of potato growth is well matched with phenological curve of potato in Figure 2. It can be found seen from Figure 5 that December 3, 2005 represents the onset of potato plantation in the study area, while February 18, 2006 may be considered as the starting of maturation of potato bulbs. Though many events may influence the life cycle of potato, still spatial distribution of potato NDVI demonstrates the average field condition of the study area.

3.4 Yield Estimation

In Table 3 official (DAE) estimates of potato yield (ton/ha) and area (ha) of each administrative unit of Munshigonj district has been presented with their NDVImean for the cropping season 2006. Yield prediction equation was established using regression analysis between yield and the average of NDVImean of the study area. The yield prediction equation has high coefficient of correlation (R^2=0.76). R^2 of each yield prediction equation from each single image of particular date was found and correlation was high for active growing period of potato.

Table 3: Production (ton), Yield (ton/ha), Area (ha), NDVImean and Average NDVImean of the study area

			$NDVI_{mean}$							
Upazila	**Yield**	**Area**	**11/17 2005**	**12/3 2005**	**12/19 2005**	**1/1/ 006**	**1/17 2006**	**2/2/ 2006**	**2/18 2006**	**Avg.**
Serajdikhan	29.00	8030	0.59	0.54	0.61	0.70	0.726	0.731	0.64	0.65
Sreenagar	29.00	2200	0.73	0.62	0.64	0.70	0.714	0.770	0.79	0.71
Gazaria	23.04	1450	0.57	0.49	0.51	0.60	0.606	0.655	0.61	0.58
Munshigonj	26.99	8350	0.58	0.55	0.56	0.69	0.752	0.752	0.57	0.64
Tongibari	28.24	7500	0.58	0.53	0.56	0.67	0.775	0.780	0.68	0.65
Louhajong	26.16	3000	0.66	0.54	0.55	0.62	0.673	0.735	0.71	0.64

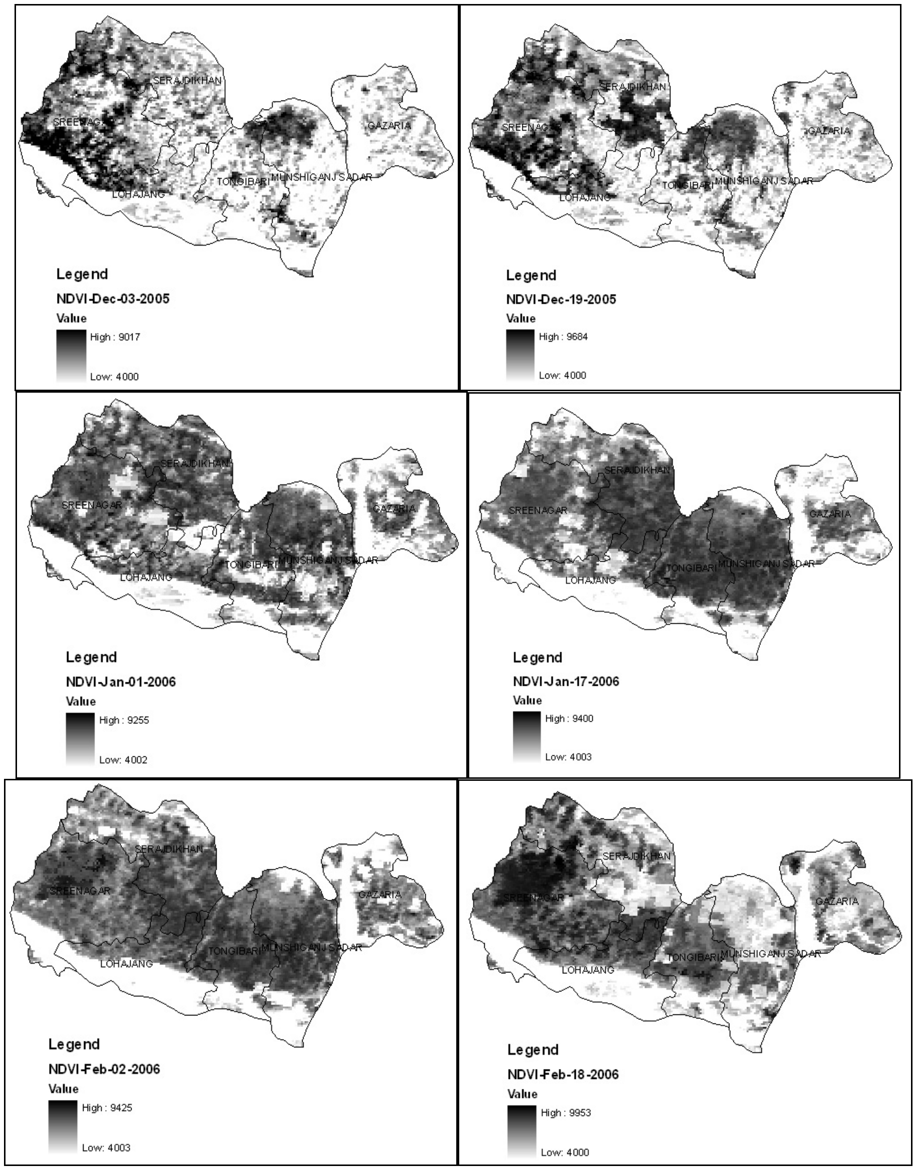

Figure 5: Spatial distribution of potato growth over the study area

The regression correlation together with predictive yield equation is shown in Figure 6(a) and regression curve for R^2 for each image is shown in Figure 6(b). The regression coefficients (R^2) vary over time. The bell shaped (normal distribution) regression coefficients (R^2) curve shows that the full growth of potato has better correlation with yield than planting and harvesting period.

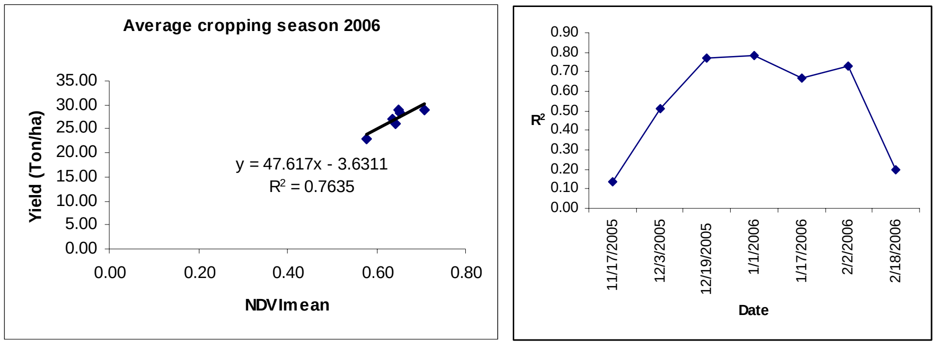

Figure 6 a) Correlation of average yield with Average of NDVImean and b) time series plot of correlation coefficient R^2

The predictive yield equation found as result of regression analysis between potato yields and average of NDVImean of Munshigonj area for the cropping season 2006 is given below:

$$y = 47.617x - 3.6311 \quad (2)$$

The spatial distribution of actual yield and predicted yield as per Equation (2) over the study area was done and shown in Figure 7. The spatial distribution of actual and predicted yield over the study area resembles each other and is very similar by characteristic.

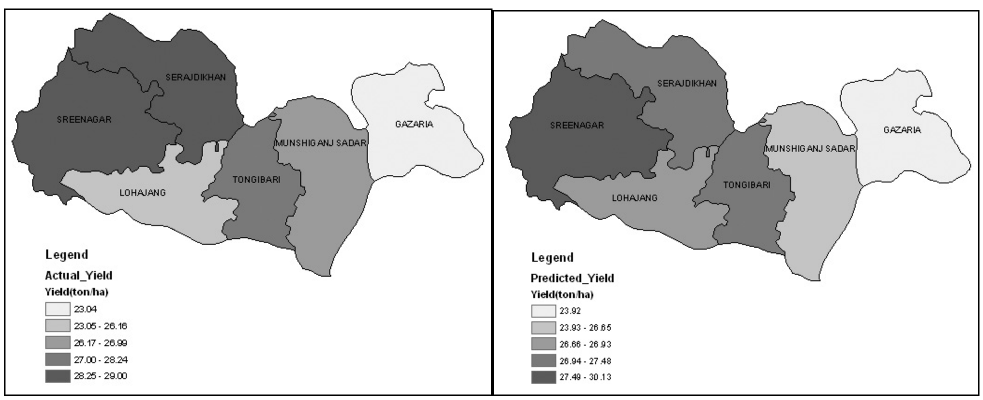

Figure 7: Spatial distribution of a) actual yield and b) predicted yield of potato for the 2006 season over the study area

The result of regression analysis of average yield versus NDVImean for a single date image of January 1st 2006 is shown in Figure 8(a). The image of January 1st 2006 was considered because R^2 value comes to be the highest (R^2=0.79) on that day. In Figure 8(b), spatial distribution of predicted yield found from the regression equation for January 1st 2006 is shown. It indicates that field level yield can be predicted from a single date image. This agrees with the findings of Parihar and Dadhwal (2002) and Dadhwall and Ray (2000). They showed yield variability with NDVI based models of single date for some states of India. The timing of image for yield estimation is important and should be taken from the active period of potato growth.

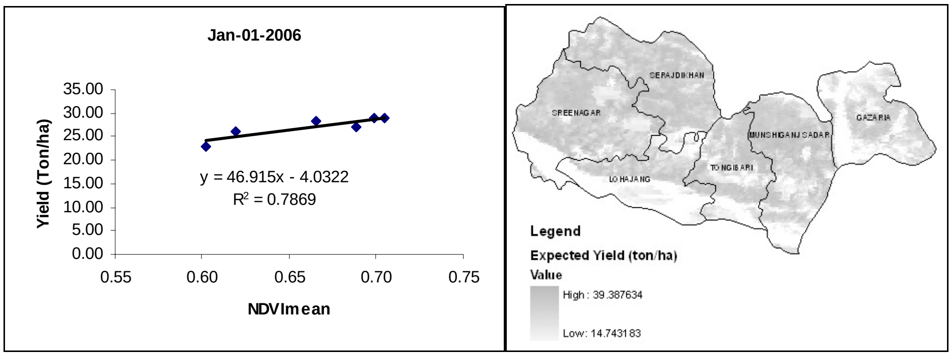

Figure 8: Correlation of a) average yield with average of NDVImean for January 1, 2006 and b) spatial distribution of predicted yield over the study area for January 1, 2006

4. CONCLUSIONS

The study has developed phenological stages of potato for the study area of Munshigonj district and derived its growth metrics. This growth metrics can be very helpful to study the behaviour of potato in the study area. This study also developed a linear regression model to predict yield from NDVI. Regression model shows a good correlation (R^2=0.76) between NDVI and yield of potato. Hence, we like to conclude that 16-day average NDVI data from Tera MODIS can be successfully used to predict yield of potato with fairly good accuracy.

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