ESTIMATION OF YIELD OF WHEAT IN GREATER DINAJPUR REGION USING MODIS DATA

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ABSTRACT

The increasing demand of food management, monitoring of the crop growth and forecasting its yield well before harvest is very important. Early yield prediction together with monitoring of crop development and its growth are being identified with the help of satellite and remote sensing images. Studies using remote sensing data along with field level validation reported high correlation between vegetation indices and yield. In recent years, there has been a growing cultivation of cereal crops including wheat in the North West region of Bangladesh especially in the greater Dinajpur area. However, it is difficult to quantify the exact area of wheat cultivation using traditional ground based measurements. However, remote sensing can provide most real time information about the wheat coverage area and can estimate the probable yield. In this study, using the Normalized Differentiate Vegetation Index (NDVI) indicator developed from time series MODIS satellite images, the phonological growth of wheat has been monitored during the Rabi season (November to March) of 2007-2008 for the greater Dinajpur area of Bangladesh. A strong correlation between the wheat production and satellite represented wheat area was found (R^2=0.71) which represents the effectiveness of the remote sensing tools for crop monitoring and production estimation.

Key words: *GIS, MODIS, NDVI, Remote Sensing, Satellite Images, Yield*

1. INTRODUCTION

Remote sensing technology is an effective tool for monitoring agricultural crops, assess growth, predict yield, etc. Now days, food security issue has taken a global dimension and emerged as a very important one for an overpopulated country like Bangladesh, application of remote sensing technique in agriculture sector needs full attention. The recent food price hike fueled its urgency. Unlike rice, farmers of Bangladesh have gone for intensive cultivation of cereal crops including wheat in Rabi. The production of wheat continued to grow from the late 1990s due to favorable price. The present price trends of wheat accelerated the process of intensive wheat cultivation. The future prospect of cultivation of wheat in Bangladesh, at present, is quite bright especially in the greater Dinajpur area of Bangladesh. But it is difficult to quantify the increased wheat acreage area and production on real time basis using conventional techniques. Conventional techniques to such jobs are based on ground-based field visits, data collection for crop and reports which are often subjective, costly and time consuming and also bear large errors for incomplete ground observations (Reynolds *et al*. 2000).

On the other hand, satellite and remote sensing images are capable of doing these jobs very effectively. In recent years, studies using remote sensing data done at field level reported high correlation between NDVI and yield. Assessment and monitoring of vegetation parameters like NDVI and crop vigor and green biomass may be ascertained through use of remote sensing. Therefore, NDVI can be used to estimate yield before harvesting **(**Groten 1993, Liu & Kogan, 2002 and Rasmussen 1997). Ali et al. (1987) and Choudhury et al. (1990) investigated hydrological and agricultural applications using AVHRR data in Bangladesh. Nessa (2005) in her M. Phil Thesis studied the use of NDVI for monitoring of rice growth and its production in Bangladesh with NOAA satellite data. Bala and Islam (2008) in their recently completed research project have shown the effectiveness of use of remote sensing technology for prediction of yield of potato in Bangladesh. Islam et al. (2008) also have shown the applicability of remote sensing technology in establishing the scale of disaster like green mass destruction over the mangrove forest of Bangladesh just after the SIDR. However, to the best of our knowledge, no research works have been carried out in Bangladesh on the determination wheat coverage area and yield estimation through remote sensing data. In this study, spatial distribution of wheat during the growing season of 2007-2008 (November to April) has been estimated from satellite data for Dinajpur, Panchagarh and Thakurgaon districts of Bangladesh.

2. METHODOLOGY

2.1 Study Area

The study was conducted in Munshiganj District of Bangladesh. The study area is located between 90°28´ E to 90°36´ E and 23°36´ N to 23°22´ N. The study area is located in the greater Dinajpur area which is consists of three districts: Dinajpur, Panchagarh and Thakurgaon. There area 7 Upazilas in the Dinajpur district and 5 Upazilas in both Panchagarh and Thakurgaon districts. Figure 1(a) shows the location map of the study area. Field data has been collected from the farmers' field during the wheat growing season of 2008. Figure 1(b) shows the locations of the farmers' field in the study area.

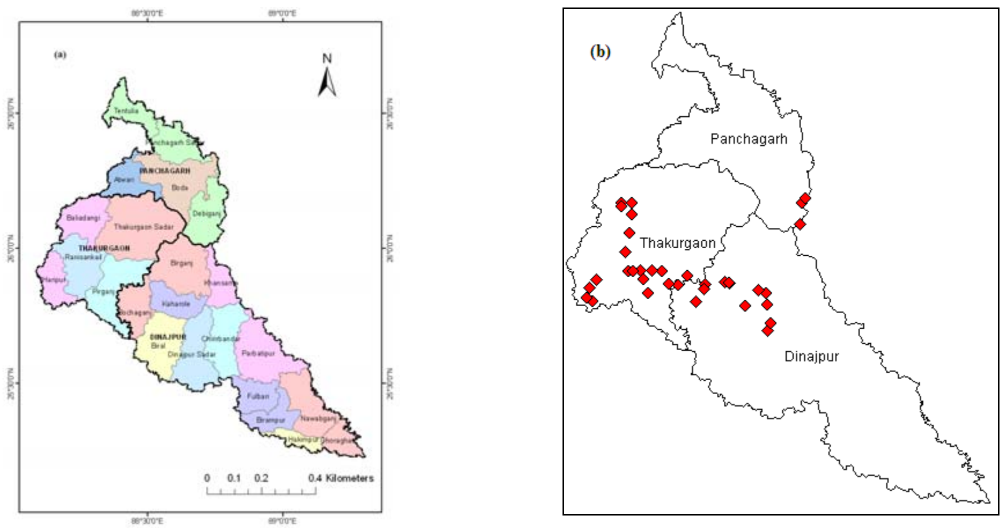

Figure 1: (a) Location map of the study area (b) location of the wheat fields (red diamond) in Dinajpur, Panchagarh and Thakurgaon district.

Dinajpur experiences a hot, wet and humid tropical climate. Dinajpur has a tropical wet and dry climate. The district has a distinct monsoonal season, with an annual average temperature of 25 °C (77 °F) and monthly means varying between 18 °C (64 °F) in January and 29 °C (84 °F) in August. Figure 2 shows the mean monthly maximum and minimum temperature of Dinajpur district. Mean monthly rainfall distribution of Dinajpur district is shown in Figure 2.

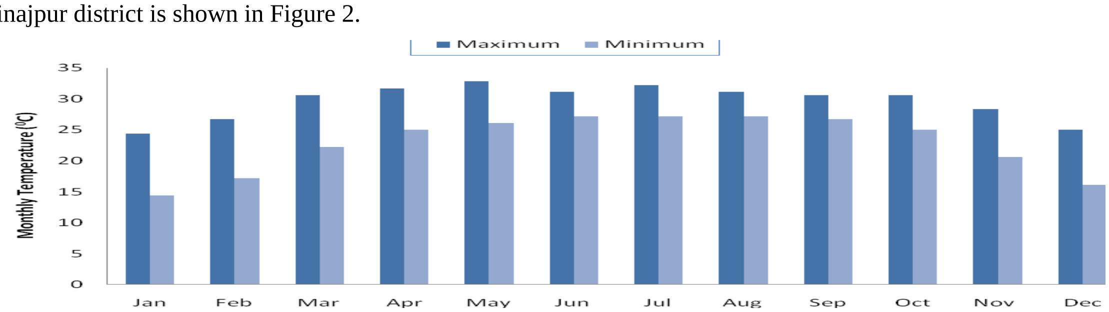

Figure 2: Monthly maximum and minimum temperature (^{0}C) at Dinajpur district

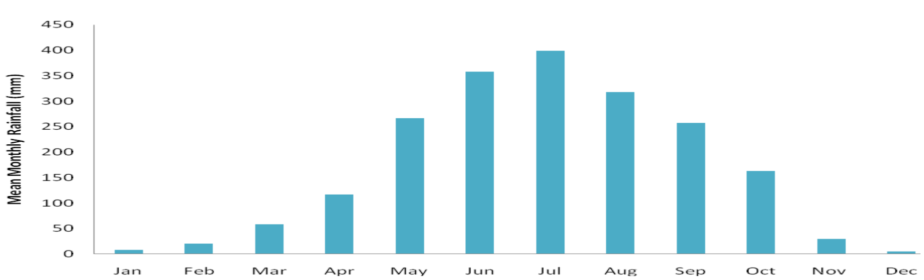

Figure 3: Mean monthly rainfall at Dinajpur district

Satellite images have been used for the study are time series MODIS surface reflectance with spatial resolution 250m. MODIS images can be freely downloaded from their web site (MODIS, 2010). MODIS data/images have been geo-referenced using MODIS Re-projection Tool (MRT) and analyzed using ILWIS software (ILWIS, 2010). Normalized Vegetation Index (NDVI) is the most commonly used vegetation index. It varies from +1 to -1. NDVI value of zero means no green vegetation and NDVI values close to +1 (0.8 to 0.9) indicates the highest possible density of green leaves. Figure 1 (a) shows the location of wheat fields in the study area. Figure 1(b) is the plot of the changes of the NDVIs value of the selected wheat fields for the wheat growing season. Based on this information rule based supervised classification techniques has been applied to determine the wheat area from the satellite images.

2.2 Remote Sensing data

In this study MODIS images acquired by TERRA instrument were used. MODIS, the Moderate Resolution Imaging Spectro-radiometer satellite was launched on 18 December 1999 as part of NASA's Earth Observing System (EOS). A product of the average of 8 days reflectance "Surface Reflectance 8-Day L3 Global 250m" were used for the winter season of 2007-2008. The images can be freely downloaded from the Earth Observing System Data Gateway by using Warehouse Inventory Search Tool (WIST). The spatial resolution of this product is approximately 250 m, and atmospheric correction has already been carried out. The MODIS data sets can be found in a sinusoidal coordinates system where Bangladesh is located at 26^{th} row and 6^{th} column of a global tile system. MODIS has 36 bands of which band 1 (red) and band 2 (NIR) are aggregated with a spectral range from 620 nm to 876 nm. MODIS data/images have been geo-referenced using MODIS Re-projection Tool (MRT) and analyzed using ILWIS software (ILWIS, 2010). Normalized Vegetation Index (NDVI) is the most commonly used vegetation index. It varies from +1 to -1. NDVI value of zero means no green vegetation and NDVI values close to +1 (0.8 to 0.9) indicates the highest possible density of green leaves. Figure 4 (a) shows the NDVI values on the study area on the 25 January 2008. Figure 4(b) shows the NDVI values only for the wheat field based on the rule based classification techniques which will be discussed in the next sub-section.

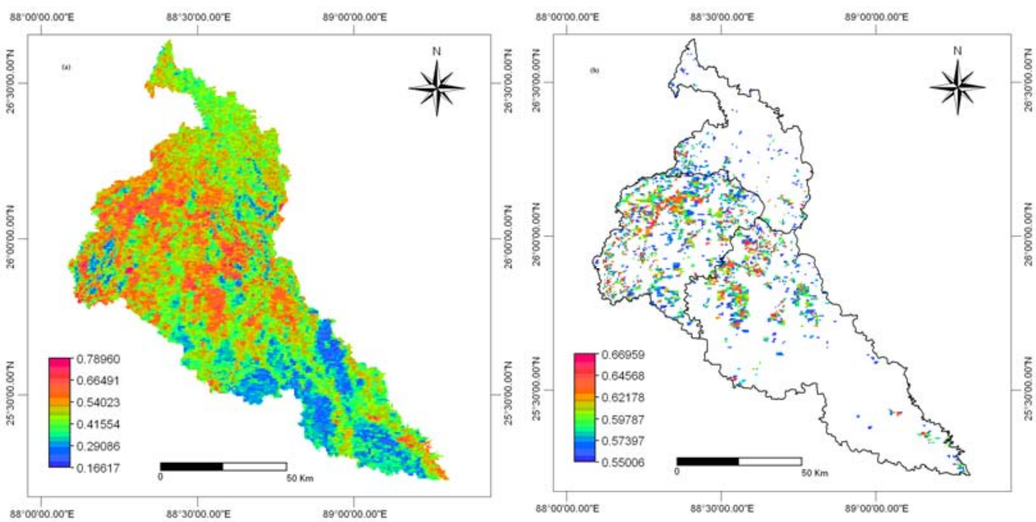

Figure 4: NDVI value (a) over the study area and (b) over the wheat cultivable area on the 25 January 2008 (Day of the year is 25).

2.3 Classification of wheat growing area

At a selected 50 farmers' field points from the starting of wheat plantation up to the harvest time for 12 images were extracted. The chronological changes of NDVI value after plantation for the 50 farmers' field has been plotted in Figure 5. The mean changes of NDVI are marked by dark black lines which can represent as the phonological curve of wheat. It can be found from the mean curve that the peak occurred on 25 January 2008 which is approximately 72 days from the plantation date. The peak of the mean curve was found as 0.6 with a range varies from 0.49 to 0.65. A rule based supervised classification technique has been applied to identify wheat growing area are as follows:

$$Wheat\ Area = 0.49 < NDVI < 0.65 \quad (1)$$

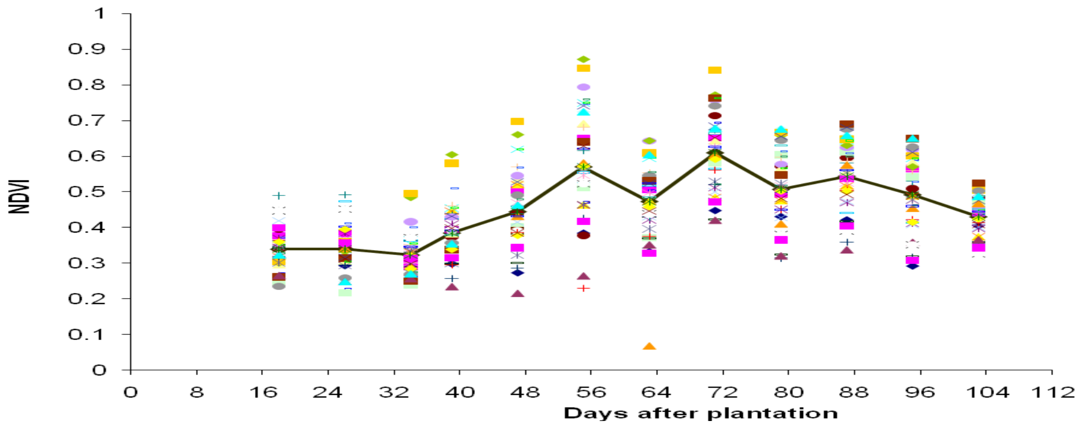

Figure 5: Changes of NDVI in the growing season of the selected fields. The dark bold line shows the average value of the changes of NDVI.

Location of the wheat fields has been identified based on the rule based classification techniques and has been shown in Figure 6. This image has been used as mask image to separate the wheat growing areas and other areas.

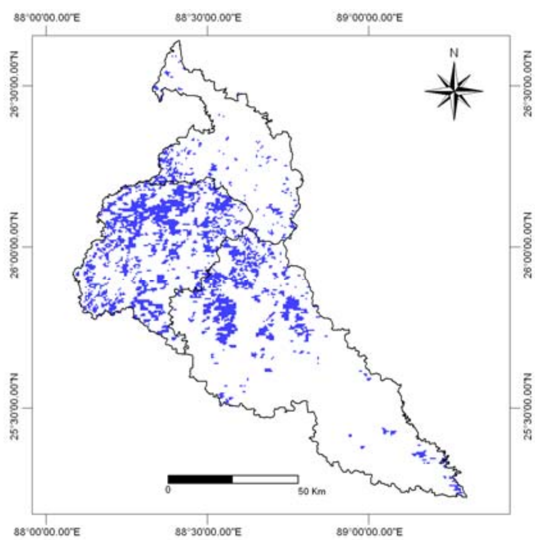

Figure 6: Location map of the wheat fields in the study area during growing season of 2007-2008.

3. RESULT

3.1 Spatial Distribution of wheat during the growing season

Figure 2 presents spatial distribution of the wheat growing areas in the study area for the whole growing season of 2007-2008 (November to April). Plantation has been started at the middle of November with an average growing season of 120 days. Harvesting occurred at the second week of March of the following year. Chronological changes of the NDVI values over the study have been shown in Figure 2. It has been found that peak value occurred around 71 days after the plantation.

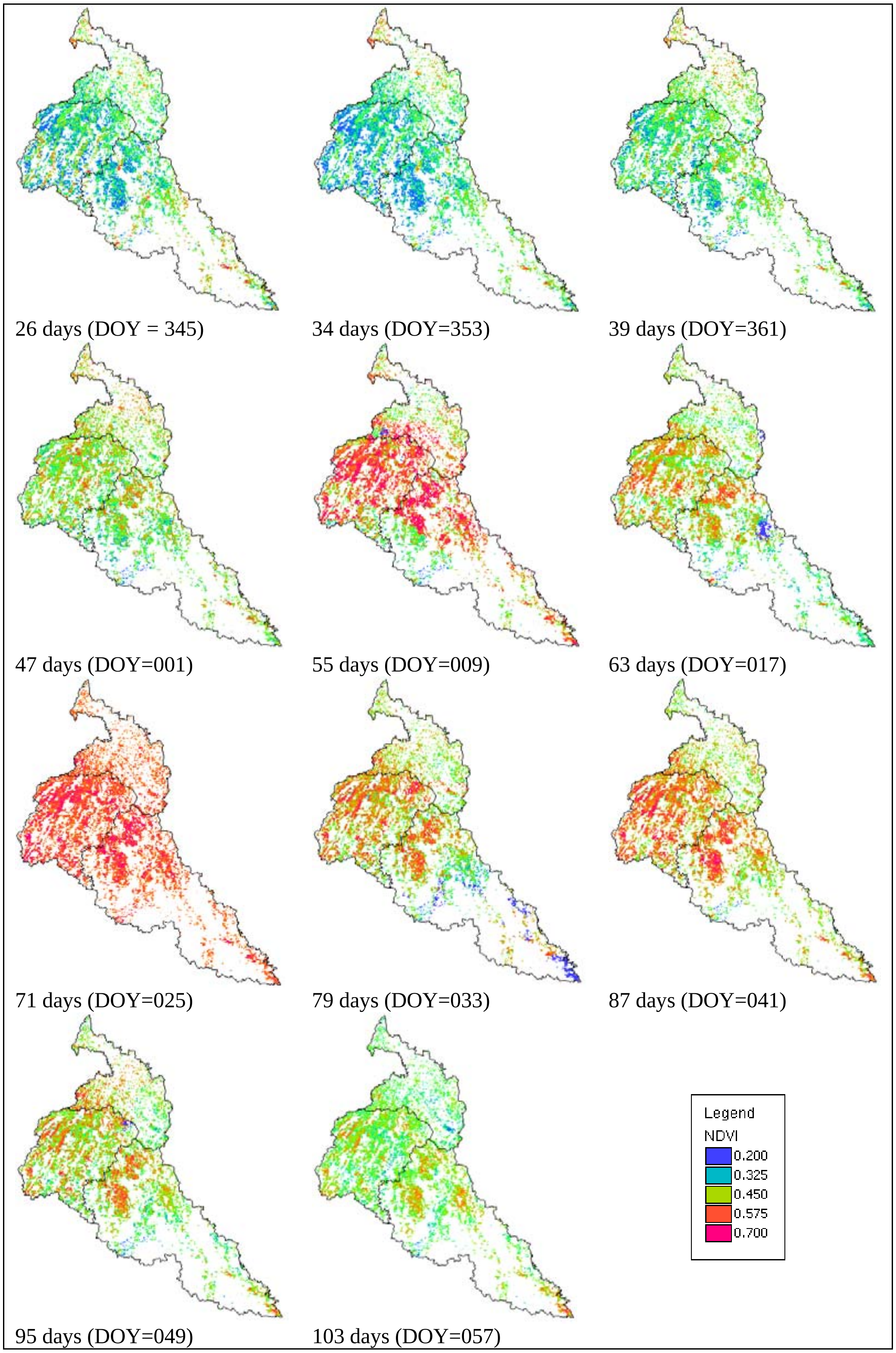

Figure 7: Changes of the NDVIs of the wheat for the growing season of 2007-2008.

3.2 Correlation between NDVI and production

Upazila-wise wheat yield data has been collected for the study area for the Department of Agricultural Extension (DAE). The maximum value of NDVI has been calculated for each Upazila using the supervised classified images. A summary of the yield, area, production and maximum NDVI value of the growing season for each Upazila have been presented in Table 1. The total productions of wheat are 83,255, 31,485 and 132,275 tons and average yields are 2.18, 2.06 and 2.33 tons/hactor for Dinajpur, Panchagarh and Thakurgaon respectively. The coefficient of determination between yield and maximum NDVI has been found 0.32 and plotted in Figure 8. Though there has been no significant correlation has been found, the trend is found positive.

However, the coefficient of determination between total production (tons) of wheat and median value of the number of wheat pixels was found as 0.71 which is significant. Figure 9 shows a plot of total wheat production (tons) in each Upazila and the respective median value of the number of wheat pixels. Median values were used for NDVI to avoid the bias in mean due to any outlier data.

Table-1: Upazilla-wise Yield and maximum NDVI during the growing season.

District	Upazila	Maximum NDVI	Area (ha)	Yield (t/ha)	Production (t)
Dinajpur	Birgonj	0.6	9875	2.45	24187
	Khansama	0.57	2830	2.40	6792
	Bochagonj	0.58	4465	2.35	10492
	Kaharol	0.59	5095	2.40	12228
	Chirir Bandar	0.56	1160	2.36	2737
	Dinajpur Sadar	0.56	1530	2.46	3764
	Parbitipur	0.54	830	1.20	992
	Birol	0.57	6510	2.45	15924
	Nawabgonj	0.56	775	2.40	1860
	Fulbari	0.54	1065	2.12	2263
	Birampur	0.54	520	2.45	1274
	Ghoraghat	0.56	230	2.23	512
	Hakimpur	0.53	220	1.04	230
Panchagar	Tetulia	0.54	830	1.90	1577
	Panchagar Sadar	0.53	4200	2.20	9240
	Atwari	0.56	4380	2.12	9286
	Boda	0.54	2420	2.10	5082
	Debigonj	0.56	3150	2.00	6300
Thakurgaon	Thakugaon Sadar	0.58	15500	2.00	31000
	Baliadangi	0.6	11500	2.50	28750
	Ranishankail	0.58	9500	2.50	23750
	Haripur	0.61	8500	2.40	20400
	Pirgonj	0.57	12500	2.27	28375

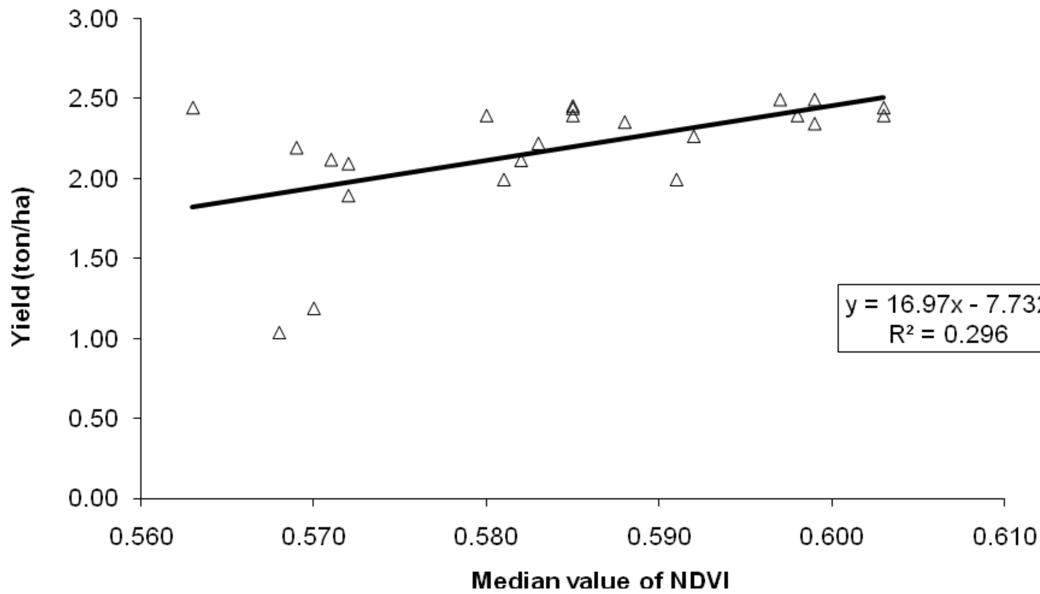

Figure 8: Correlation between wheat yield (t/ha) and median value of NDVI during the peak growth (DOY=25) for each Upazila of the study area.

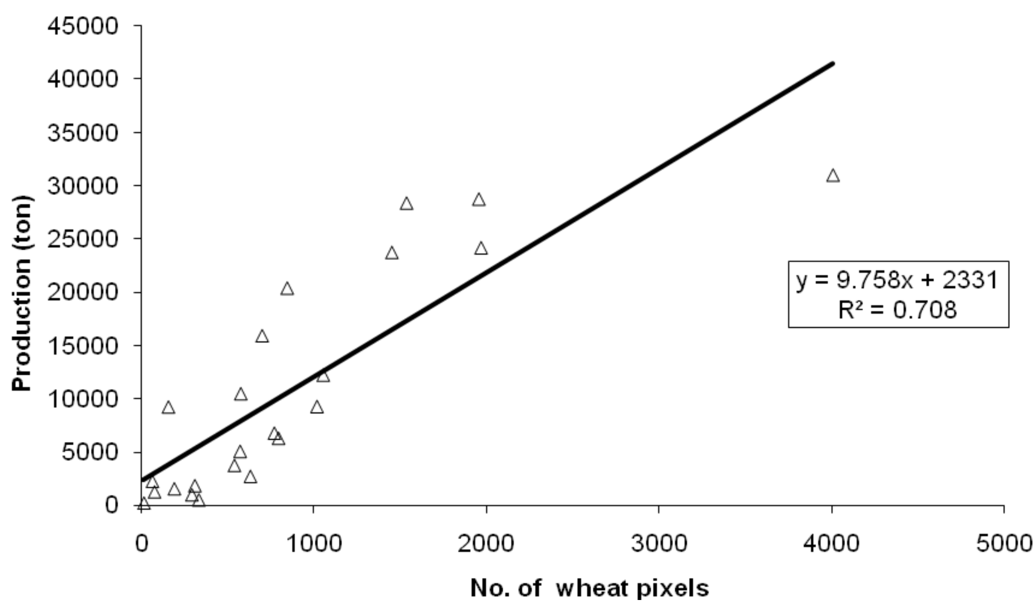

Figure 9: Correlation between wheat Production (ton) and no of wheat pixels in the Upazila

4. CONCLUSIONS

This study has been work on finding out of NDVI of wheat from remotely sensed image and its correlation for understanding its effect on yield may pave the way for better understanding and prediction of yield using remote sensing technique. The value of R^2 for the relationship between maximum NDVI and yield for each Upazila of the study area was found as 0.32 which is not significant. However, there is significant correlation (R^2=0.71) between total production and median number of NDVI pixels which represent wheat fields. It can be conclude from this study that satellite images can successfully determine the coverage area and spatial distribution of the wheat during the growing season.

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