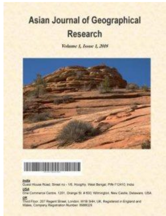

Asian Journal of Geographical Research

2(3): 1-12, 2019; Article no.AJGR.50270

Identifying Climatic Variables with Rice Yield Relationship and Land Cover Change Detection at Sylhet Region

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJGR/2019/v2i330088

Editor(s):

(1) Dr. Xu Chong, Professor, Institute of Geology, China Earthquake Administration, Beijing, China.

Reviewers:

(1) Snehadri Ota, Institute of Physics, India.

(2) Olumide Adesina, Olabisi Onabanjo University, Nigeria.

Complete Peer review History: http://www.sdiarticle3.com/review-history/50270

Original Research Article

Received 08 May 2019
Accepted 19 July 2019
Published 31 July 2019

ABSTRACT

The study is conducted to determine the correlation between climatic parameters and rice yield. The present study is also undertaken to analyze the land cover change in Sylhet district between 2013 and 2018 using LANDSAT-8 images. Local climate and rice yield data are collected from BMD (Bangladesh Meteorological Department) and BRRI (Bangladesh Rice Research Institute) and BBS (Bangladesh Bureau of Statistics). ArcGIS 10.5 and SPSS software are used to show the vegetation condition and correlation coefficient between rice yield and climatic variables respectively. It is revealed from the result that rainfall is negatively correlated with *Aman* and *Boro* (local and HYV) rice whereas temperature and relative humidity showed a positive correlation with local Aman and *Boro* rice. On the other hand, relative humidity showed a strong linear relationship with HYV *Boro* rice. Finally, both temperature and relative humidity have substantial effects on yields in the *Boro* rice. Furthermore, vegetation condition is observed through NDVI and found the moderate-high vegetation in 2013. After that NDVI value is fluctuating which evidently signifies the rapid vegetation cover change due to a flash flood, flood and other climate changing aspects. Additionally, Forested and high land vegetation's are endangered rapidly. Some adaptation strategies should be followed to minimize the effects of natural calamities for improving better vegetation condition.

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Keywords: Climatic parameters; rice yield; Landsat-8 satellite images; ArcGIS 10.5; NDVI.

1. INTRODUCTION

Bangladesh is considered one of the countries that is most susceptible to climate change because of its location in the tropics, the supremacy of floodplains, its low elevation from sea level, its high population density and its little economic and technological capacity [1-5]. Because of growing emissions of anthropogenic greenhouse gases through human activities, climate change has arisen as a key concern for environmentally and economically vulnerable countries, such as Bangladesh. Combined with the possible increase in global temperature, rainfall has already become inconstant and erratic, and the incidence and strength of climate related extreme events, such as floods, droughts, heat waves, and cyclones, are projected to increase in the future [6-9].

Bangladesh is the sixth biggest rice-producer country in the world. In the last three to four decades, great efforts in rice research and agricultural innovations were made to increase rice production, and it has increased to about 48 million tons in 2009 from about 17 million tons in 1970. The country is also said to have amongst the highest per capita ingesting of rice (about 170 kg annually), and its food safety and economy largely depend on good production of rice [10]. The percentage share of rice in value is more than 60% of the total crop agriculture [9,11]. Furthermore, agriculture accounts for nearly 20% of gross domestic product (GDP), and almost 66% of the labor force depends on agriculture for employment [12].

Even though the success in rice production, the country still appearances many challenges in the agricultural sector because of predict climate change impacts and always growing population. Effects like temperature rise, unpredictable rainfall, ambiguous environment as well as great climatic events like frequent cyclones, prolonged flood, sea level rise and others, are already being felt in Bangladesh.

Temperatures in Bangladesh have been increasing, mainly during the monsoon season, for the last three decades [13]. Additionally, the country is predicted to experience a rise in average day temperatures of 1.0 C by 2030 and of 1.4 C by 2050 [6-7]. Rainfall has become increasingly adjustable and has verified an uneven distribution. The number of days without rain is increasing, although the total annual rainfall essentially remains the same. This erratic pattern produces extreme events, such as floods and drought, which have noticeable hostile effects on rice yields [14]. As a result, rice production is likely to decline by 8–17% by 2050 [7,10]. Sylhet is one of the most affected areas in Bangladesh due to the threats of climate change effects. Sylhet is located in the active monsoon areas with an average rainfall of around 3963 mm each year [15]. So far, the rainfall distribution isn't uniform steadily. The rainy season from April to October is hot and humid with very heavy showers and thunderstorms almost every day, whereas the short dry season from November to February is very warm and fairly clear [16]. Rainfall varies not only with time but also with geographical area and altitude in space and is a continuous random variable [17].

The land use/land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Hereafter, information on land use / land cover is important for the assortment, planning and implementation of land use and can be used to meet the swelling demands for basic human needs and welfare. This information also assistances in monitoring the dynamics of land use resulting out of changing demands of increasing population.

Land use of Sylhet has progressively changed. This is found from the field survey that in 1970 the area was dominated by marshy land (645.33 katha), vacant land (430.88 katha) and crop land (336.17 katha). By 1988 there was no university in the area. Residential area also increased, it covered 39.11% of total study area. Now in 2007 there is a radical change noticed in the area in comparison with 1988. Population has increased and consequently residential area has also increased. Now it covers 58.71% of the study area. It was stated that water bodies of Sylhet district were 81535.2 ha, 34535.7 ha and 28435.6 ha in 1988,1997 and 2006 respectively and unplanned urbanization played the key role in reduction in water bodies [18]. The impacts of land use changes are desertification, climate changes and hill cutting. Inappropriate lands use like removal of vegetal cover carries about marked changes in the local climate of Sylhet. Deforestation changes rainfall, temperature, wind speed etc. It was observed that rainfall pattern, atmospheric window of Sylhet has been rehabilitated significantly within ten years. Considering this, the following objectives are; to correlate between climatic variables and rice yield, and to detect the land cover change through landsat-8 satellite images.

2. MATERIALS AND METHODS

2.1 Study Area

The study area lies in latitude 24º89 N and longitude 91º86 E. The total area of the Sylhet is 12298.4 km square. Density of the area is 980/km-square. Average rainfall of area is around 3876 mm and relative humidity is 74%.

2.2 Methodology

2.2.1 Time series data and its sources

The local climate data on daily temperature, rainfall and relative humidity for the 1970–2017 period was collected from the secondary sources of Bangladesh Meteorological Department (BMD) for Sylhet district weather station. The climate data converted to seasonal average data according to the growing periods of the three major rice varieties (Aus, Aman, and Boro). Then the data were processed for the following two growing seasons [19].

- Aman Growing Season (June-November): Production of this season is overwhelmed by the regular intensive rainfall of monsoon, highly humid weather and cloudiness.
- Boro Growing Season (December-may): This season is depicted as the driest and sunniest time of the year comprises of the long periods of winter and pre-monsoon summer.

2.2.2 Panel data and their sources

Data on the rice yields of the two major varieties of rice in Bangladesh (Aman, and Boro) in the time span (1970–2017) were gathered from the Yearbook of Agricultural Statistics of Bangladesh published by the Bangladesh Bureau of Statistics (BBS), Department of Agricultural Extension (DAE) also BRRI (Bangladesh Rice Research Institute). The rice yield data (measured in Metric tons per acre [M.ton/acre]) include the time series average crop yields for rice growing district. Yield data were found as the fiscal year basis, such as 1971–1972, 1972–1973, etc. Then, these fiscal year data were transformed into yearly data, for example, 1971–1972 was considered as 1972.

2.2.3 Satellite images acquired and source

For the present study, landsat-8 satellite images of Sylhet district were acquired for six years namely 2013, 2014, 2015, 2016, 2017 and 2018 by using earth explorer. All the images have been taken for different month of each year. All the LANDSAT images have been taken from https://earthexplorer.usgs.gov/. and having resolution of 30 meters of each.

2.2.4 Analysis of collected data

Time series data and panel data is analyzed through the scatter plot diagram according to the Aman and Boro growing seasons. Scatter plot diagram is done by SPSS software. For Correlation results have been used log-transformation for converting absolute differences into relative differences. Rice growing seasons are selected as a dependent variable (i.e. LnAman, LnBoro) and three climatic parameters are selected as an independent variable (i.e. LnRainfall, LnAvg.Temp and LnRH).

2.2.5 NDVI analysis process

- Landsat 8 images download
- ArcGIS 10.5 (Atmospheric Correction)
- NDVI
- Clipping of NIR & RED with shapefile and NDVI creation
- NDVI classification
- Determination of area

NDVI is calculated on a per-pixel basis as the normalized difference between the red and near infrared bands from an image:

$$NDVI = NIR – RED / NIR + RED$$

where NIR is the near infrared band value for a cell and RED is the red band value for the cell. The wavelength for Band 4 (RED) and Band 5 (NIR) are 0.636-0.673 and 0.851-0.879 respectively.

3. RESULTS AND DISCUSSION

The summary statistics of all the climate data series used in this study are presented in Table 1.

From Table 1, it is clear that yield of Aman rice for local variety is the highest compared to Boro rice. On the other hand, for HYV Boro rice is the highest mean yield. In the case of climatic variables, the lowest mean seasonal rainfall for Boro growing period. In contrast the highest avg. temperature is observed for Aman growing period and lowest Avg. temperature is found for Boro growing period. Though, in the case of

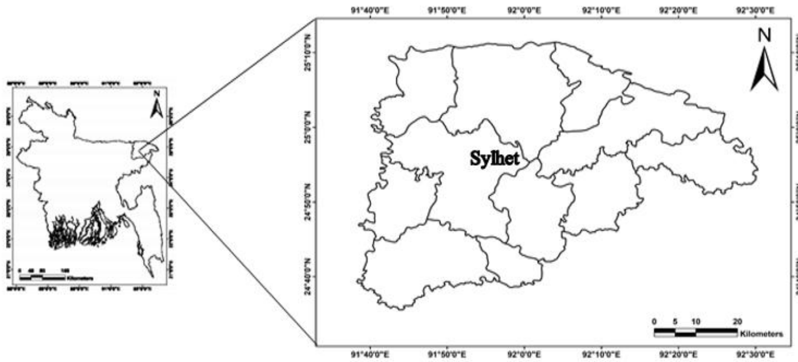

Fig. 1. Map of the study area

Table 1. Summary statistics of the data series for the period 1970–2017

Variables	**Rice varieties**	**Statistics**			
		Mean	**Median**	**Maximum**	**Minimum**
Local variety-yield (M.tons)	Aman	12.33	12.51	12.87	11.32
	Boro	11.88	12.24	12.96	9.50
HYV-yield (M.tons)	Aman	11.49	11.94	12.97	6.49
	Boro	12.13	12.02	13.44	9.68
Rainfall (mm)	Aman	2.40	2.42	2.74	2.05
	Boro	2.18	2.19	2.47	1.81
Avg. temp°C	Aman	3.45	3.46	3.60	3.26
	Boro	3.17	3.20	3.31	2.93
Relative humidity (%)	Aman	4.40	4.43	4.51	4.19
	Boro	4.14	4.16	4.25	3.93

relative humidity the maximum percentage of humidity is perceived in Aman growing season, whereas Boro growing season is detected the lowest percentage. Maximum rainfall, temperature and relative humidity is found 2.74 (mm), 3.60°C and 4.51% respectively while minimum is observed 1.81 (mm), 2.93°C, and 3.93% respectively during the study period.

3.1 Correlation Coefficients between Rice Yield and Climatic Parameters

The bivariate Pearson Correlation produces a simple correlation coefficient, r, which measures the strength and direction of linear relationships between pairs of continuous variables. A scatterplot is a type of data display that displays the relationship between two variables.

The mathematical formula of linear correlation coefficient of Pearson product moment method is,

$$r = n\sum x - (\sum x)(\sum y)/\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y^2)]}$$

Which can be written as, $r = Sx \div \sqrt{(Sx)(Sy)}$

Where x and y are n paired observations,

$$Sx = \sum(xi - \bar{x}) - (yi - \bar{y})$$

$$Sx = \sum(xi - \bar{x})^2$$

$$Sy = \sum(yi - \bar{y})^2$$

Requirements for Pearson's correlation coefficient:

- Scale of measurement should be interval or ratio.
- Variables should be approximately normally distributed.
- The association should be linear.
- There should be no outliers in the data.

3.1.1 Interpretation of coefficient of correlation

Coefficient of correlation denoted by r is the degree of correlation between two variables. The value of r always lies between -1 and +1.

- ✓ When r is 1, we say there is a perfect positive correlation. A value of the coefficient close to +1 indicates a strong positive linear relationship.
- ✓ When r is a value between 0 and 1, we say there is a positive correlation.
- ✓ When r is 0, we say there is no correlation. A correlation of zero means there is no.
- ✓ Relationship between the two variables. A value close to 0 indicates no linear relationship.
- ✓ When r is a value between -1 and 0, we say that there is a negative correlation.
- ✓ When r is -1, we say there is perfect negative correlation. A value close to -1 indicates a strong negative linear relationship [20].

3.1.2 Local aman rice variety

From Figs. (2-4), It can be perceived from the scatter plot that the points are reasonably closely scattered about an underlying straight line so there is a strong linear relationship between the two variables (yield vs temperature, yield vs RH). The correlation analysis showed that rainfall is negatively correlated with Aman and showed a weak relationship.

3.1.3 HYV (High Yielding Variety) aman rice

From Figs. (5-7) showed that the line drawn through the parameters were a negative slope, so this scatterplot is a negative linear correlation. The value of R^2 for all parameters indicated that the co-relation between the variables is not well enough. The slope of the line is very negligible which indicated that yield has very little dependency on the climatic parameters.

3.1.4 Local boro rice

From Figs. 8-10, it is predicted that rainfall shows a weak correlation between yield. The strong linear relationship between the temperature, relative humidity and yield is also found from co-relation coefficients. The value of R^2 for temperature and relative humidity indicated that the co-relation between the variables is well enough. The slope of the line is moderate which indicated that yield has a good dependency on the climatic parameters.

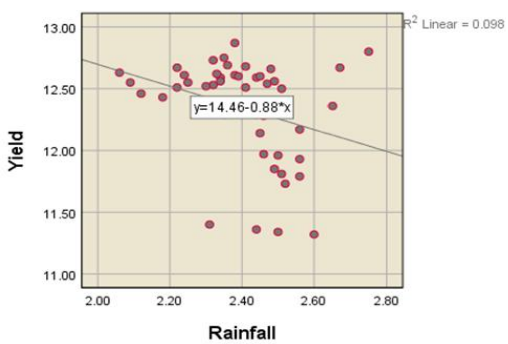

Fig. 2. Rainfall vs yield

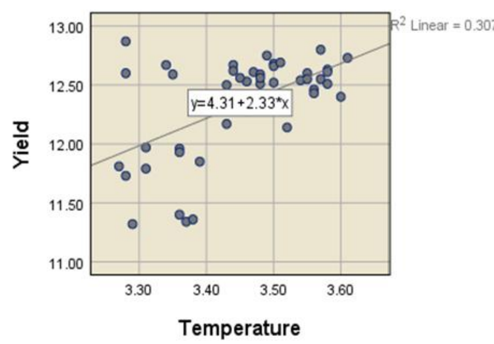

Fig. 3. Temperature vs yield

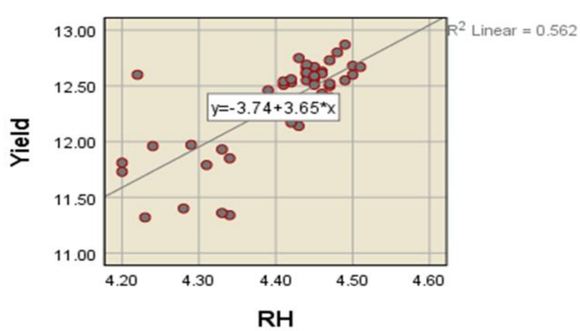

Fig. 4. Relative humidity vs yield

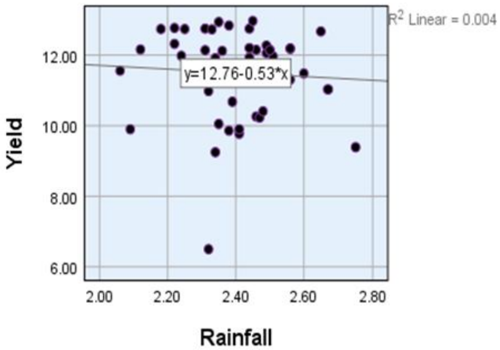

Fig. 5. Rainfall vs yield

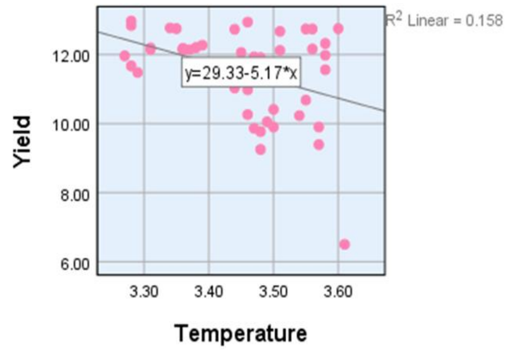

Fig. 6. Temperature vs yield

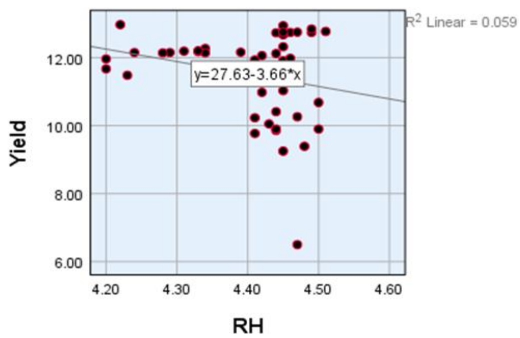

Fig. 7. Relative humidity vs yield

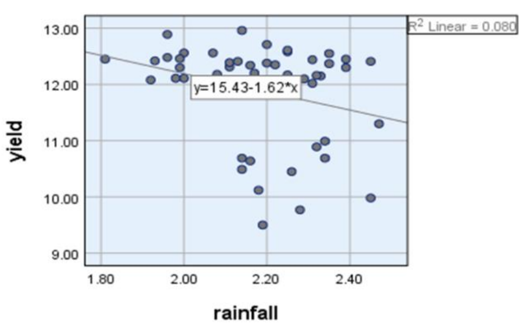

Fig. 8. Rainfall vs yield

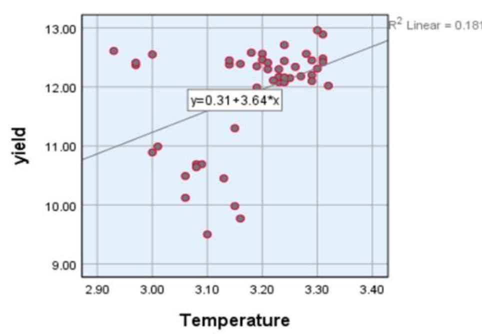

Fig. 9. Temperature vs yield

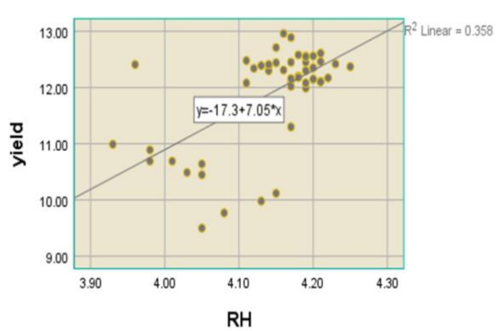

Fig. 10. Relative humidity vs yield

3.1.5 HYV (High Yielding Variety) boro rice

From Figs. (11-13), it is predicted that for HYV Boro, rainfall and temperature show a weak correlation between yield. However, relative humidity shows a positive linear.

3.2 Land Cover Change Detection

Land cover change detection is measured by ‘‘Vegetation Index Differencing (NDVI)”. The use of the Normalized Difference Vegetation Index (NDVI) is applied to detect areas of forest cover change and different year wise NDVI derived quantitative data are generated and summarized using remote sensing, GIS software and spreadsheet. The NDVI is the most common measurement used for measuring vegetation cover. It ranges from values -1 to +1. Red color indicates (-0.1 and below) correspond to barren areas of rock, sand, or urban/built-up. Dark red color represents Zero that indicates the water cover. Yellow represent low density of vegetation (0.1 to 0.3), while high values of green color indicate vegetation (0.4 to 0.8). Some NDVI maps using Landsat 8 Satellite Imageries (2013-2018) are given in Fig. 14 (a-d).

From Fig. 14 (a-d), highest NDVI value is found in 2013 (0.65) which denotes presence of moderate-high vegetation cover at that time period. After 2013, highest NDVI value is found following a decreasing trend which clearly represents the rapid vegetation cover change in the study area. During the period of 2015 march, NDVI value represents the highest value is 0.4234 that means most cultivation area is suitable for better yield/ cultivation.

From Fig. 15 (e-h) stated that, In the year 2016, most of the areas represent shrub and grassland while maximum temperate and tropical rainforests areas are found in 15 march 2017.

The devastating flash flood in 27 march 2017 caused an enormous impact on the vegetation coverage which is described above in NDVI maps. After the flash flood of 16th April 2017, NDVI map described that vegetation field is totally damaged for cultivation and all of the areas are full of rock, sand or snow. During March 2018, the NDVI results showed that maximum areas are full of low-density vegetation whereas November 2018 described high vegetation area for cultivation of crops.

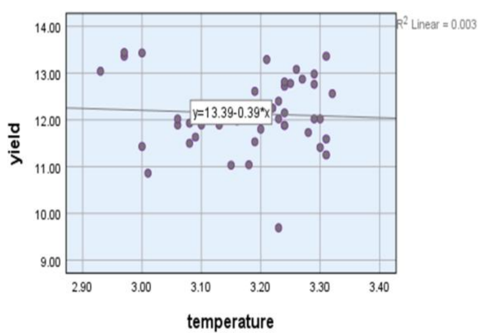

Fig. 11. Temperature vs yield

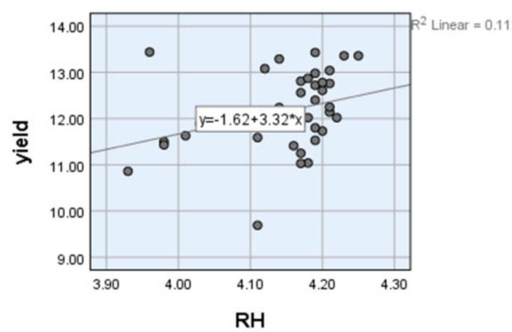

Fig. 12. Relative humidity vs yield

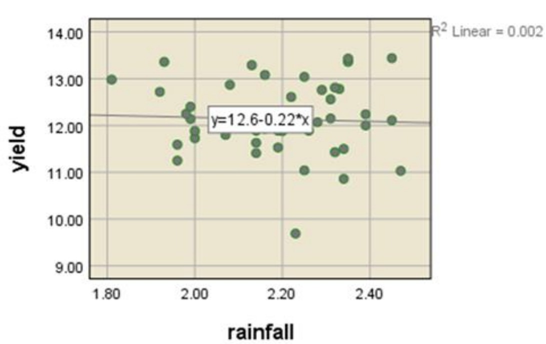

Fig. 13. Rainfall vs yield

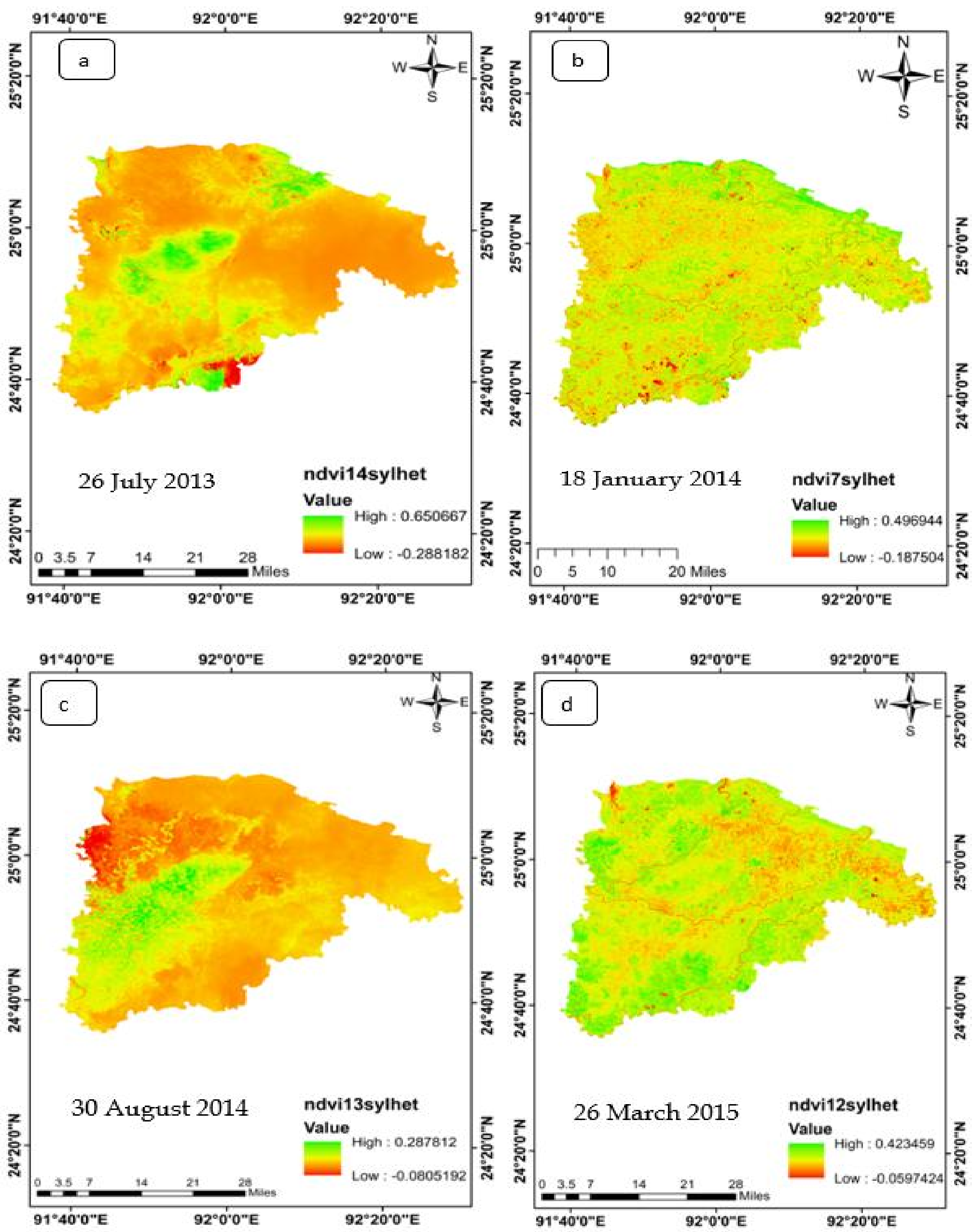

Fig. 14(a-d). NDVI derived classified map of study area for different years (2013-2015)

3.3 Proper Management Approach

Land use is obviously inhibited by environmental factors such as soil characteristics, climate change, topography, vegetation etc. In contrast, land cover change means the loss of natural areas.

- The divergence of crop agriculture is a crucial method in addressing climate change but requires research on suitable varieties for the new physical, social and climatic situations.
- High-temperature and excessive rainfall stresses can be avoided by changing the transplanting date or growth period.
- Developing competent and high-intensity cropping systems and compatible agro-techniques also understanding crop-weather relationships that serve as basis

for preparing crop weather production models [21].

- The introduction of water-saving technology in rice production is an efficient method to keep the underground water table in a safe zone. Instead of flood irrigation, alternate wetting and drying (AWD) methods of irrigation can be used.
- Established of seed banks to confirm that verities remain accessible in disaster periods.
- To avoid vegetation degradation the thrust of research should be in the following areas- i) inventory of soil resources at thana level, ii) preparation of thematic maps for land use planning, iii) soil degradation assessment, iv) developing a long-term climatic data base and v) database for surface and ground water resources.
- Documentation, motivation, training in order to concern about the impacts of natural calamities and adaptive technologies by the farmers. Finally, government should take some faithful steps.

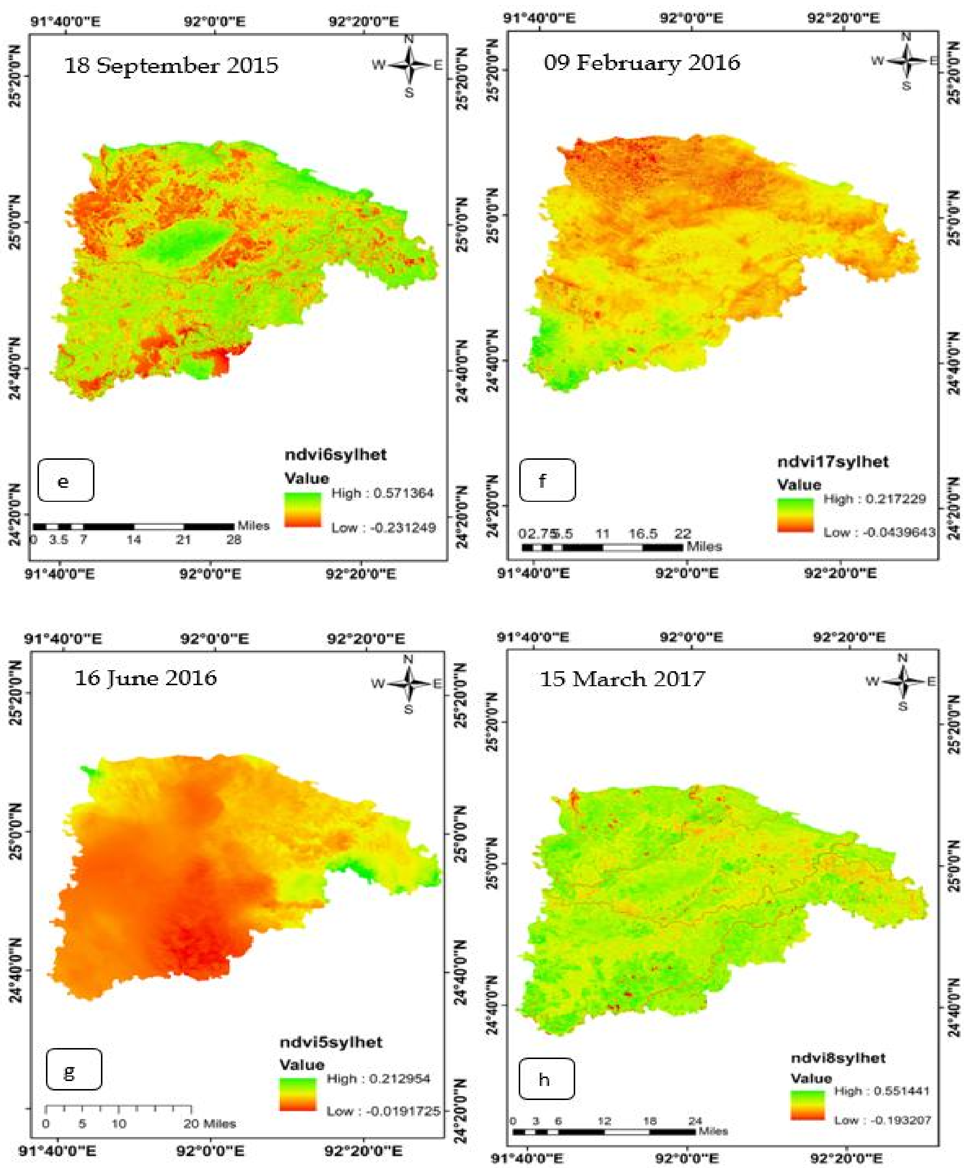

Fig. 15(e-h). NDVI derived classified map of Study area for different years (2015-2017)

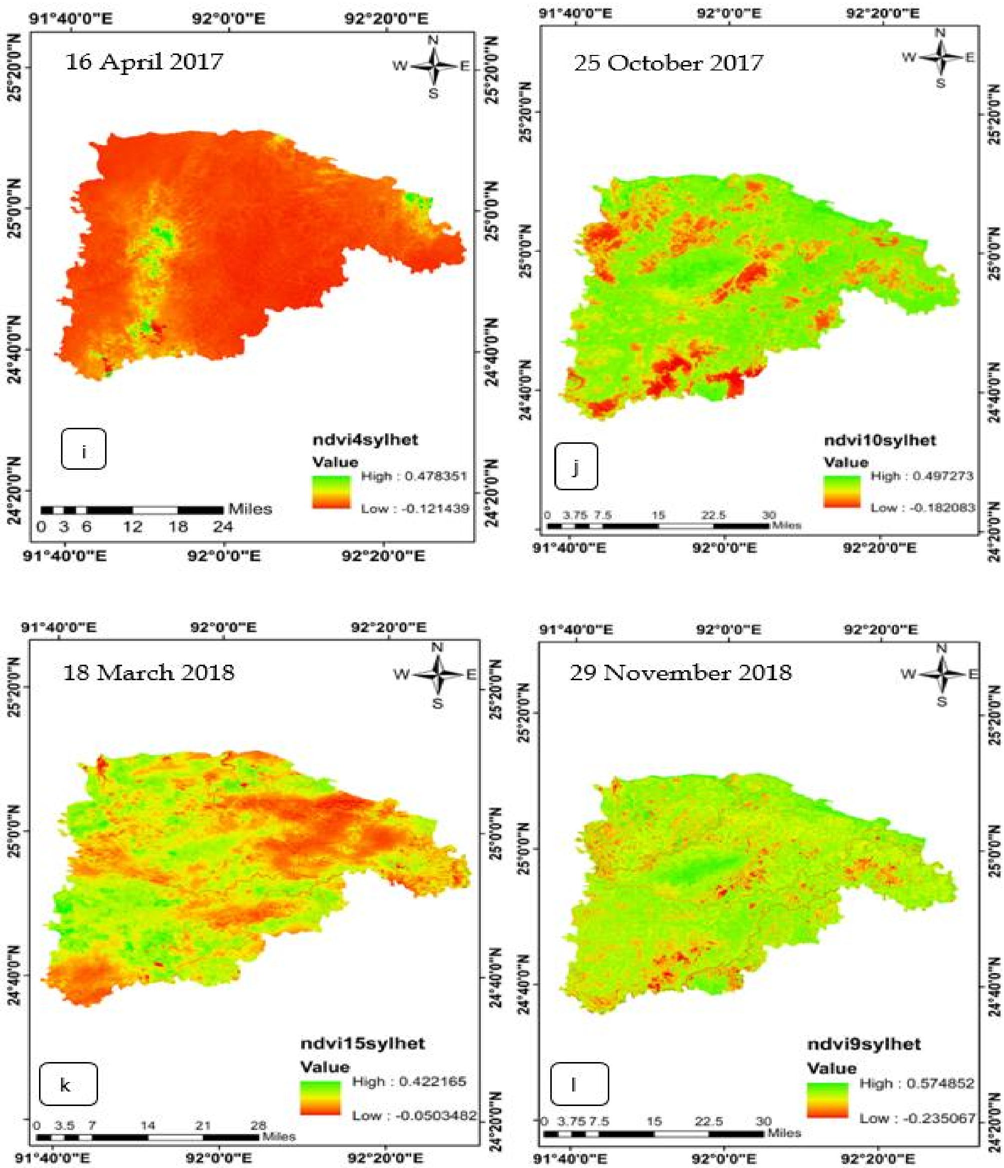

Fig. 16 (i-l). NDVI derived classified map of study area for different years (2017-2018)

4. CONCLUSION

The objective of this study is to estimate the relationship between rice yields and climate variables using time series data. The overall findings expose that three climate variables have significant effects on the rice yield. The correlation coefficients varied according to seasons. However, Rainfall, temperature and relative humidity are found to be negatively related to HYV Aman rice yield. Moreover, Maximum temperatures and relative humidity have positive effects on local Boro yield, whereas rainfall affect yields negatively. One fascinating finding is that rainfall is insignificant for all yields, this result supports the fact that these varieties do not grow well in excessive rain-fed conditions. On the other hand, there is a change of vegetation condition during the pre-monsoon, monsoon and post-monsoon period from 2013 to 2018. The number of agricultural lands and water bodies have been decreased. Due to the flash flood in march 2017, the maximum vegetation areas are damaged and pre-flash flood and post flash flood vegetation condition is also identified in this research. As such, the rice can be harvested preceding to the beginning of the flash flooding season that is usually common in the month of April. Another option is that analysis of climatic conditions, particularly temperature and rainfall regimes, to minimize the negative effects of climate change and improving better production. In the future, other climatic parameters like evaporation rate, cloud, wind velocity, vapor pressure, soil type, and soil moisture may be considered. For further land cover change detection study is needed to examine the historical data with new methods, tools, and data resources in the context of environmental change at the national and local scale.

ACKNOWLEDGEMENTS

It is pleased to acknowledge (Ministry of Science and technology) for granting fund the project entitled "Identifying climatic variables with rice yield relationship and land cover change detection at sylhet region" under which the research work was conducted.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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