REGIONAL DROUGHT MONITORING AND ANALYZING USING MODIS DATA - A CASE STUDY IN RANGPUR

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ABSTRACT

Due to the high temperatures and minimal rainfall, droughts occur more frequently in Bangladesh, and they are a common phenomenon in the northwestern region. In Bangladesh, droughts mainly occur during the dry season. In this study, the spatial and temporal pattern of agricultural drought in Rangpur, a northwestern division of Bangladesh, has been identified using a Moderate Resolution Imaging Spectroradiometer (MODIS) sensor, and Terra-MODIS/NDVI (Normalised Difference Vegetation Index) data for the pre-Kharif season of 2023. Two major indicators for detecting the agricultural drought, LST (Land Surface Temperature) and NDVI, were assessed with two different MODIS sensors using GIS. The evapotranspiration measurements for the specified time period are used to look at the impact of climate variability, which influences both the severity and type of drought. Finally, the NDVI and LST simulations from the model are compared with the ET (evapotranspiration). According to the study, Panchagarh has a higher NDVI and a lower LST, which denotes comparatively more vegetative land. On the other hand, Kurigram, Dinajpur, and Gaibandha districts of Rangpur have lower NDVI and higher LST, which denote barren ground and less lush flora. Contrary to places with a higher NDVI and a lower LST, these regions are more affected by drought. This study will help the authorities make further decisions about water resource management, irrigation plans, and crop patterns in the future.

Keywords: *Drought, MODIS, Land Surface Temperature, NDVI index, Evapotranspiration*

1 INTRODUCTION

Drought is one of the most complex types of chronic natural hazards. It is defined as an extended period of low precipitation that affects the ecosystem, agriculture, and human activity significantly and results in a scarcity of water. The disparity in the water budget is the factor that causes the unusual water shortage. That's why drought is frequently regarded as a natural disaster when it begins to endanger human lives and the standard of living (Angearu et al., 2020). The likelihood and severity of the warming climate pattern are going to increase, which may cause droughts to be more common and severe, resulting in a great threat to food security (Giorgi et al., 2019). For this reason, learning about the scales of drought and the drought-prone areas has become an important issue to secure the food sector in the near future.

With the development of remote sensing and different missions of NASA for acquiring geospatial data for the globe, it has become easier for scientists to detect drought-prone areas and the scale of drought in that area. The different indices easily calculable from the remote sensing data made the path smoother. For example, NASA's Mission on MODIS significantly enhances our comprehension of global dynamics and the numerous processes taking place on land, in the oceans, and within the lower atmosphere. Furthermore, MODIS plays a pivotal role in advancing the development of validated, worldwide, interactive Earth system models capable of accurately forecasting global changes. These models, in turn, provide valuable support to policymakers in making informed decisions intended to safeguard our environment. It has provided the Land Surface Temperature (LST), Normalised Difference Vegetation Index (NDVI), and Evapotranspiration (ET), which are great indicators of the condition of drought. Previous studies (Ashraf et al., 2022; Orimoloye et al., 2021) used different types of MODIS products to analyse and detect the drought in their studies.

Bangladesh's temperature rises over the past few decades correspond with the global trend of rising temperatures brought on by climate change. Over the past few decades, Bangladesh has seen an average rise in temperature of 0.5 to 0.6 degrees Celsius per decade. In addition, the climate models predicted that precipitation in South Asia would rise during the monsoon and decrease during the dry season (Janes et al., 2019). During 1979–1981, a prolonged and severe drought hit Bangladesh. It had a devastating impact on agriculture and caused food shortages. In 1999, Bangladesh experienced a severe drought that affected crop production and water resources. The drought led to drinking water shortages and agricultural losses. Bangladesh, on the one hand, is a major vulnerability to climate change events, and on the other hand, as an agriculture-based country, it is required to analyse and forecast drought conditions in the near future in order to maintain its food chain and safeguard food security. In Bangladesh, the north-western region is more open to drought. But very few studies have worked on that perspective. So, this study aims to focus on the drought situation in Rangpur, a north-western division of Bangladesh, due to its significant consequences. The study utilised the data from the Moderate Resolution Imaging Spectroradiometer (MODIS) Sensor during the pre-Kharif season of 2023 as a fundamental component of this research. The main objectives of these studies are: (i) to calculate the LST and the NDVI for the Rangpur Division; (ii) to detect the drought-prone region from the LST and the NDVI value for the Rangpur Division; and (iii) to compare the evapotranspiration of the drought-prone areas.

1.1 Study area

The region for study is the Rangpur division, situated in Bangladesh's northwest (Figure 1). Rangpur division covers an area of roughly 16320.26 sq km, primarily consisting of an alluvial plain that spans 25°20' to 26°37'N latitudes and 88°50 ' to 89°53 ' E longitudes. The region is well-known for its agricultural output, which includes oilseeds, rice, jute and cigarettes, etc. Its borders are to the north and west by West Bengal, to the east by Meghalaya, and to the south by South of the division is Rajshahi. The principal rivers in this area are the Atrai, Brahmaputra, Dharla, Mahananda, Tangon, and Teesta. Area (Mamun et al., 2022).

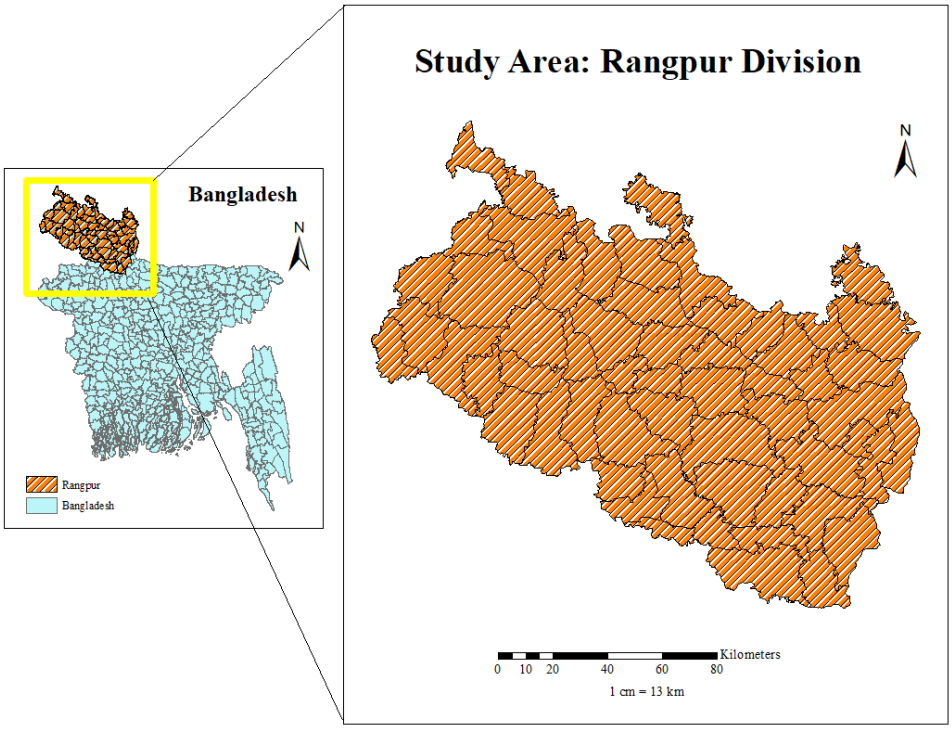

Figure 1. Study area

2 MATERIALS AND METHODS

2.1 Data Collection

To assess the drought condition, three indices were analysed. These are: i) Land Surface Temperature (LST); ii) Normalized Difference Vegetation Index (NDVI); iii) Evapotranspiration (ET). MODIS functions as a critical instrument on both the Terra (EOS AM) and Aqua (EOS PM) satellites (Cai et al., 2011). The data was obtained through MODIS for the different issues; MODIS uses different products, and all of the products have different spatial resolutions. For our study, we retrieved three MODIS product for calculating NDVI, LST, Evapotranspiration, respectively. A brief description of datasets is given in Table 1.

Table 1. Data used for this study.

Data Type	MODIS Product Name	Source	Spatial Resolution
NDVI	MOD13Q	NASA Earthdata website	250 m
LST	MOD11A2	NASA Earthdata website	1000 m
Evapotranspiration (ET)	MOD16A2	NASA Earthdata website	500 m
Study Area shapefile	NA	DIVA-GIS website	NA

MOD13Q data were downloaded for the purpose of calculating the Normalized Difference Vegetation Index (NDVI). The version was 06, and the date of the MODIS data is April 23, 2023. MOD11A2 data were downloaded to calculate the Land Surface Temperature (LST). The version was 06, and around the same date as the MODIS data used**.** The shapefile for the study area, Rangpur district, was extracted from ArcGIS using the Bangladesh (BD_ADM) shapefile. MOD16A2 data were downloaded to calculate Evapotranspiration (ET). The data were downloaded from January 1, 2022 to August 1, 2023.

2.2 Data Processing

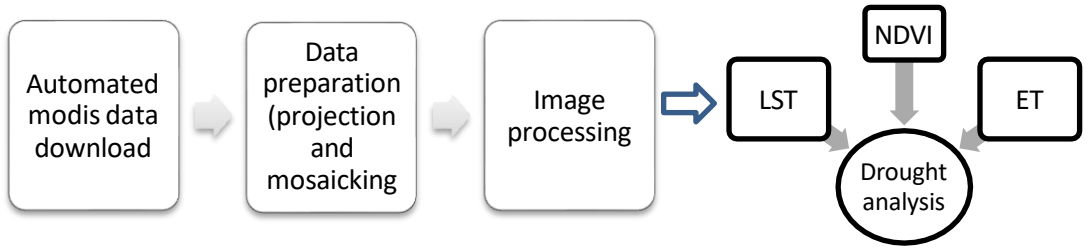

Figure 2. Conceptual framework of the study

The initial phase of data processing involves the acquisition of MODIS satellite images that cover Rangpur district, focusing on two specific blocks. Once the satellite images are obtained, the next step is to prepare the data for further analysis. In this stage, the two individual raster images are merged into a single, seamless composite. This merging process is carried out using the "Mosaic to New Raster" tool within ArcGIS. To focus specifically on Rangpur division, a region of interest, the data extraction process is initiated. The "Masking" tool in ArcGIS is employed to extract data from the Rangpur division from the Raster data obtained from the previous step, guided by a shapefile that delineates the division's boundaries. This shapefile was initially created by clipping the Rangpur division from the broader Bangladesh country shapefile using the ArcGIS clipping tool. Then, the calculations of LST, NDVI, and ET were performed accordingly.

2.2.1 Calculation of LST

Using a raster calculator, the LST values were initially adjusted by multiplying them with a scale factor of 0.02. This scaling operation was essential to ensuring that the LST values were within a suitable range for interpretation. Subsequently, the LST values were converted from Kelvin to Celsius. This conversion was carried out using ArcGIS's Raster calculator tool, where 273.15 was subtracted from the scaled LST values. The resulting LST data was presented in the Celsius scale format, making it more accessible for temperature analysis and interpretation.

2.2.2 Calculation of NDVI

By using a scale factor, the NDVI values that were extracted from the data were further refined. Specifically, a raster calculator was used to multiply each NDVI value by the scale factor of 0.0001. The NDVI measurements are adjusted using this scaling method to make sure they fall within the proper range for analysis and interpretation. The NDVI data is corrected using a scale factor of 0.0001 to yield more insightful information about the health and condition of the vegetation in the Rangpur division.

2.2.3 Calculation of ET

Following the assessment of NDVI and LST, the calculation of ET for projected drought-prone areas was needed to compare the actual condition and reason behind the drought. The analysis of ET is crucial in understanding the water balance and ecosystem dynamics within these districts, allowing for a comprehensive evaluation of the impact of drought conditions on regional water resources and vegetation health. The ET values obtained through MODIS data, offer valuable insights into the water loss from the land surface due to evaporation and plant transpiration. As a subsequent step, Evapotranspiration (ET) values for these districts were derived from MODIS data. The data found from the MODIS were multiplied by 0.1 as the scale factor to change the MODIS data into actual.

3 RESULT AND DISCUSSION

3.1 Result

3.1.1 Calculation of LST and NDVI

Upon processing the MODIS data and applying the appropriate scaling, notable LST trends and patterns across Rangpur Division were observed. LST data are used to describe the effect of temperature on vegetation health because high temperatures and low humidity can cause plant stress (Mohammad et al., 2018). The maximum Land Surface Temperature found for the Rangpur Division was about 40.47 °C, where the lowest value was 19.95 °C (Figure 4). The maximum temperature of the Rangpur division has an overage of 30 °C to 35 °C during the study period. In terms of NDVI, Rangpur Division shows an almost uniform distribution of NDVI during the study period, except in some parts of the region. The maximum NDVI was found to be 0.9891, where the minimum was -0.2 (Figure 5).

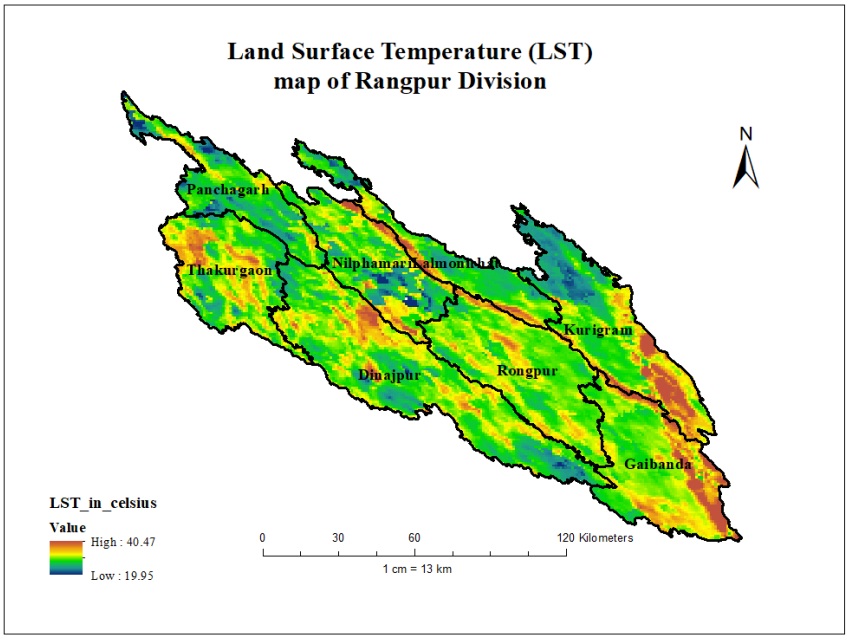

Figure 3. LST map of Rangpur division in April 2023

3.1.2 Detection the Drought-Prone Region

The analysis of LST, in conjunction with Normalized Difference Vegetation Index (NDVI) data, highlighted areas of particular concern. Panchagarh, Kurigram, and Gaibandha districts emerged as regions with more pronounced drought conditions. Elevated LST values in these districts indicated increased aridity and reduced moisture availability. The analysis of NDVI in Rangpur Division unveiled valuable insights into the region's vegetation health and density. Notably, NDVI values were found to be lower in Gaibandha, Kurigram, and Dinajpur, indicating reduced vegetation cover, possibly due to drought conditions. In contrast, Panchagarh exhibited high NDVI values, signifying healthier vegetation. A significant correlation between NDVI and LST was observed. Areas with lower NDVI values correlated with higher LST, reflecting the reduced vegetation cover and potentially more severe drought conditions in the regions of Gaibandha, Kurigram, and Dinajpur (Das et al., 2023).

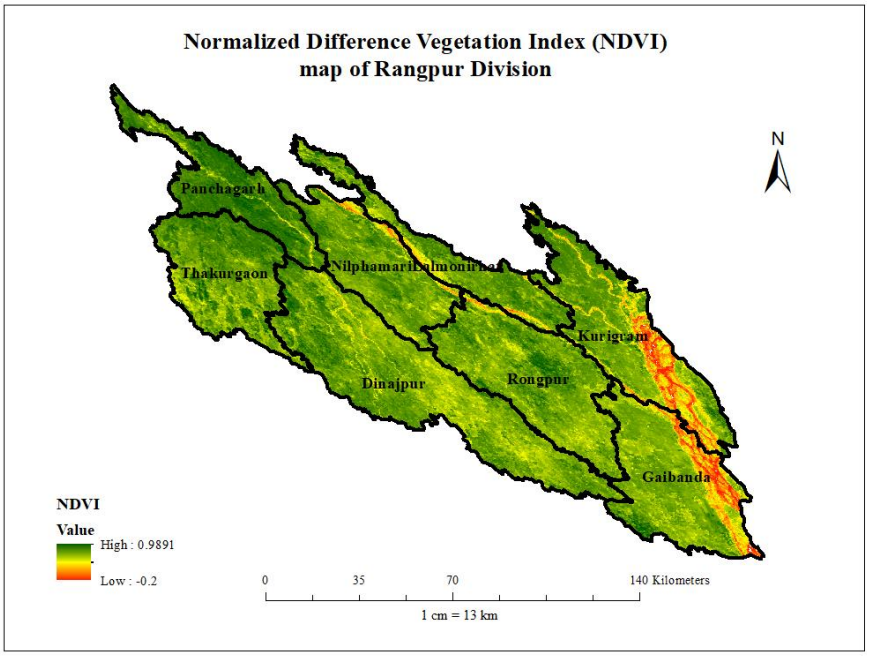

Figure 4. NDVI map of Rangpur division in April 2023

3.1.3 Comparison of Evapotranspiration of the Drought-Prone Areas

To gain a deeper understanding of the impact of drought conditions on water resources and vegetation, Evapotranspiration (ET) values were derived from MODIS data for these districts. The ET analysis provides crucial data on water loss due to evaporation and plant transpiration, aiding in the assessment of environmental challenges. From Figure 5, it is evident that during the study period (April- 2023), the maximum ET was seen for the Kurigram (almost 35 kg/m^2/day). However, the Gaibandha showed the minimum ET of at three locations.

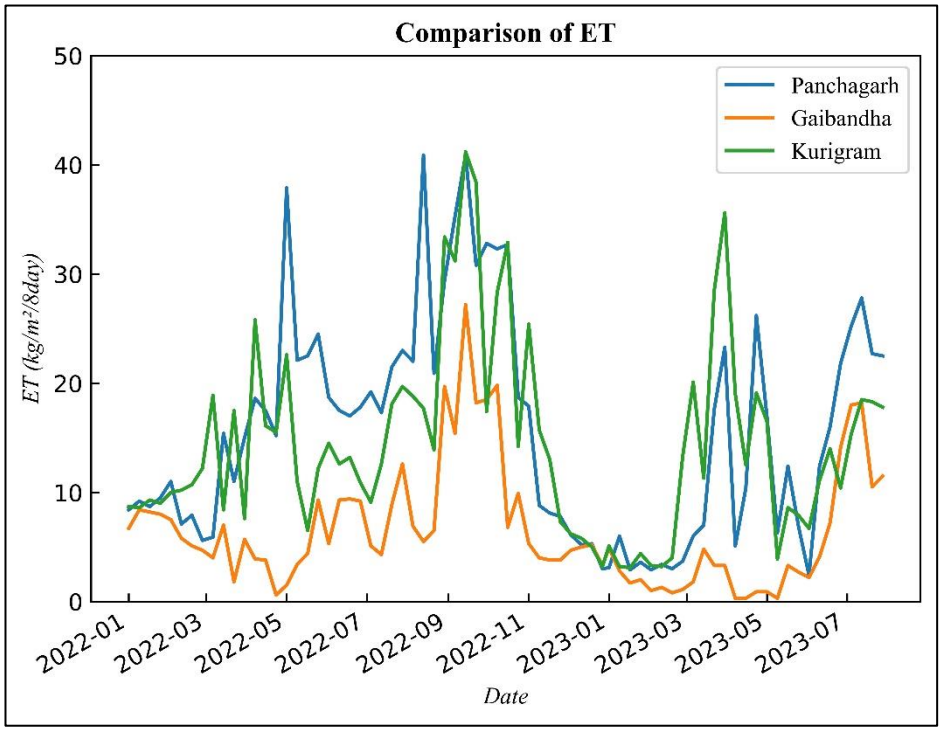

Figure 5. Graph Of comparing ET of the districts Panchagarh, Gaibandha, Kurigram

3.2 Discussion

LST in the area is increasing due to unplanned urbanization, like in other parts of the country, but the trend is alarming in this area (Sultana et al., 2021). Elevated temperatures have been found to enhance the depletion of soil moisture, impair photosynthesis in plants, decrease plant recruitment and seedling establishment, and increase plant mortality (Siddik et al., 2022)(Hossain & Li, 2020)(Hossain & Li, 2021). This is supported by the NDVI value, which can be linked to increasing drought intensity and frequency in the study area (Sultana et al., 2021). According to a recent study conducted in Bangladesh's northwest, the country's current water courses—such as rivers and canals—are becoming more affected by drought, which has further reduced ecosystem functioning. It was observed that the river bar area identified as most drought prone that is actually due to the drying out of the existing river channels. A river sand bar shows a higher temperature with low moisture content because it reflects heat to the atmosphere from enriched sands deposited by the rivers (Sultana et al., 2021). There could be multiple reasons for the negative correlation found in our study between vegetation NDVI and LST. However, this study follows the 30-year analysis of NDVI value that has a negative trend, which means the vegetation of the study area is being stressed due to the increasing trend of drought events as asserted by previous investigations (Isbell et al., 2015).

4 CONCLUSIONS

The present study is an attempt to use drought indices for monitoring drought scenarios in the Rangpur division of Bangladesh. Many studies around the globe have used spatial analytical methods for drought monitoring. However, the present study has a uniqueness as it has applied an approach to image analysis using MODIS satellite data. From the result, it is evident that the land surface temperature covers a steep distribution from only 19 degrees Celsius to 40 degrees Celsius for the study area during the study period, where the distribution of maximum and minimum NDVI varies in a larger range. However, according to the values of LST and NDVI, three locations were found to be more prone to drought. The time series of Evapotranspiration draws almost the same conclusions. Based on the results of this paper, the locations identified as drought-prone can be taken into account for future steps to overcome the drought impacts by making a proper plan.

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