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Application of Remote Sensing to Investigate the Impact of Musapur Reservoir on the Morphology of Little Feni River and Local Agricultural Production

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Abstract

This study investigates the impact of Musapur reservoir construction on the morphology of the Little Feni River and local agricultural development. Remote sensing and GIS techniques were used to analyze satellite imagery and satellite-based indices related to vegetation growth like MODIS NDVI, LAI, EVI and NPP. Before the reservoir's construction, the river experienced significant bankline shifting and dynamic morphological activity, leading to loss of land. After reservoir construction, the river exhibited stability with minor erosion/accretion. Analysis of time series datasets of vegetation indices showed a significant increasing trend for LAI and a slight increase for other indices, indicating a positive impact on local agriculture.

Keywords: *Vegetation index; Erosion-accretion; Remote sensing; Trend analysis; River morphology.*

1 Introduction

Globally, a significant part of freshwater is utilized for agriculture along rivers (Yousaf et al., 2021). This remarkably stands up for Bangladesh, a part of the Ganges-Brahmaputra-Meghna delta, which historically played a pivotal role in shaping the country's topography, socio-economic and cultural profile. Governed by the seasonal and inter-annual variability in river flows as well as sediment discharges, the morphology of the rivers in Bangladesh is highly dynamic. Due to the dynamic nature of river morphology, people who live along riverbanks suffer from erosion and sedimentation, which leads them to alter their way of life and level of food security (Chowdhury et al., 2022). Along with natural phenomena, human intervention like the construction of dams, regulators, reservoirs etc. can dramatically alter the morphology of rivers, which can have both positive and negative impacts on the livelihood and socio-economy of the people residing along the rivers (Brandt et al., 2000; Schmutz and Moog, 2018; Gazi et al., 2020). The Little Feni River, located in south-eastern Bangladesh, flowing through the region surrounding the Musapur Reservoir, furnishes water for local transportation, aquaculture and irrigation, making it an essential lifeline for the socio-economic development of the area (Moshfika and Rahman, 2018). Due to the construction of the Musapur reservoir downstream of the Little Feni River, a significant change in the river morphology and local agricultural activities has taken place. While numerous past studies have analyzed the morpho dynamics of major perennial rivers (Ganges, Brahmaputra and Meghna) in Bangladesh, limited research was conducted to quantify the morphological changes of intermittent rivers like the Little Feni River due to anthropogenic influence. This research investigates the effect of constructing the Musapur reservoir on the morphology of the Little Feni River, particularly in its lower 25 km reach, and assesses the impact of the reservoir construction on local agricultural production. Understanding of the environmental and socioeconomic impacts of reservoir construction can be enhanced by comparing these changes over the last two decades which could assist in evidence-based decision-making.

2 Study Area

The study area (Figure 1) extends 25 km around the lower part of the Little Feni River, encompassing parts of Comilla and Feni districts, from Musapur Closure Dam to Sonagazi Upazila. The topography is generally flat and surrounding land use is dominated by agricultural land and rural landscape.

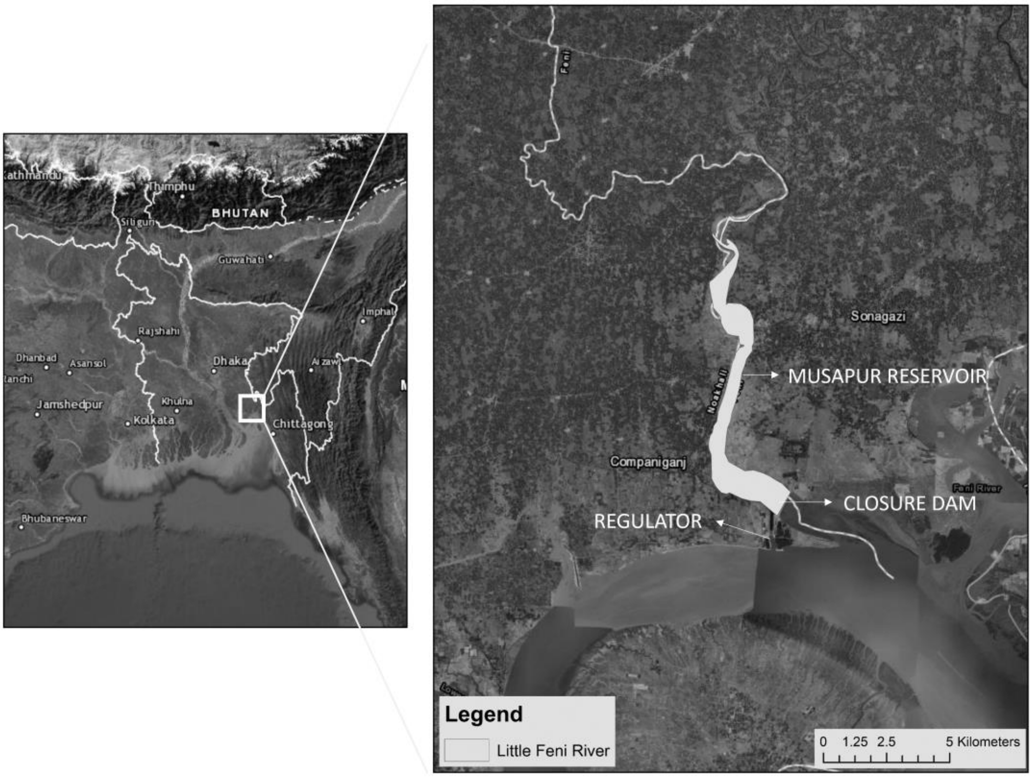

Figure 1: Map of the Study Area

3 Methodology

The present research was conducted by applying remote sensing technique and analyzing satellite-based data. Remote sensing is widely used to track riverine hydro morpho-biodynamics due to the growing accessibility of free imagery from satellites and Geographic Information Systems (GIS) (Nones and Guerrero, 2020). It is less expensive as compared to a traditional survey that can complete a task with a desired level of accuracy and is preferred by project managers (Lewis et al., 2013). This study utilized Landsat 5 TM and Landsat 8 OLI-TIRS images of 30-meter resolution from different years during 1990-2023. The USGS websites were accessed to obtain the satellite data sets. The visibility of the scene, the amount of cloud cover (less than 5% was preferable), the dry season, the satellite image quality and availability of the MSS, TM, and OLI-TIRS sensors were the key factors for selecting the satellite images. The bank lines of the Little Feni River for the years 1990, 2000, 2010, 2015, 2017 and 2023 were extracted using NDWI and unsupervised classification techniques (following Kabir et al., 2020) and the amount of eroded and accreted areas for each consecutive interval, as well as before and after dam construction, were calculated by the overlay method (Emran et al., 2019).

Satellite images are widely used to monitor and simulate changes in vegetation cover dynamics (Xin et al., 2008; Liu et al., 2016). There are many different remotely sensed vegetation datasets, including the normalized difference vegetation index (NDVI), leaf area index (LAI), Enhanced Vegetation Index (EVI) and net primary productivity (NPP) (Levin, 2016) which are used to detect changes in vegetation growth. For this study, the MODIS Terra NPP dataset was retrieved from Google Earth Engine. The MODIS MOD13A1 Collection6 datasets offer timeseries of NDVI and EVI data and the MODIS MOD15A2H dataset provides timeseries of LAI measurement, which were collected through Google Earth Engine. Those datasets were collected for a of 5-kilometer buffer area extending from the Musapur closure dam to the Kazirhat old regulator on the Little Feni River. Trend analysis was performed by testing the slope of the linear best-fit regression line (Yang et al., 2022; Cui & Li, 2022) fitted to the NDVI, EVI, LAI and NPP datasets. Several statistical tests like the t-test, Mann-Kendall test and bootstrap-based slope tests are widely acknowledged for testing the significance of a trend. While for normally distributed data, the power of the t-test can be similar to or better than rank based test like the Mann-Kendall test, for non-normal data, the accuracy of a t-test becomes much lower than the Mann-Kendall test (Yue et al., 2004). By analyzing the skewness, non-linearity was observed for all the datasets except for NDVI. Thus, we performed the Mann-Kendall test (Mann, 1945; Yang et al., 2022; Cui & Li, 2022) at 5% significance level for testing the significance of linear trends.

4. Analysis, Result and Discussion

4.1 Morphological analysis

The banklines of the Little Feni River for the years 1990, 2000,2010, 2015, 2017, 2019, 2021 and 2023 have been extracted and presented in Figure 2. The amount of eroded and accreted area for the duration of 1990-2000, 2000-2010 and 2010-2015 was calculated representing the pre-construction period, while the computed eroded and accreted area for time span 2017-2023 (Figure 3) represents the post-construction period. It was observed that the lower 25 km reach of the Little Feni River, before the construction of the reservoir, experienced high bankline shifting and was morphologically dynamic, leading to significant land loss. However, after the construction of the reservoir, the lower river reach remained highly stable, resulting in minor erosion/accretion. A substantial amount of erosion and accretion occurred, especially during the last five years of the pre-construction period (2010-2015) when the river was erosion dominant and around 2.3 square kilometer area eroded, posing risks to human settlements, infrastructure, and agricultural activities located near the river. However, during the post-construction period, the bankline remained stable, and no noticeable shifting was observed, and 0.3 square kilometer area went under erosion-accretion. Overall, the river exhibited morphological stability after the construction of the Musapur reservoir which reflects a positive sign.

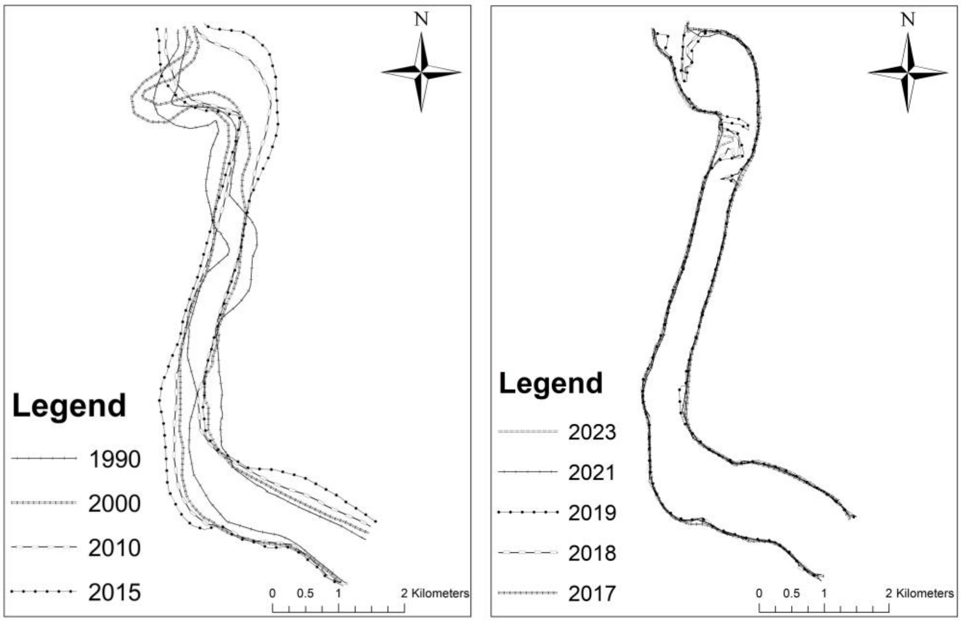

Figure 2: Bankline shifting before (1990-2015) and after (2017-2023) reservoir construction

Figure 3: Amount of erosion/accretion before and after reservoir construction.

4.2 Agricultural Impact Analysis

To analyze the impact of reservoir construction on local agriculture, the MODIS NDVI, LAI, EVI time series data, and annual average MODIS NPP data for the study area were filtered for the period of 2000-2022 and 2000-2020 consecutively using Google Earth Engine. Liner trend analysis was performed for all the dataset. The trend analysis showed that the dataset for MODIS LAI exhibited an increasing trend over the years especially after 2017 which is the post reservoir construction period. LAI is a measure of the leaf area index, which is the amount of leaf area per unit ground area (Li et al., 2019). It is an important factor in determining the amount of carbon that can be captured by photosynthesis (Gao et al., 2016; Yu et al., 2018). The trend of LAI dataset was found statistically significant at the 5% significance level (Figure 4). This means that the observed increase in LAI is unlikely to have occurred due to random fluctuations. NDVI is a vegetation index that can be used to indicate changes in vegetation cover (Song et al., 2010; Bai et al., 2019). By minimizing the impact of soil background and atmospheric factors, the Enhanced Vegetation Index (EVI) is optimized for detecting areas with limited vegetation coverage, as explained by Zhang et al., 2017. Both the NDVI data and EVI data showed a slight increasing trend over the years which implies the vegetation growth increment in the study area but the trend is not statistically significant (Figure 4). NPP is the net primary productivity, which is the rate at which plants produce organic matter through photosynthesis. It is a measure of the overall health of an ecosystem. (Gao et al., 2016; Yu et al., 2018). The annual Average value of NPP also showed slight increasing trend (though statistically insignificant as shown in Figure 4) which indicates positive ecological and environmental impact of the region and increasing land productivity.

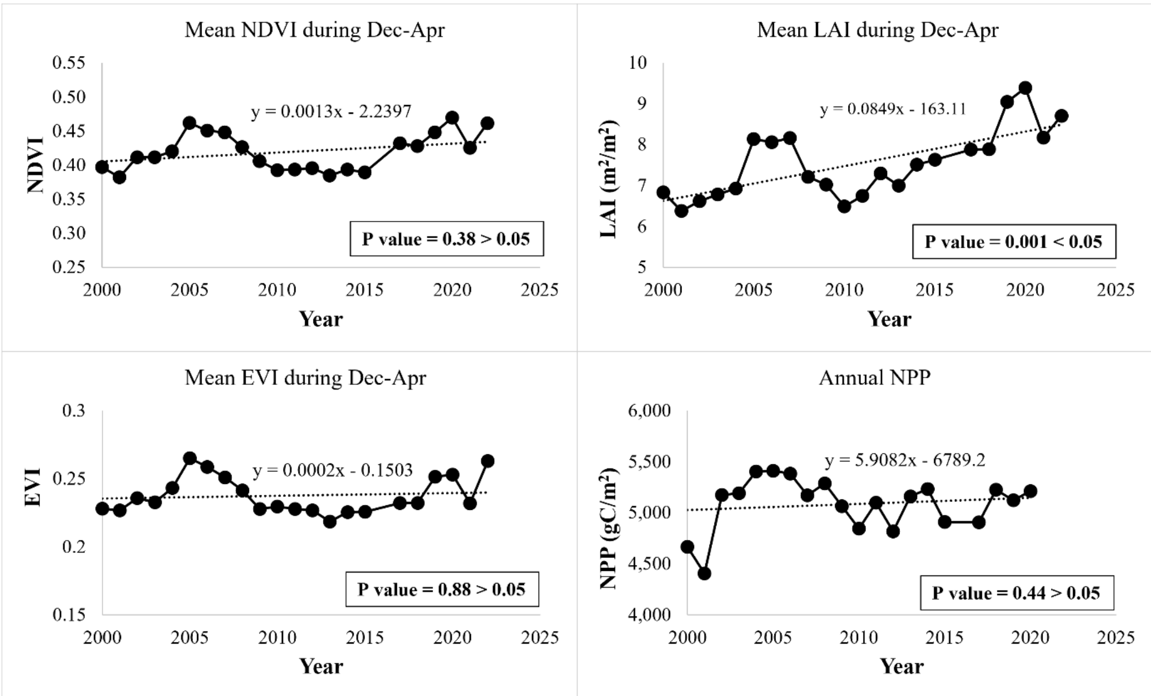

Figure 4: Trend analysis of NDVI, LAI, EVI and NPP in the Study Area during 2000-2022

Even though the increasing trend for NPP data was found statistically insignificant, frequency analysis of the NPP data showed a significant increase in higher value region (ranging from 6001 gC/m2/day to 9000 gC/m2/day) during post-construction period as compared to the pre-construction period (Figure 5). This is evidence for enhanced agricultural activities in the region after the reservoir construction. This finding complies with the study of Khan et al., (2022) which revealed a significant positive growth in production of certain crops on the region like mustard, ground nuts, and garlic after construction of the Musapur reservoir. The study also showed positive growth trends for paddy, red gram, peas, wintry chilies, wintry vegetables, and gherkins in the region which is indicative of positive impact of the reservoir in local agriculture. So, despite the increasing trends of NDVI, EVI and NPP dataset being insignificant, a clear positive impact on of the Musapur reservoir on the local agriculture is evident. It is possible that the NDVI, EVI and NPP dataset is not sufficient enough after the construction of the reservoir to detect a definitive trend and probably with monitored dataset for more longer period, a trend in those indices could be detected.

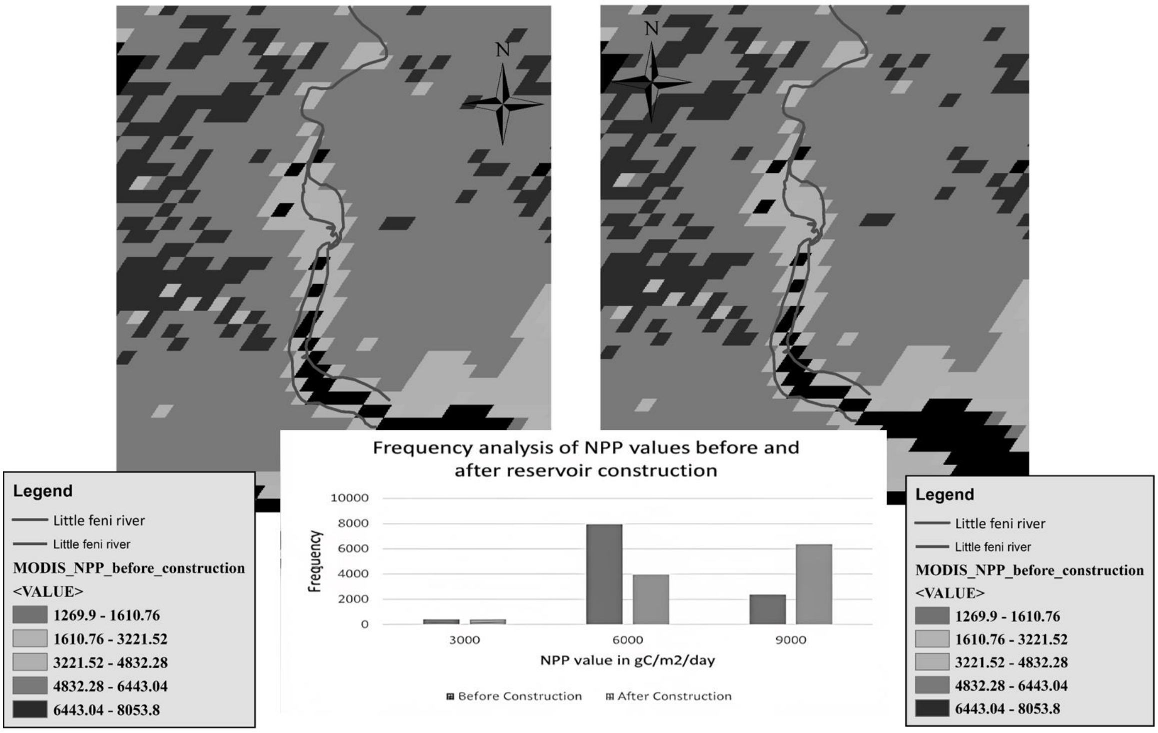

Figure 5: Total average NPP before (2001-2015) and after (2017-2020) reservoir construction

5. Conclusion

The construction of the Musapur reservoir aimed to reduce saline water intrusion, facilitating the conservation and storage of fresh water in the Little Feni River during the dry season. This stored water can be utilized for various purposes, including irrigation, drinking water supply, and supporting local agricultural activities (Moshfika and Rahman, 2018). This study identifies that during the pre-construction period, the lower reach of the river experienced high bankline shifting governed by significant erosion/accretion. In contrast, during the post-construction period a notable reduction in erosion/accretion tendency of the river has been observed. Despite altering the natural balance of the ecosystem and disrupting water-land relationships, the reservoir's construction has led to decreased erosion on agricultural land, which is crucial for densely populated countries like Bangladesh. However, these analyses do not encompass the entire morphological behavior, necessitating further research to understand sediment behavior and riverbed morphology (Semwal et al, 2019). A positive impact of the Musapur reservoir construction on local agriculture is evident. Trends in NDVI, LAI, EVI, and NPP indices suggest enhanced vegetation growth and increased land productivity after reservoir construction. Although statistical significance varies, collectively, the increasing trends in LAI, NDVI, EVI, and NPP indicate improved agricultural conditions. This aligns with Khan et al.'s (2022) findings, which observed increased crop production and positive growth trends in the region after the construction of the reservoir. While the dataset's duration is limited post the reservoir construction, these results imply a beneficial influence on local agriculture production, likely supporting regional food security and economic development. However, continued monitoring and assessment are essential to evaluate the reservoir's long-term sustainability and effectiveness.

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