



# Predicting Vegetation Trends in Sylhet Division: An LSTM-Based Analysis of NDVI Dynamics

Shovon Das\*, Niloy Biswas, Afifa Islam Niha, Sandip Paul

Urban and Rural Planning Discipline, Khulna University, Khulna-9208, Bangladesh

\*shovonkuurp@gmail.com,

**Abstract.** Understanding how vegetation changes over time and across different areas is important for assessing ecological health and planning land use, especially in places experiencing rapid environmental shifts. This study looks at vegetation patterns in the Sylhet Division of Bangladesh using NDVI data from 2000 to 2024. It combines remote sensing with Long Short-Term Memory (LSTM) neural networks to predict vegetation trends from 2025 to 2030. The Mann-Kendall test is used to analyze historical changes from 2013 to 2024, focusing on the summer season (March–April). The LSTM model captures complex vegetation changes well, with an  $R^2$  value of 0.84, RMSE of 0.05, and MAE of 0.03. The combination of remote sensing and machine learning helps track and forecast vegetation patterns. These findings can help policymakers in Sylhet take steps to restore degraded areas and support conservation efforts where needed. This approach can play a key role in sustainable land management and planning for future environmental challenges.

**Keywords:** Vegetation trend, NDVI, LSTM, Time-series analysis, Ecology.

## 1 Introduction

Vegetation substantially impacts terrestrial ecosystems by affecting biodiversity, controlling energy fluxes, and supporting vital ecological processes [2]. Understanding vegetation patterns across time is critical for decision-making to reduce losses from environmental hazards, assessing ecological health, and developing sustainable land-use policies, especially in areas undergoing rapid climatic and urban transitions [3,6]. The Sylhet Division of Bangladesh, rich in biodiversity, is a climate-vulnerable region undergoing severe ecological deterioration. The Normalized Difference Vegetation Index (NDVI), generated from satellite remote sensing, has emerged as an effective tool for measuring vegetation health and tracking spatiotemporal changes. It helps to provide essential information on vegetation cover impacted by climate change, seasonal patterns, and human activities [1,2]. For accurate forecasting of complex ecological systems and the changing nature of vegetation across the world, the implementation of advanced computational techniques is emerging [2,5]. Long Short-Term Memory (LSTM) is prominent for effectively resolving the multiplex scenario having a breakthrough in machine learning. Researches depict that, it can meticulously predict NDVI

© The Author(s) 2025

M. R. Selim et al. (eds.), *Proceedings of the 8th International Conference on Engineering Research, Innovation, and Education 2025 (ICERIE 2025)*, Advances in Engineering Research 278,

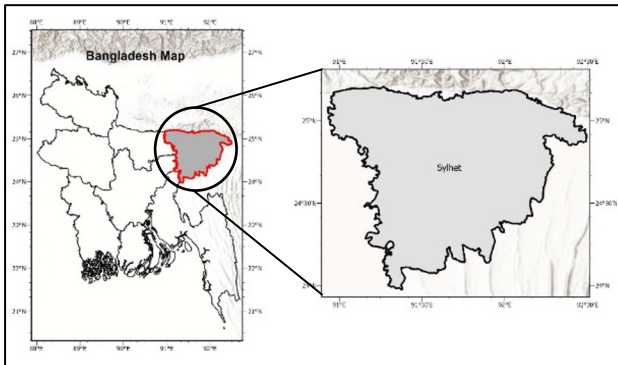
[https://doi.org/10.2991/978-94-6463-884-4\\_11](https://doi.org/10.2991/978-94-6463-884-4_11)

changes even in areas having unusual environmental transformation. However, the auto-regressive integrated moving average (ARIMA) assumptions fail to provide authentic outcomes regarding the slightest change caused by multiple disturbances. Besides, Wang et al. suggested that NDVI time series forecasting can be accurately done through LSTM due to its higher capacity for gathering internal information over a long period [4]. By combining historical NDVI data with machine learning techniques, future changes in vegetation can be predicted accurately through intensive research. To identify the changing vegetation patterns in the Sylhet Division, this study examines Normalized Difference Vegetation Index (NDVI) data from 2013 to 2024, applying LSTM-based machine learning techniques. It intrinsically focuses on analyzing the vegetation cover change over the last decade in Sylhet, distinguishing areas experiencing rapid change. Additionally, the future NDVI trends over the next five years for determining areas at the highest risk for ecological degradation and potential for restoration. Adopting strategies to restore Sylhet’s bio-diversity by combining environmental planning with progressive remote sensing and machine learning systems, this study will be a way forward for policymakers.

## 2 Experimental

### 2.1 Study Area

Sylhet Division is ideal for this research due to its diverse landscape, rapid urbanization, and ecological significance. It offers a unique case to assess vegetation trends and the impact of land-use changes. This analysis supports sustainable planning in a region crucial for both conservation and development.

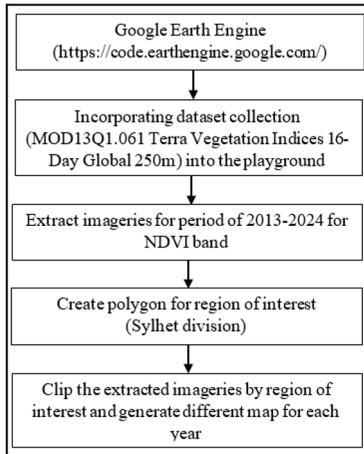


**Fig. 1.** Map of study area.

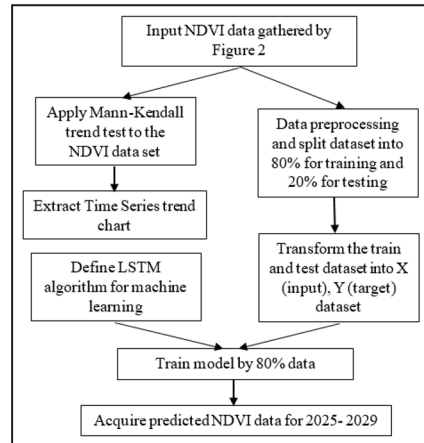
### 2.2 Experimental procedure

The flowchart of *Fig.2* illustrates the steps for processing NDVI data using Google Earth Engine, including dataset integration (MOD13Q1.061), extracting imagery for 2013–2024, defining Sylhet Division as the region of interest, and clipping the imagery

to generate yearly maps. And the flowchart of *Fig.3* describes how the total research is done, explaining both Mann Kendall Test and LSTM algorithm for predicting future NDVI of Sylhet Division.



**Fig.2.** Methodology of data collection.



**Fig.3.**Flow chart for Trend Analysis and prediction of NDVI.

### 2.3 Materials

NDVI data from 2013-2024, a total of 12 year summer season (March-April) acts as core material for this study by which the NDVI trend will be extracted. The data is shown at *Fig.4*.

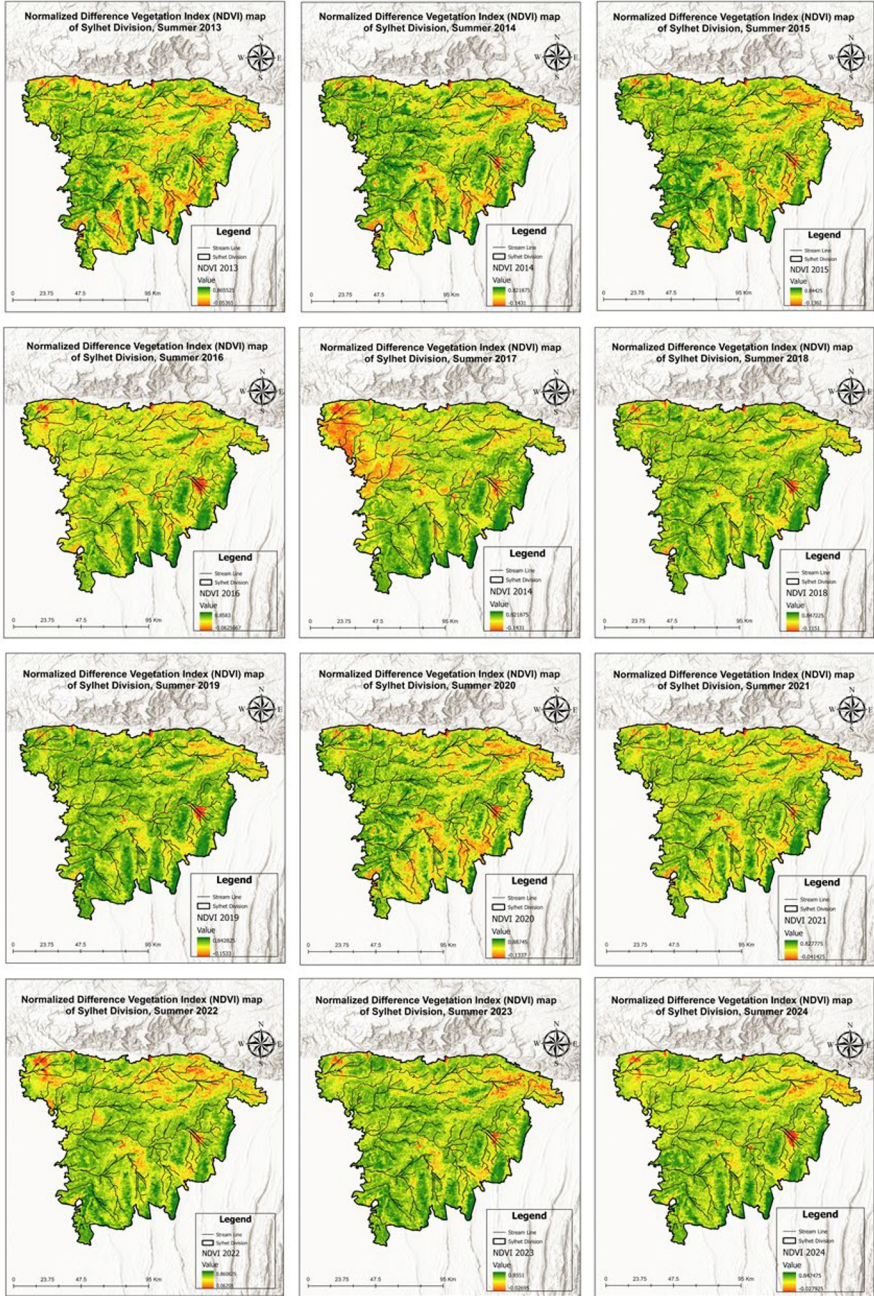


Fig. 4. NDVI map from 2013 to 2024.

### 3 Calculation

There are different formulas are used in this study for calculating NDVI, Mann-Kendall trend, and LSTM algorithm. Though we are working with MODIS Level-3 NDVI products, NDVI values are already provided as a derived data product, usually scaled by a factor of 10,000 (e.g., NDVI of 0.4 is stored as 4000). But we can calculate NDVI manually through the *Equation i*.

$$NDVI = \frac{NIR-Red}{NIR+Red} \dots\dots\dots (1)$$

The Mann-Kendall test is a non-parametric statistical test commonly used for trend analysis in time-series data, such as NDVI values. It evaluates whether there is a statistically significant upward or downward trend in the data over time. We have used the following function (*equation ii*) for this, and the Mann-Kendall test starts by calculating the statistic S based on the ranks of the time-series data.

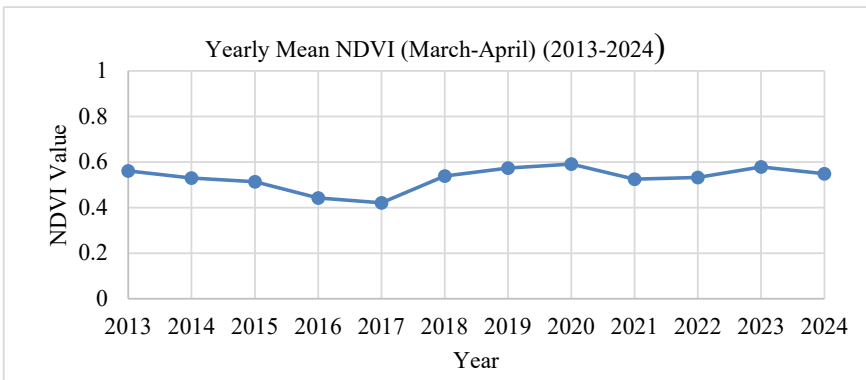
$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^n sgn(x_j - x_i) \dots\dots\dots (2)$$

In this equation, n = number of data points,  $x_i$  and  $x_j$  are data values at times i and j ( $j > i$ ), and sgn is the sign function , where,

$$sgn(x_j - x_i) = \begin{cases} +1 & \text{if } x_j - x_i > 0 \\ 0 & \text{if } x_j - x_i = 0 \\ -1 & \text{if } x_j - x_i < 0 \end{cases}$$

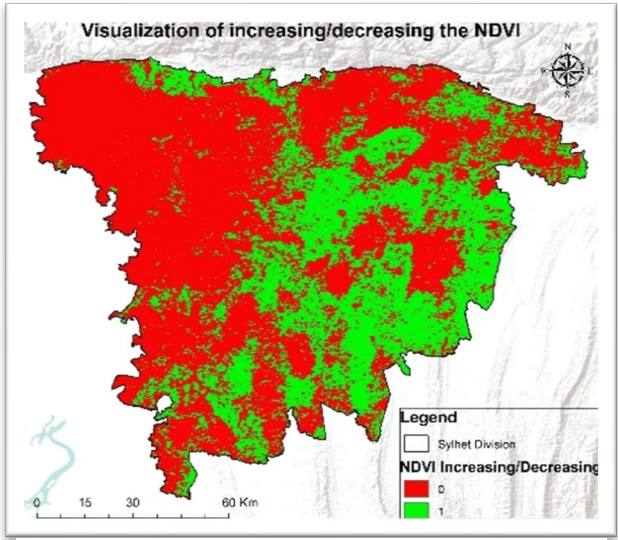
### 4 Result and Discussions

By using 2013-2024, a total of 12 year summer season (March-April) NDVI data, through the Mann-Kendall test, a trend is extracted, which is shown below in *Fig.5*. The trend shows the yearly mean NDVI values for March to April from 2013 to 2024, indicating variability over time. After an initial decline until 2016, NDVI trends show recovery and stabilization with slight fluctuations in later years.



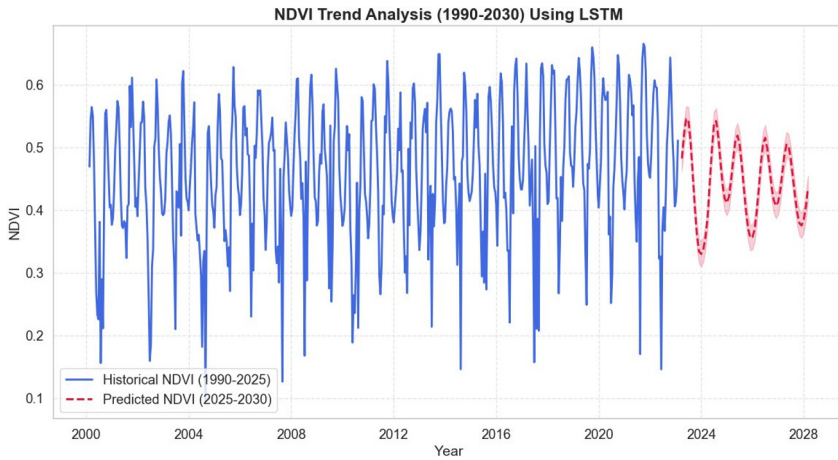
**Fig.5.** Yearly mean NDVI from 2013-2024 (March- April).

The following map (*figure 6*) visualizes the trends in NDVI changes in Sylhet Division from 2013 to 2024, analyzed using the Mann-Kendall test. Green areas (1) represent regions where mean NDVI values have increased, indicating vegetation improvement, while red areas (0) show a decrease in NDVI, indicating vegetation decline. The spatial distribution highlights varying patterns of change across the division, providing a clear picture of regions with increasing or decreasing vegetation density over Sylhet division.



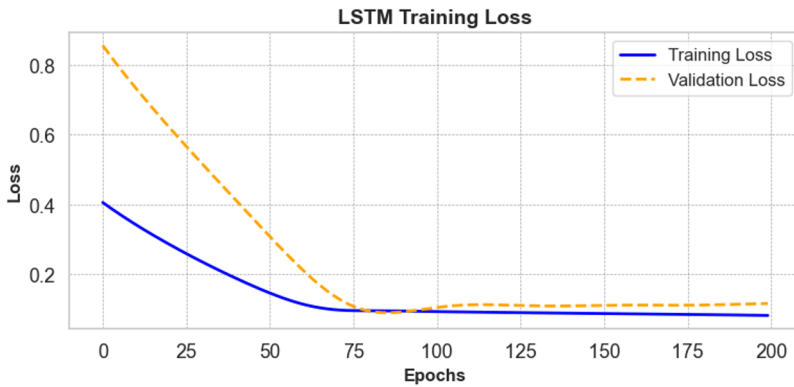
**Fig.6.** Spatial NDVI trend over time.

To predict NDVI trends, we used an LSTM neural network, which is great for working with time-series data. We started by extracting NDVI values from MODIS satellite images for 2000 to 2030 and normalized them to a range between 0 and 1 to make them suitable for the model. Using a sliding window approach, we created sequences where past values were used to predict the next one. The LSTM model had 50 units and a dense output layer that produced the predicted NDVI value. It was trained with the Adam optimizer and Mean Squared Error loss over 200 epochs. After validating the model on data from 2000 to 2024, we used it to forecast NDVI values for 2025 to 2030, feeding its own predictions back as input for future years. The LSTM model performed really well in predicting future trends based on past NDVI data. When tested, it showed an  $R^2$  score of 0.84, which means it explained 84% of the variation in the data, a solid result. The model also had a Root Mean Square Error (RMSE) of 0.05 and a Mean Absolute Error (MAE) of 0.03, which indicates it was accurate in minimizing prediction errors. These results show that the LSTM model is not only accurate but also reliable, making it a strong tool for analyzing both short-term fluctuations and long-term trends in NDVI datasets.



**Fig.7.** NDVI trend prediction by LSTM.

However, this could also suggest that the model is overly simplistic or lacks the ability to capture more complex trends in the data, which can be interpreted through LSTM training loss (figure 8), which displays the loss values during the training of an LSTM. The divergence between the two curves after 75 epochs suggests overfitting. The model starts memorizing the training data instead of learning patterns, leading to poorer performance on unseen data. To mitigate overfitting, techniques like early stopping, dropout, or regularization could be used. Additionally, reassessing the model's architecture or the data preprocessing steps might improve performance.



**Fig.8.** LSTM training loss.

## 5 Conclusion

This study demonstrates the potential of employing Long Short-Term Memory (LSTM) models and NDVI time-series data to analyze and predict vegetation trends in Sylhet Division. By capturing spatiotemporal variations, the research identifies areas of ecological concern and those showing promising improvements in vegetation cover. The model effectively forecasted future trends with acceptable accuracy, highlighting its applicability in ecological and land-use planning. However, challenges such as overfitting and the complexity of capturing all ecological dynamics indicate room for methodological enhancements. The findings underscore the importance of integrating remote sensing and machine learning for informed policy-making, offering actionable insights for sustainable land management and conservation strategies. Future studies could explore advanced model architectures or incorporate additional environmental variables to refine predictions and broaden the scope of analysis.

**Acknowledgements.** The authors extend their gratitude to the Bangladesh Meteorological Department and the MODIS for providing access to valuable data used in this study. The authors also acknowledge the assistance of ChatGPT for grammatical corrections and refining the manuscript.

**Disclosure of Interests.** Authors didn't receive any funding for this research, and no competing interests as well. The data used in this study are available upon request to corresponding author.

## References

1. Verma, G., Mehta, A., Goswami, S.: Trend and Time Series Analysis of Vegetation Dynamics Using Satellite Data: A Case Study of Uttarakhand, India. *Current Journal of Applied Science and Technology* 41(33), 14-26 (2022).
2. Reddy, D. S., Prasad, P. R. C.: Prasad: Prediction of vegetation dynamics using NDVI time series data and LSTM. *Modeling Earth Systems and Environment* 4, 409–419, (2018).
3. Vasilakos, C., Tsekouras, G.E., Kavrouidakis, D.: LSTM-Based Prediction of Mediterranean Vegetation Dynamics Using NDVI Time-Series Data. *Land* 11(6), (2022).
4. Wang, J., Rich, P. M., Price, K. P.: Temporal responses of NDVI to precipitation and temperature in the central Great Plains, USA. *International Journal of Remote Sensing* 23(11), 2345-2364 (2003).
5. Cui, C., Zhang, W., Hong, Z., Meng, L.: Meng: Forecasting NDVI in Multiple Complex Areas Using Neural Network Techniques Combined Feature Engineering. *International Journal of Digital Earth* 13(12), 1733–1749 (2020).
6. Ferchichi, A., Abbes, A. B., Barra, V., Farah, I. R.: Farah: Forecasting vegetation indices from spatio-temporal remotely sensed data using deep learning-based approaches: A systematic literature review. *Ecological Informatics* 68(3), (2022).

**Open Access** This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

