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RESEARCH ARTICLE

Land suitability Analysis for Sustainable Agriculture Development using Multi-Criteria Analysis and Machine Learning Techniques: Case Study of Shibpur Upazila

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ABSTRACT

Assessing the suitability of crops is crucial for determining a plot of land's capacity for producing crops sustainably. The primary objectives of this study are to conduct a land suitability analysis for sustainable agricultural development and to develop a land information system with crop recommendations. This research utilizes a Multi-Criteria Decision Analysis (MCDA) framework in conjunction with Geographic Information Systems (GIS) to determine appropriate agricultural land throughout the nation. In this study, land suitability categorization and crop recommendations were produced while considering many criteria such as slope, elevation, land cover, low flood risk, soil moisture, and favorable soil. To improve spatial accuracy and thematic relevance, Sentinel-2 satellite imagery is merged with SRTM elevation data and field data. Each criterion received a weight determined by expert opinions and prior studies, and scores are derived from that. The results of the land use map analysis show that agricultural land is 57% of total land. Out of total agricultural land, 19.44% is most appropriate for agriculture, while 32.22% is suitable and 48.34% is less suitable. The research conducted here developed a Mouza Plot-wise Land Information System (LIS) that is placed on a cloud server, providing simplicity of use and flexibility. This system helps people or local authorities to know if this land is suitable, less suitable, or not suitable for Agriculture.

1. INTRODUCTION

The land is one of the most pivotal natural resources globally. Agriculture remains the cornerstone of economic activity in developing nations (Anusha et al., 2023). The global agricultural sector is facing unparalleled challenges due to globalization and urbanization (Li, 2023 & Xue et al., 2023). Over the past 20 years, the global population has grown significantly, increasing demand for new areas designated for housing and food production. (Bandyopadhyay et al., 2009). As a result of these demands, natural resources such as wetlands, forests, pastures, and agricultural land are converted into industrial or residential areas and misused for their intended use. To maximize the potential of these resources, it's crucial to create land use plans that prioritize planning and sustainability (Akinci et al., 2013).

This study has been conducted in Shibpur Upazila which located in Bangladesh, has significant portion (54.55%) from its total population directly and indirectly engaged in agriculture, but Agriculture lands are decreasing day by day because of land conversion to urban and industrial uses, which threatens food security. This study has conducted an agricultural land suitability analysis to safeguard the agriculture cropland from unplanned non-agricultural land development.

An evaluation to determine the land's suitability is a requirement for land use planning (Mokarram and Amin, 2010). Land use suitability research evaluates a land area's wellness for purposes (e.g., agriculture, forest, recreation) and defines the degree of suitability. It is a valuable instrument in facilitating decision-making processes within land use planning (Roy & Saha, 2018). It is imperative to evaluate the suitability of cropland to ascertain a segment of the land's capacity for supporting crop cultivation production (Bandyopadhyay et al., 2009). A crucial aspect of this procedure involves the identification of the criteria that influence the land's suitability (Al Shalabi et al., 2006). No set criterion determines land suitability for agriculture, and similar studies typically employ accessible factors. Land's topographical and soil properties are frequently used for these studies (Akinci et al., 2013).

Different studies have been carried out throughout the world about land suitability analysis using other criteria.

Kalogirou (2002) grouped 17 factors into three distinct groups: soil biomechanics and contaminants, slope, eroding hazards, rooting conditions, excess salts, water level, flood risk, and drainage. Perveen et al., (2007) analyzed agricultural land suitability in their research using the following criteria: soil texture, condensation, uniformity, pH level, drainage, nutrient content, and slope. Kihoro et al. (2013) studied the suitableness of rice-growing regions according to climate (temperature and humidity), soil (texture, drainage, and pH), and elevation (slope). The factors applied by Kamau et al. (2015) were soil, pH level, texture of the soil, level of soil, soil drainage, precipitation, average temperature, and slope. Roy and Saha (2018) assessed paddy land suitability using various factors, including climatic factors (rainfall and temperature), hydro-geomorphological factors (geology, elevation, slope, proximity to river and groundwater depth), soil physical attributes (texture and depth), and chemical characteristics of the soil (pH, copper, iron, manganese, nitrogen, organic carbon, phosphorus, potassium, sulfur, zinc, and boron). Saha et al., (2021) measured agricultural land suitability in a branching site of the Spoon River in India through variables such as rainfall, temperature, soil texture, pH, slope, elevation, distance from the river, distance from the road, geology, modified soil adjusted index, modified normalized difference water index, and LULC. Sarker et al., (2023) considered elevation, slope, geology, geomorphology, rainfall, Land Use Land Cover, Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), groundwater level, soil type, and pH as parameters for land suitability for vegetable crops in their studies.

Multiple methods have been used to evaluate the suitability of land for agriculture. Geographic Information System (GIS) is a strong and adaptable tool for agricultural suitability research because it permits users to alter and integrate enormous amounts of heterogeneous datasets to produce the most recent datasets (Haque et al., 2022). Using GIS and the Analytical Hierarchy Process (AHP) is a well-known MCE approach for determining the relative significance of elements (Kamau et al., 2015). Bangladesh is largely an agricultural economy. The land and atmosphere are suitable for cultivating a range of crops all year. Around 57% of the total land is agricultural (Haque et al., 2022). However, the country has experienced significant land-use changes in recent decades due to urbanization and population growth. Land-use change in urban areas is responsible for slimming down agricultural land and wetlands which have an impact on crop production (Ferdous et al., 2023). In this research, the Analytical Hierarchy Process (AHP) is used to integrate Multi Criteria Analysis with GIS. Before that, land use is classified to identify the major land uses using machine learning techniques, The specific objectives of this study are: i) to identify land use land cover classification using a machine learning algorithm in Google Earth Engine.; ii) to use a multi-criteria analysis to create a land suitability map for agriculture through GIS and iii) to develop a user-friendly system for Land Information System (Mouza plot-wise), Crop Recommendations, and Property Price Estimator using Python, HTML, and CSS. The findings should have a favorable impact on agricultural resource management and production.

2. MATERIALS AND METHODS

2.1. The study area

This research examines the Land Suitability Analysis for agricultural land and the Crop Recommendation System for Shibpur Upazila, Narsingdi, Bangladesh. Shibpur is situated at 24.3750°N and 90.7375°E. Upazila has an area of 21780.97 hectares and a total area of 206.89 km2. The Shibpur Upazila is bounded on the north by Manohardi Upazila, on the east by Raipura and Belabo Upazilas, on the south by Narsighdi Sadar Upazilas, and on the west by Palash Upazila and Kapasia and Kaliganj Upazilas of Gazipur District. It is under Narsingdi District. The Agroecological zones of the Upazila are the Young Brahmaputra and Jamuna Floodplain, the Old Brahmaputra Floodplain, and the Madhupur tract. Shibpur Upazila consists of one Municipality and 9 Unions (BBS, 2022).

In Shibpur Upazila, most people depend on agriculture, but rapid population growth and land conversion to urban and industrial uses are causing agricultural resources to deteriorate. Natural disasters such as floods, droughts, and storms also damage crops (Rahman, 2018). Insufficient land use is causing land degradation, which threatens food security and impacts local ecosystems, to address these issues. This study has conducted an agricultural land suitability analysis to safeguard cropland.

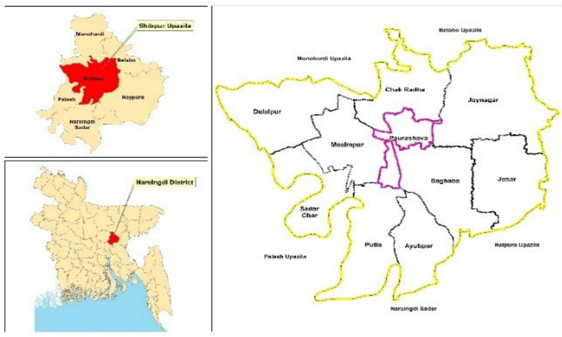

Figure 1: Topographical Map of the study area.

2.2. Methodology

Step-1: The first step involved analyzing satellite images using a machine learning model on Google Earth

Engine (GEE). This helped classify different land use and land cover types, such as agricultural land, forests, water bodies, and urban areas. Understanding land cover is essential for assessing the suitability of different areas for farming.

Step-2: Various datasets were gathered, including administrative boundaries, road networks, population distribution, geological features, and hydrological data. These datasets provide additional context about the land, such as accessibility, soil type, and water availability. Using this information, thematic maps were created to visualize different factors that influence agricultural suitability.

Step-3: Multi-Criteria Analysis (MCA) was applied to integrate the land cover data with the collected datasets. Each factor such as soil quality, slope, elevation, and flood risk were assigned a specific weight based on its importance in determining land suitability. The analysis categorized the land into three classes: most suitable, suitable, and less suitable for crop cultivation.

Step-4: Finally, a web-based Land Information System (LIS) was developed to provide farmers and policymakers with real-time access to land suitability assessments. The system suggests the most appropriate crops for each plot of land based on soil conditions and weather patterns, enabling better agricultural planning and sustainable land management.

2.3. Data collection

The specifications of the satellite image used in this research, sourced from Sentinel-2 data on the Google Earth Engine platform, are detailed in Table 1. The image was taken on February 8, 2024, featuring only 1% cloud cover, which guarantees excellent visual clarity. With a spatial resolution of 10 meters, it is well-suited for medium-scale land use classification and environmental observation.

In Table 2, a detailed enumeration of data layers employed in Multi-Criteria Analysis (MCA) is provided, focusing on the assessment of land suitability and environmental evaluations. Each main criterion is assigned a weightage reflecting its influence in the overall analysis, totalling 100%.

Crop Intensity is assigned a weight of 20%, with areas that support triple cropping receiving the highest score of 10, highlighting their significance in agriculture. Slope is weighted at 15%, with flatter terrains (0–2°) scoring highest due to their suitability for farming. Land Use and Land Cover constitutes 10% of the overall analysis, with agricultural land achieving the highest score of 7, highlighting its significance in land use planning.

Flood Depth, which is weighted at 20%, plays a vital role in the flood-prone areas of Bangladesh. Regions experiencing minimal flooding (0–0.1m) are deemed the safest and most appropriate, earning a score of 10, whereas areas subjected to severe flooding (greater than 3.6m) receive no points. In addition, Soil Type is also weighted at 20%, with both Alluvial soils and Madhupur clay residuum attaining a high score of 10, underscoring their fertility and importance in supporting agricultural productivity.

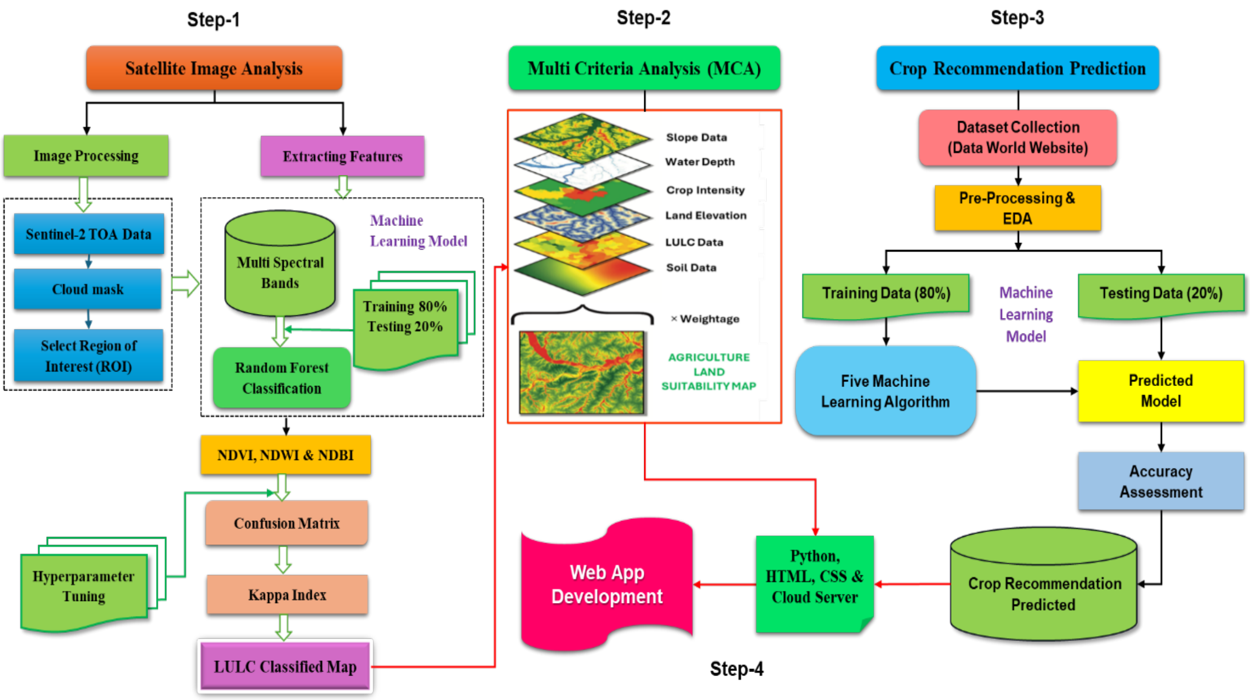

Figure 2: Methodological Flowchart.

Table 1: Sentinel-2 Satellite Image.

Data Type	Acquisition Date	Cloud Coverage	Spatial Resolution	Number of Bands
Sentinel-2 (Multispectral Instrument)	2024-02-08	1%	10 m	12

Source: https://earthengine.google.com

Table 2: Different Types of Data with Weightage for Multi-Criteria Analysis.

Main Criteria	Weightage	Influence (%)	Sub-Criteria	Score	Data Source
Crop Intensity	0.20	20	Triple Crop Double Crop Single Crop	10 7 3	Concern Union SAAOs, DAE 2016, Shibpur Upazila.
Slope (Degree)	0.15	15	0–2° 2–4° 4–6° 6–8° 8–10°	5 4 3 2 1	A slope map has been prepared from SRTM DEM-30m (Digital Elevation Model) through GIS using hydrology tools.
Land Elevation (m)	0.15	15	5–8m 8–11m 11–14m 14–17m 17–20m	4 3 3 3 2	SRTM DEM-30m (Digital Elevation Model) has been collected from Google Earth Engine. https://earthengine.google.com
Land Use and Land Cover	0.10	10	Agriculture Land Bare Land Settlement	7 2 1	Land use Land Cover has been prepared using satellite image analysis on Google Earth Engine. https://code.earthengine.google.com
Flood Depth (m)	0.20	20	0 - 0.1m 0.1 – 0.3m 0.3 – 0.9m 0.9 – 1.8m 1.8 – 3.6m Above 3.6m	10 5 3 1 1 0	Raster Data-2020 and Collect from Flood Forecasting and Warning Centre (FFWC), Bangladesh Water Development Board (BWDB).
Soil Type	0.20	20	Alfisol (alluvial soil) Madhupur clay residuum	10 10	Field Survey-2016, Fourteen Upazila Master Plan, Urban Development Directorate (UDD), Bangladesh Agricultural Research Council (BARC)-2010.
Total	1	100		100	

Table 3: Crop Dataset.

Dataset Name and Details	**Data Source**
Crop Dataset and its fields ✓ N - ratio of Nitrogen content in soil ✓ P - ratio of Phosphorous content in soil ✓ K - ratio of Potassium content in soil ✓ temperature - temperature in degree Celsius ✓ humidity - relative humidity in % ✓ ph. - ph. value of the soil ✓ Rainfall - Rainfall in mm ✓ label – Categories of crop.	https://query.data.world/s/24aldlhwuj5m2xypz4zzz7p5savzpt?dws=00000

The datasets are obtained from reliable sources, which encompass field surveys, governmental agencies like the Bangladesh Water Development Board, and satellite-based Digital Elevation Model (DEM) data that has been analyzed through Geographic Information Systems (GIS).

Table 3 outlines the composition of a crop dataset utilized for agricultural analysis and predictive modeling. This dataset encompasses vital soil and climatic factors, including the concentrations of nitrogen (N), phosphorus (P), and potassium (K) in the soil, which are crucial nutrients for crop development.

2.4. Satellite image analysis

The remote sensing technique stands as a pivotal method for delineating land use features, utilizing multispectral satellite imagery. The approaches employed for classifying remotely sensed images can be categorized into supervised and non-supervised methods (Kafy et al., 2020). This study utilized sentinel-2 satellite images with 10m resolution for land use/land cover classification using Google Earth Engine (GEE). To mitigate the impact of seasonal fluctuations associated with changes in land use, all Landsat images were acquired during the dry season (Anley et al., 2022). Then run the code to execute the process. The satellite image is visualized with an RGB color band according to the ROI.

Collect a total of 620 training points (band value) from the satellite image and split them into 80% for training and 20% for testing points for the applied machine learning model.

A Random Forest (RF) classifier has been used for this machine learning. Then use the confusion matrix to rest on how the classifier works. This classifier gives an average accuracy score and that is 89%.

To improve the accuracy score, extra bands such as NDVI, NDWI, and NDBI are utilized. Optimize the Random Forest model by setting Hyperparameter tuning and finding that 150 trees provide the best accuracy of 92%. Figure 2 describes the general steps taken to create a LULC map on GEE. Figure 3 shows the number of validation training points. Table 4 & Figure 4 display hyperparameter tuning for the number of trees and percentage of accuracy score for different classifiers, revealing the influence of pixel sample size on classification performance.

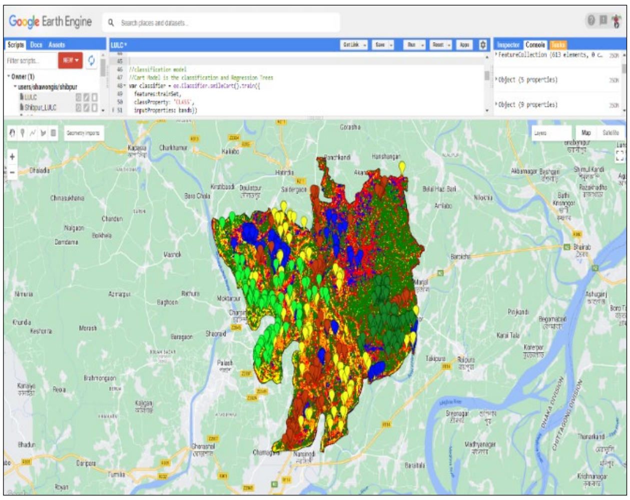

Figure 3: Training Validation Points.

Table 4: Accuracy of RF classification for pixels sample size.

	RF Classifier Parameters		No. of Pixels/Class			Accuracy Assessment		
Class	No. of Trees	Predictors (Image Bands)	Total Training Validation points	Training 80%	Testing 20%	Pixel misclassified	Overall Accuracy	
Agriculture	200	B2, B3, B4, B5, B6, B7, B8, B11, B12, NDVI, NDWI & NDBI.	130	104	26	0	100	92%
Bare land	200		110	72	18	20	82	
Settlement	200		150	96	24	30	80	
Vegetation	200		110	85	21	4	96	
Waterbody	200		120	96	24	0	100	

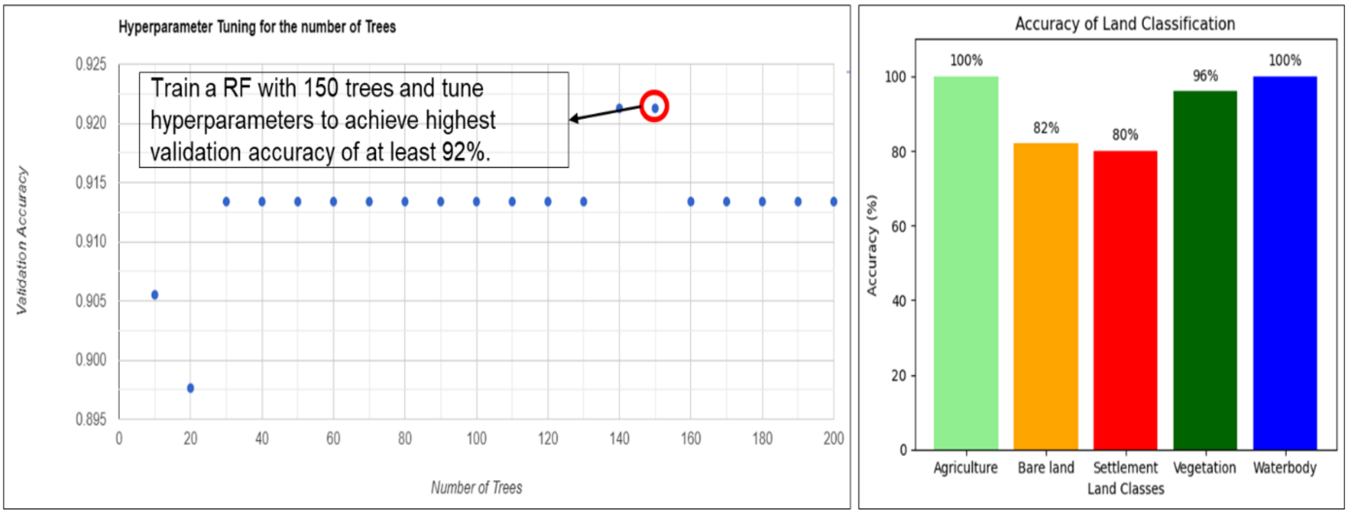

Figure 4: Hyper parameter tuning for The Number of Trees and Percentage of Accuracy Score.

2.5. Multi-Criteria Analysis (MCA)

Multi-criteria analysis (MCA) is a technique for weighing several elements while making complex choices. Geographic Information Systems (GIS) employ multi-criteria analysis (MCA) to assess and rank options based on a variety of factors. By combining and assessing location and characteristic data, MCA may choose the best alternative based on cost, environmental impact, and accessibility (Malczewski et al., 1999). Multi-criteria analysis (MCA) in GIS uses both spatial and attribute data to assess and prioritize options based on multiple criteria. MCA enables thorough evaluation by combining various data layers and employing weighted scoring techniques to identify the most suitable alternative (Church et al., 1974). The classification of satellite images is a very popular and complex topic.

The relative importance of criteria was determined using an Analytical Hierarchical Process. The resulting weights were then used to construct the suitability map using GIS software. Ultimately, the current land cover map was used to generate a land suitability map by overlaying these maps (Kamau et al., 2015). GIS-based AHP has gained fame because of its ability to combine a large quantity of diverse data, and because finding the necessary weights can be relatively simple, even for many criteria (Bakhtiar Feizizadeh, 2014). Used weighted overlay analysis to find out if the land in Shibpur Upazila was good for farming. The weight values have been used by certain factors from the Analytic Hierarchy Process and the scores of certain sub-criteria (Khan et al., 2022).

However, the GIS-based MCA approach has been widely used in land suitability analysis in other countries. To recommend a crop for the chosen land with site-specific parameters with high accuracy and efficiency, this paper consists of a theoretical and conceptual platform of recommendation system through integrated models of collecting environmental factors using machine learning techniques concerned with artificial intelligence (Bandara et al., 2020). MCA assists in developing an agricultural land suitability map using GIS. It integrates a variety of factors, including geology, hydrology, and topography data, to identify the most suitable land for cultivation. This method ensures that all critical criteria are considered, resulting in more precise and practical recommendations regarding the most promising agricultural regions. This approach can improve productivity and sustainability of agriculture by making better decisions about land use.

Shibpur Upazila's future agriculture plan requires a suitability analysis using multi-criteria analysis (MCA) or ArcGIS overlay weightage technique to identify suitable areas for enhancing agricultural productivity. Figure 2 shows the process of overlaying weightage techniques on GIS. The analysis identifies the most suitable agricultural land for conservation, considering factors such as slope, flood depth, soil moisture, elevation of land, land use, soil type, and cropping intensity. Weights of the criteria and scores of the sub-criteria are shown in Table 2.

Formula

The weighted sum overlay analysis for LS evaluation using the formula (Mahato et al. 2024):

Suitability (MCA) = $\sum_{i=1}^{n}(Wi \times Fi)$

Where:

- n = the number of criteria
- W_i = is the weight assigned to the ith criterion.
- F_i = is the normalized value (between 0 and 1)

2.6. Crop recommendation prediction

Crop recommendations have been developed using a machine-learning model. First data is collected from the world website and processed. The data is divided into two parts, 80% for training and 20% for testing. Five different types of machine learning algorithms are used for training on the training data. The model is then tested with the testing data to make predictions. Finally, the accuracy of those predictions is assessed, leading to recommendations for crops.

2.7. Web application development

This study has developed a Mouza Plot-wise Land Information System (LIS) and it is deployed on a cloud server https://land-suitability.streamlit.app. This system is built with Python, HTML, and CSS. It is compatible with both smartphones and computers, ensuring user-friendly access from anywhere in the world. To see the land status for a specific plot, the user must sequentially select the division, district, upazila, union, mouza sheet and plot number, then click “Calculate Land Status”. This app assists individuals or local governments in determining whether a piece of land is suitable, less suitable, or not suitable for agricultural purposes. Users provide weather information such as nitrogen, phosphorus, temperature, humidity, and rainfall. After selecting a model, the app recommends the best crop to grow under those conditions, allowing farmers to increase yield and food production.

3. RESULT AND DISCUSSION

The main objectives are to find suitable land for sustainable agricultural cultivation and recommend the best crop for that land. Day by day, agricultural land has been converted to unplanned urbanization and non-agriculture purposes. This research is trying to find out the most suitable for agricultural purposes so that concerned authorities can take action to preserve that land for only agricultural purposes. Now remote sensing technology has been used worldwide to determine land use and land cover change. To find out the best suitable land for agricultural purposes, different thematic maps have been prepared, such as cropping intensity, DEM and Slope, Soil Classification, and Flood Water Depth, etc.

The result of the land use map analysis shows that agricultural land is 29428 acres, which is 57% of total land (Table 5).

Table 5: Land Use Classification.

Land Classification	Area (acres)	%
Agriculture Land	29428	57
Bare land	860	2
Settlement Land	16392	32
Vegetation Land	2640	5
Water body	2649	5
Total Area	**51969**	**100**

In this study, land suitability classification and crop recommendation were developed considering different factors such as gentle slope, good elevation, suitable land cover, low flood risk, adequate soil moisture, and favourable soil, etc. Land Suitability has been divided into three categories –Most Suitable, Suitable, and Less Suitable.

Most suitable land was characterized by a gentle slope, good elevation, low flood risk, adequate soil moisture, favourable soil type, etc. This land category is fertile for the cultivation of paddy during the monsoon season and vegetables in other seasons. Suitable land well suited for cultivation of all crops but has a gentle slope and slightly high altitude is the most suitable land. Less suitable land is mainly single-cropped areas and high-slope areas. This land is bare and mainly used for only vegetable purposes. Out of total agricultural land, 19.44% is most suitable for agriculture, suitable is 32.22%, and Less Suitable 48.34% (Table 6).

Table 6: Land Suitability.

Suitability	Area (Acre)	%
Less Suitable	13349.87	48.34
Suitable	8898.25	32.22
Most Suitable	5368.36	19.44
Total	27616.49	100

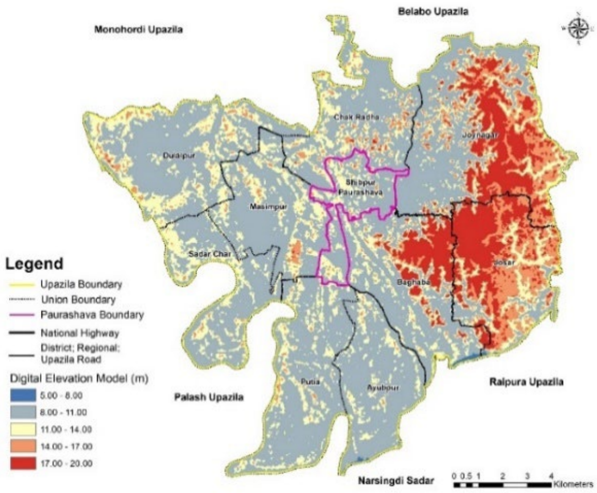

Figure 5: Digital Elevation Model (DEM).

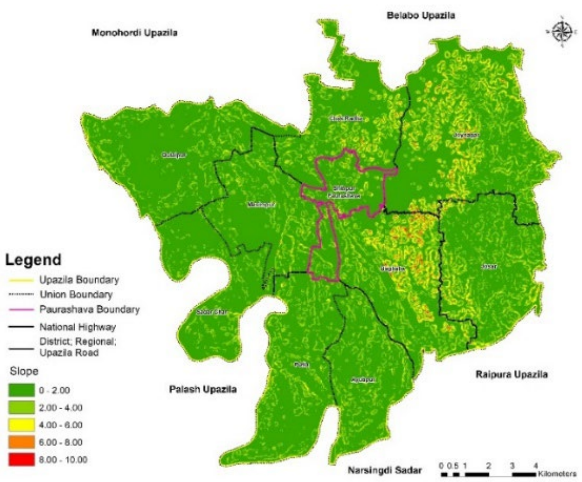

Figure 6: Slope.

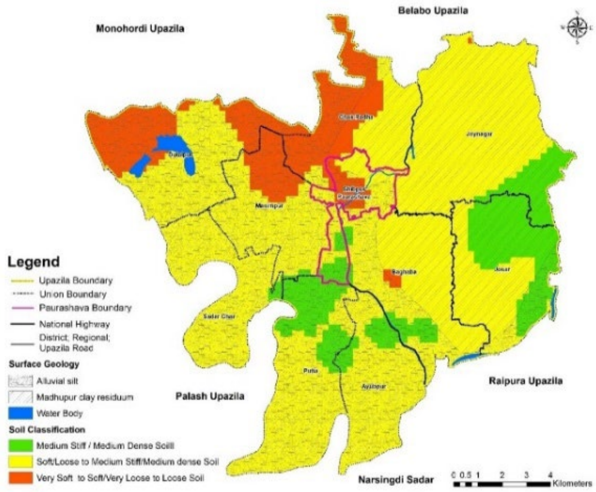

Figure 7: Soil Classification.

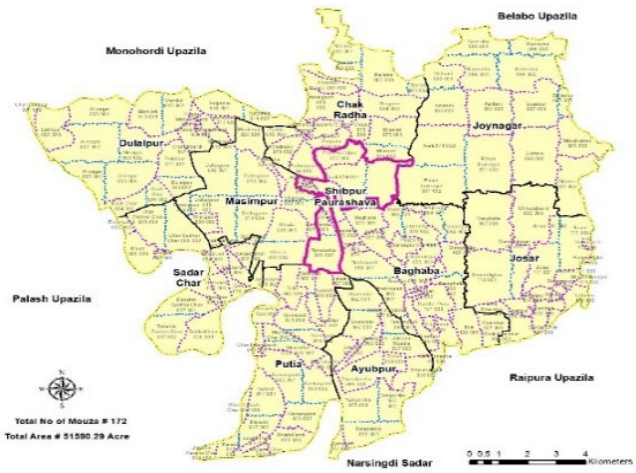

Figure 8: Mouza Map.

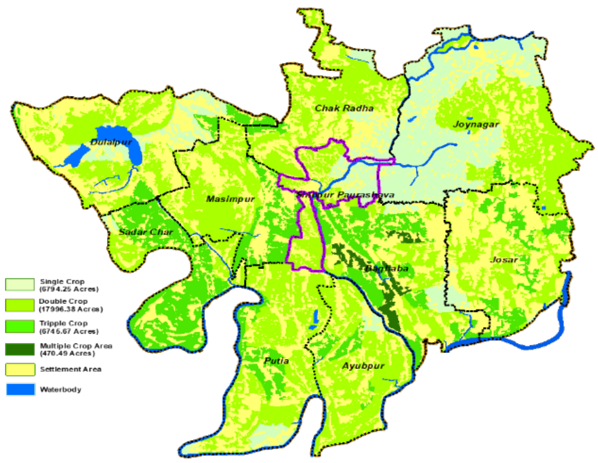

Figure 9: Crop Intensity.

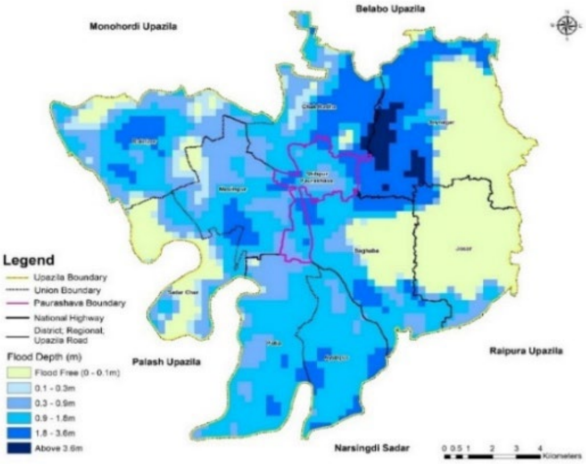

Figure 10: Flood Water Depth of Study Area.

Figure 11: Boro Rice Crop Field.

Figure 12: Jute Field.

Figure 13: Dhaincha Field (Green Manuring).

Figure 14: Lemon Garden.

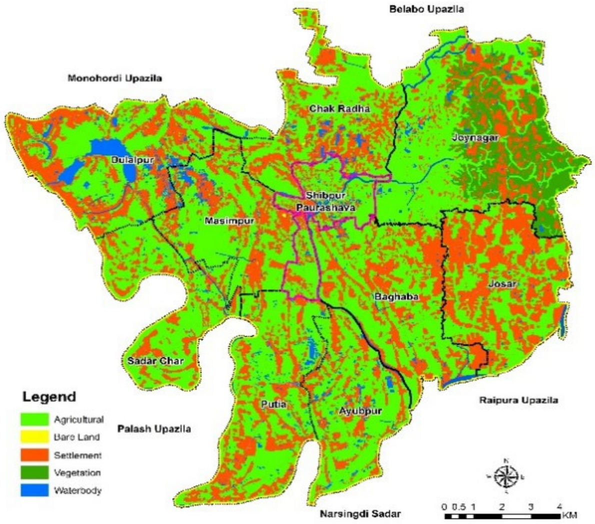

Figure 15: Land use Map.

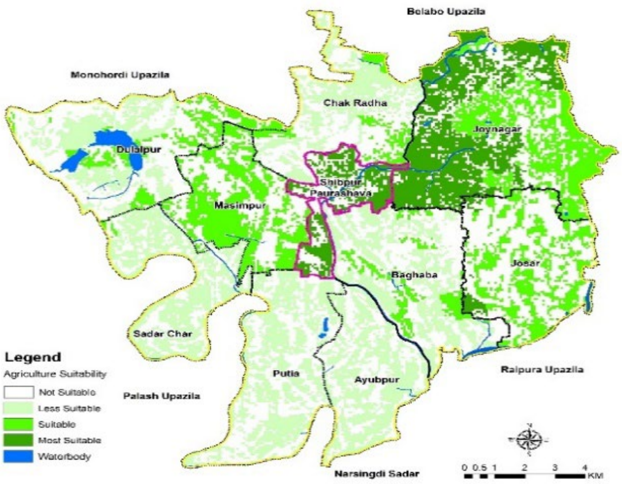

Figure 16: Agriculture Suitability Map.

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The agricultural land of Joynagar, Masimpur, Dulalpur, and Chak Radha union is most suitable for agricultural purposes, and Masimpur, Dulalpur, and Josarunion land is Suitable for cultivation. The land of Sadar Char, Putia Ayubpur, and Chak Radha Union is less suitable for agriculture due to the flood flow zone, High Elevation, and slope. Less suitable land area is more than Most Suitable and Suitable land because those areas are mainly industrial area and high land. Most Suitable and Suitable land is double and multiple cropped area and less suitable land is single cropped area. Boro (HYV) is the main irrigated crops cultivated by using ground water. Major crops cultivated in this union are paddy, Potato, Jute, Lemon, Mustard, and different Rabi & Kharif vegetables. The area-wise distribution of different land suitability classes in Shibpur Upazila exhibited significant variation (Table 4).

As global population and food demand increases, there an urgent need to utilize land resources according to its suitability (Müller et al., 2009) to minimize the economic and environmental costs of land management. This analysis will help to find the suitable land for agriculture cultivation and protect the land from unplanned settlement. Shibpur Upazila is a growing industrial area and agriculture land converted to non-agricultural purpose. It's high time to take initiatives to preserve most suitable and suitable agriculture land and consult with farmers about how they use that land for triple or multiple cropping. The next steps could involve using smart farming techniques and sustainable land practices in suitable areas, like Joynagar and Masimpur. The findings can also guide the concerned authority to plan for agriculture planning and contributing to the overall sustainable agriculture growth of Shibpur Upazila.

3.1. Crop recommendation system

The crop recommendation system has been developed by using machine learning models, including Decision Tree, Random Forest, Support Vector Machine, K-Nearest Neighbors, and Logistic Regression. This system analyzes key parameters such as Nitrogen, Phosphorus, and Potassium Levels, Temperature, Humidity, pH, and Rainfall. This system assists the farmers in selecting the most suitable crop for cultivation based on the above parameters. The Random Forest model, with an astonishing accuracy of 99.32%, is the most reliable predictor, followed by the Support Vector Machine at 97.95%. Figure 18 shows the machine learning model's accuracy score. This technique does not only improve crop selection decision-making but also promotes agricultural production and sustainability.

Users just input detailed information about the weather conditions of crops like nitrogen, phosphorus, temperature, humidity, and rainfall, select models, and click the "Crop Prediction". It shows you which crops are likely to grow well based on the prediction. This app helps farmers by indicating the best seeds for their soil, indicating then growing more crops. This helps the country to produce more food. This app is a useful and user-friendly tool for farmers, making it easier for them to decide what to plant in their fields. Figure 17 shows the interface of the crop recommendations system.

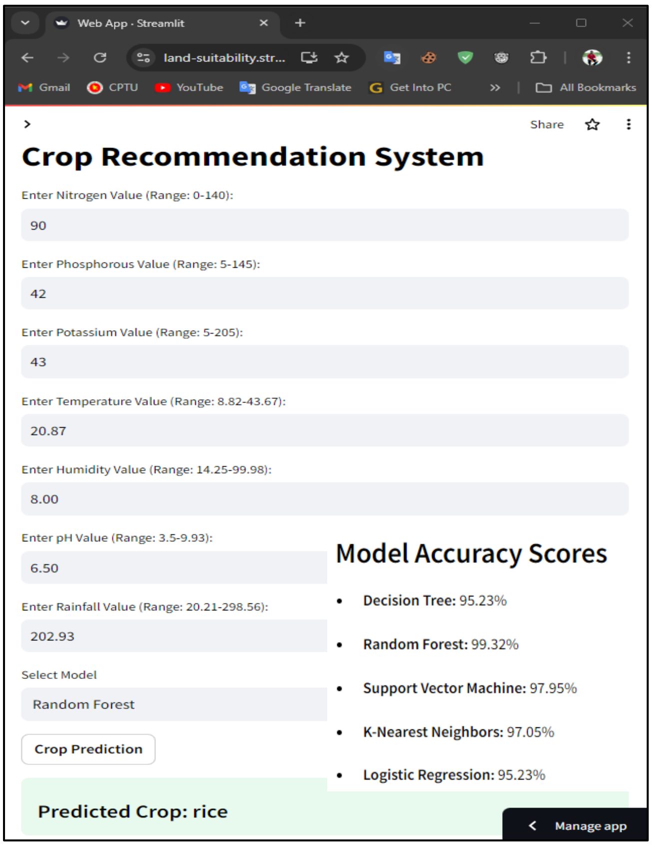

Figure 17: Crop Recommendation System.

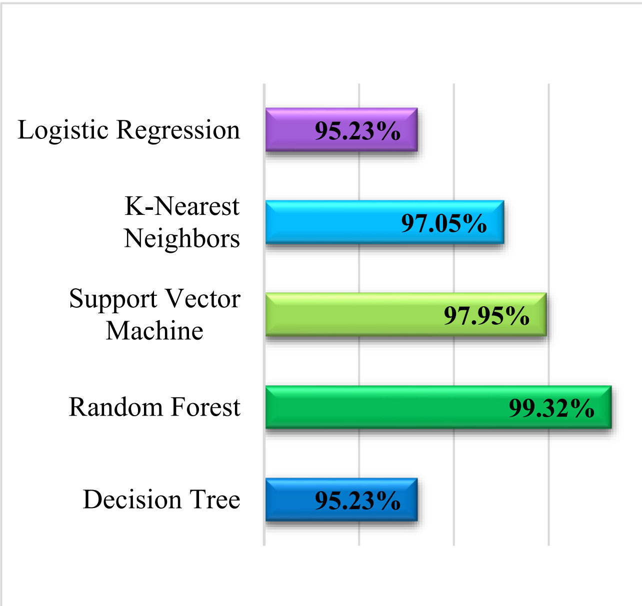

Figure 18: Accuracy Score of this ML model.

3.2. Land Information System

This research has developed a Mouza Plot-wise Land Information System (LIS) and it has been deployed on a cloud server, which offers ease of use and flexibility. The system, built with Python, HTML, and CSS and deployed via Stream Lit, provides the suitable land type for the selected plot. The app is compatible with both smartphones and laptops.

To see the land status for a specific plot, users must sequentially select the Division, District, Upazila, Union, Mouza, Sheet, and Plot number, then click "Calculate Land Status". This app helps people or local authorities to know if this land is suitable, less suitable, or not suitable for Agriculture (Figure 19).

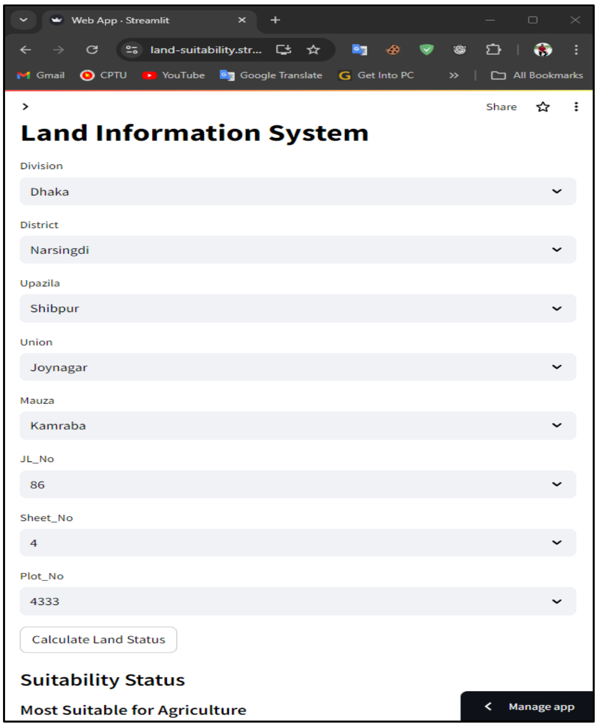

Figure 19: Plot Wise Land Status.

4. CONCLUSION

Through The findings of this study highlight the effective use of a Multi-Criteria Decision Analysis (MCDA) framework alongside Geographic Information System (GIS) techniques to assess agricultural land suitability in Bangladesh. By integrating six essential factors—crop intensity, slope, elevation, land use and land cover, flood depth, and soil type—the model provides a thorough spatial evaluation of regions most appropriate for sustainable agricultural practices. The resulting suitability map divides land into five unique categories, empowering policymakers, planners, and agricultural stakeholders to make informed choices regarding land management and crop planning.

The results highlight the significance of integrating remotely sensed data with on-the-ground information to improve spatial precision and inform decision-making processes. Utilizing smart agriculture and adopting sustainable land management practices in specific zones like Joynagar and Masimpur has the potential to improve agriculture outputs while ensuring beneficial sustainability in the long term. This approach is not only reproducible in other regions of Bangladesh but is also versatile enough to be applied in diverse environmental contexts around the globe. In the future, the incorporation of socioeconomic data and climate change forecasts could enhance the model's effectiveness in long-term agricultural planning. In conclusion, this research promotes the strategic use of land resources to enhance food security, mitigate environmental risks, and foster sustainable agricultural methods.

REFERENCES

Akıncı, H., Özalp, A. Y., & Turgut, B. (2013). Agricultural land use suitability analysis using GIS and AHP technique. Computers and electronics in agriculture, 97, 71-82.

Al-Shalabi, M. A., Mansor, S. B., Ahmed, N. B., & Shiriff, R. (2006, October). GIS based multicriteria approaches to housing site suitability assessment. In XXIII FIG congress, shaping the change, Munich, Germany, October (pp. 8-13).

Anley, M. A., Minale, A. S., Haregeweyn, N., & Gashaw, T. (2022). Assessing the impacts of land use/cover changes on ecosystem service values in Rib watershed, Upper Blue Nile Basin, Ethiopia. *Trees, Forests and People*, 7, 100212.

Anusha, B. N., Babu, K. R., Kumar, B. P., Sree, P. P., Veeraswamy, G., Swarnapriya, C., & Rajasekhar, M. (2023). Integrated studies for land suitability analysis towards sustainable agricultural development in semi-arid regions of AP, India. Geosystems and Geoenvironmental, 2(2), 100131.

Bandara, P., Weerasooriya, T., Ruchirawya, T.H., Nanayakkara, W.J.M., Dimantha, M.A.C., Pabasara, M.G.P. (2020). Crop Recommendation System. International Journal of Computer Application, 0975-8887.

Bandyopadhyay, S., Jaiswal, R. K., Hegde, V. S., & Jayaraman, V. (2009). Assessment of land suitability potentials for agriculture using a remote sensing and GIS based approach. International journal of remote sensing, 30(4), 879-895.

Church, R., Velle, C. (1974). The Maximal Covering Location Problem. Papers of the Regional Science Association. Papers of the Regional Science Association, 101-18.

Ferdous, S. F., Islam, G.M.T., Islam, A. K. M. S., Haque, A. (2023). Assessing Land Use Change and Its Impact on Ecosystem Services in Khulna Conurbation. Remote Sensing of Land, 7(1).

Haque, M. N., Fatema, K., & Joy, M. A. R. (2022). Crop suitability analysis by adopting geo-spatial algorithm: a case study of Sirajganj district (flood-prone area) in Bangladesh. Arab Gulf Journal of Scientific Research, 40(4), 392-414.

Kafy, A. A., Faisal, A. A., Sikdar, S., Hasan, M., Rahman, M., Khan, M. H., & Islam, R. (2020). Impact of LULC changes on LST in Rajshahi district of Bangladesh: a remote sensing approach. *Journal of Geographical Studies*, *3*(1), 11-23.

Kalogirou, S. (2002). Expert systems and GIS: an application of land suitability evaluation. Computers, environment and urban systems, 26(2-3), 89-112.

Kamau, S.W., Kuria, D., Gachari, M.K. (2015). Crop-Land Suitability Analysis Using GIS and Remote Sensing in Nyandarua Country, Kenya. Journal of Environment and Earth Science, 06.

Khan, M.A., Ahmad, R., Khan, H.H. (2022). Multi –Criteria Land Suitability Analysis for Agriculture Using AHP and Remote Sensing Data of Northern Region India. Geographic Information System and Application in Coastal Studies, 275.

Kihoro, J., Bosco, N. J., & Murage, H. (2013). Suitability analysis for rice growing sites using a multicriteria evaluation and GIS approach in great Mwea region, Kenya. SpringerPlus, 2, 1-9.

Li, J. (2023). Land suitability analysis of urban agriculture for different investment scenarios: Evidence from fuzhou of China. Heliyon, 9(10).

Mahato, R., Bushi, D., Nimasow, G., Dai Nimasow, O. (2024): Remote sensing and geographic informationsystem–based land suitability analysis for precision agriculture: a case of paddy cultivation in East Siang district of Arunachal Pradesh (India). In Remote Sensing in Precision Agriculture (pp. 151-173).

Malczwski Jacek. (1999). GIS-based Multi criteria Analysis. John Wiley & Sons.

Mokarram, M., & Aminzadeh, F. (2010). GIS-based multicriteria land suitability evaluation using ordered weight averaging with fuzzy quantifier: a case study in Shavur Plain, Iran. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 38(2), 508-512.

Müller, D., T. Kuemmerle and M. Rusu et al., 2009. Lost in transition: determinants of post-socialist cropland abandonment in Romania. Journal of Land Use Science, 4: 109–129

Ouchra, H, Belangour, A., Erraissi, A. (2023). Machine Learning Algorithms for Satellite Image Classification Using Google Earth Engine and Landsat Satellite Data: Morocco Case Study. IEEE Access, 71127-71142.

Perveen, F., Nagasawa, R., Uddin, M. I., & Delowar, H. K. (2007, June). Crop land suitability analysis using a multicriteria evaluation and GIS approach. In 5th International Symposium on Digital Earth (ISDE5), June (Vol. 5, No. 9).

Roy, J., & Saha, S. (2018). Assessment of land suitability for the paddy cultivation using analytical hierarchical process (AHP): A study on Hinglo river basin, Eastern India. Modeling Earth Systems and Environment, 4, 601-618.

Saha, S., Sarkar, D., Mondal, P., & Goswami, S. (2021). GIS and multi-criteria decision-making assessment of sites suitability for agriculture in an anabranching site of sooin river, India. Modeling Earth Systems and Environment, 7, 571-588.

Sarkar, D., Saha, S., & Mondal, P. (2023). Modelling agricultural land suitability for vegetable crops farming using RS and GIS in conjunction with bivariate techniques in the Uttar Dinajpur district of Eastern India. Green Technologies and Sustainability, 1(2), 100022.

Xue, L., Cao, P., Xu, D., Guo, Y., Wang, Q., Zheng, X., ... & You, A. (2023). Agricultural land suitability analysis for an integrated rice–crayfish culture using a fuzzy AHP and GIS in central China. Ecological Indicators, 148, 109837.

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