Change Detection of Invasive *Swietenia macrophylla* (Mahogany) in Bohol Man-Made Forest from 2013-2023 Through Vegetation and Soil Spectral Indices Using Landsat 8 in Google Earth Engine

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Abstract

Swietenia macrophylla (Mahogany), an invasive species introduced in Bohol over half a century ago to mitigate deforestation, was primarily used to reforest the now ecologically vulnerable Bohol Man-Made Forest. Allelopathic effects of IAPS on Philippine ecosystems were previously unknown, but recent studies show Mahogany inhibits nearby biodiversity. This study employed remote sensing to delineate and classify the Mahogany population in Bohol Man-Made Forest, detect land classification differences over ten years, and determine its effects on local vegetation and soil using various indices. Google Earth Engine was utilized to select Landsat 8 Level 2 images, apply cloud masks, and create a 70:30 generalization for Random Forest classification. The timeline and mapping units for using Landsat in training data relied heavily on a 2018 reference map. With this, a key limitation was the assumption that Mahogany points identified in 2018 remained unchanged in 2013 and 2023, based on its growth development. Results show 90.77% and 91.36% overall accuracy for classification in 2013 and 2023. Mahogany class had the highest positive change in total area at 5.334 sq. km. Non-Mahogany vegetation showed the highest change with a decrease of 6.039 sq. km. Bivariate maps of NDVI, MSI, and BSI showed Mahogany's effects on non-Mahogany vegetation, degrading health and moisture content, and consistently preventing small vegetation growth, allowing high intensity of bare soil. This study recommends planting the right trees in the right places and enforcing strict reforestation policies, especially in forests and protected areas, to preserve natural biodiversity.

1. Introduction

1.1 Background of the Study

Invasive alien plant species (IAPS) are plants that inhabit areas where they do not natively occur due to anthropogenic introduction, with occasional instances being caused by natural erosion mechanisms (Kumar Rai & Singh, 2020). IAPS employ various invasion mechanisms to successfully penetrate the native ecosystem, eventually disrupting the relationships of the resident species therein. Allelopathy, the biological phenomenon wherein a plant species produces chemicals that affect other plants or soil nutrients around it either negatively or positively, has been studied to be pervasive in many IAPS (Kalisz et al., 2021). These anti-plant allelochemicals contribute to the studied occurrence of IAPS thriving at the expense of decreasing native plant populations, weakening the health of both resident flora and fauna (Vilà et al., 2011).

In the Philippines, proliferation of IAPS has established roots from the prehistoric and colonial eras of the country. *Swietenia macrophylla* (big leaf Mahogany), currently one of the most prominent IAPS in the Philippines, was introduced to the country in as early as 1907 during the American regime (Baguinon et al., 2005). It is an evergreen tree species with heights ranging from 30 m to 40 m and diameters from 1.5 to 2 m (Dayan, 1995). The tree gradually spread throughout the archipelago as a popular means for reforestation due to its undemanding requirements and resiliency for survival (Baguinon et al., 2005). The invasive nature of big leaf Mahogany has remained largely unknown, with recent studies still continuously demonstrating its negative effects on surrounding ecosystems. In particular, *Swietenia macrophylla* was found to display strong inhibitory allelopathic effects on the growth of other plants, specifically radicle lettuce and Narra tree (*Pterocarpus indicus*) seedlings (Mukaromah et al., 2016; Galano & Rodriguez, 2021). Furthermore, it was also found to inhibit biodiversity of both native undergrowth and tree species (Galano & Rodriguez, 2021).

Bohol Man-Made Forest, a prominent tourist attraction in Bohol, started as a reforestation effort initiated more than half a century ago (Reyes Jr, 2019; Pagunsan, 2023). *Swietenia macrophylla* was the reforestation species used for the project, owing to its fast growth and spread which were deemed ideal qualities for reforestation at the time (Baguinon et al., 2005). The man-made forest, currently located in the municipalities of Loboc and Bilar, has grown to occupy around 115.21 ha of total land area and a 3 km stretch of the Bohol national road as of 2019 (Reyes Jr., 2019). It has been observed as a dead zone for biodiversity, owing to the relative absence of other species on its undergrowth sections (Pagunsan, 2023).

1.2 Objectives

The primary objective of this study is to utilize remote sensing techniques in Google Earth Engine to determine and monitor the effects of *S. macrophylla* in Bohol Man-Made Forest on the surrounding soils and vegetation from 2013 to 2023. Specifically, this study aims to locate and classify areas covered by *S. macrophylla* in Bohol Man-Made Forest. It seeks to calculate land coverage of *S. macrophylla* after a period of 10 years from 2013 to 2023. It assesses the effects of *S. macrophylla* on surrounding vegetation from 2013 to 2023 through NDVI and MSI differencing, supported by bivariate mapping. Consequently, it assesses the effects of *S. macrophylla* on surrounding soil from 2013 to 2023 through BSI and MSI differencing, supported by bivariate mapping.

1.3 Significance of the Study

Understanding the nature and extent of the effects of *S. macrophylla* in the study area would be beneficial for ecological,

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economical, and administrative purposes. The results of science-based monitoring and evaluation can be used for targeted administrative management, control, and lawmaking. This supports the United Nations Sustainable Development Goal (SDG) 15 Life on Land, particularly Target 15.8, which urges countries to prevent the introduction and reduce the impact of invasive alien species on land and water ecosystems.

Contributing factors of adverse ecological impacts can be identified and minimized, which may lead to more robust native ecosystems. In support of SDG 12 Responsible Consumption and Production, especially Target 12.2 (sustainable management and use of natural resources), the monetary damage done by invasive Mahogany can also be assessed in comparison to the benefits it brings to the economy of the country, allowing for fairer valuation of risks and returns.

Moreover, because the current condition of literature still suggests a lack of investigation in the study area, the study will illustrate the benefits and limitations of using remote sensing that is novel in the locality. This addresses SDG 13 Climate Action by enhancing data-driven decision-making and improving adaptive forest management strategies in response to environmental changes. This methodology and results of this study can cover large areas while still outputting accurate results, which can contribute to the literature and knowledge gap in the Philippines about the effects of invasive species on ecology and forestry. Further, the results of this study will serve as a supplement for further research to advance the field of interest in the country.

2. Methodology

2.1 Study Area

The scope of this study is a 1-kilometer buffer zone around the Loboc-Bilar Mahogany plantations (Figure 1). An existing map of the plantation dated 2018 from Reyes (2019) was used to produce a shapefile of the precise region of interest in this research. The shapefile was constructed using georeferencing and digitizing procedures in QGIS Firenze (Version 3.28).

2.2 Data Instrumentation and Pre-Processing

2.2.1 Satellite Imagery Selection: The satellite dataset used was USGS Landsat 8 Level 2, Collection 2, Tier 1. This satellite has a spatial resolution of 30 by 30 meters, a temporal resolution of 16 days, and a radiometric resolution of 12 bits. It has seven spectral bands composed of one coastal aerosol, three visible bands, one near-infrared, and two shortwave infrareds. Along with this, the Landsat 8 mission was launched in 2013, which is appropriate for a 10-year period to examine the growth of *S. macrophylla*. Before gathering Landsat 8 data, a bounding polygon around the study location was established to filter out images. Instead of determining the least cloud cover, a manual inspection of browsing images was performed to determine whether the given study site was cloud-covered.

After scanning satellite images, an image collection for each year involved in the project, 2013, 2018, and 2023 was created in Google Earth Engine. Filtering methods concerning dates and regions of interest were taken into consideration. The year 2018 was used as the training and testing dataset as it contains the existing ground truth data for *S. macrophylla* plantation.

2.2.2 Cloud Masking and Compositing: A function was created to perform cloud masking based on the information of the 'QA_PIXEL' and 'QA_PIXEL_Bitmask' bands of the image. Cloud masks were created employing bitmask information derived from the combination of dilated clouds, cirrus clouds, clouds, and cloud shadows, and applying bitWise filtering. Individual cloud masks from each year were retrieved, combined, and applied to the images of 2013, 2018, and 2023. Combining cloud masks was done to remove the cloud area from the change detection.

2.2.3 Spectral Indices: Spectral indices were computed using the wavelength bands of the satellite images, along with the provided formula for the index. These were added as bands in the image. In this study, the spectral indices used were the Normalized Difference Vegetation Index (NDVI) and Moisture Stress Index (MSI) for vegetation, and Bare Soil Index (BSI) for the soil features in the study site (Equations 1-3). NDVI assesses the vegetation greenness, vegetation density, and changes in plant health with the range of values from -1 to 1. MSI evaluates the sensitivity to increasing leaf water content, where higher values are equal to greater water stress and less water content. Lastly, BSI improves the identification of bare land features and fallow land where greater BSI values indicate more exposed soil on the Earth's surface without plant cover (Nguyen et al., 2021).

$$NDVI = \frac{NIR - Red}{NIR + Red} \tag{1}$$

$$MSI = \frac{SWIR}{NIR} \tag{2}$$

$$BSI = \frac{(SWIR + Red) - (NIR + Blue)}{(SWIR + Red) + (NIR + Blue)} \tag{3}$$

where *NDVI* = Normalized Difference Vegetation Index
MSI = Moisture Stress Index
BSI = Bare Soil Index
Blue = 'SR_B2' or Band 2,
Red = 'SR_B4' or Band 4,
NIR = 'SR_B5' or Band 5,
SWIR = 'SR_B6' or Band 6

2.3 Random Forest Classification

2.3.1 Image Classification: Training and testing datasets were identified across the images. This was done through selecting 50 well-distributed sample points in the image, each representing Mahogany, non-Mahogany vegetation, water, soil, and built-up areas using base maps. For the Mahogany sample for the year 2013 and 2023, the Mahogany points determined in 2018 were used as part of the limitations of the study. Due to the unavailability of the multi-temporal ground validation data, an assumption was made that the Mahogany tree samples in 2018 were still present in the other years considering that it is still a tourist attraction which originally a reforestation project. Each sample point was stored in a feature collection along with respective property values for land cover classification. These sample points were randomized to achieve a 70:30 ratio of training to testing data, also known as generalization.

The Random Forest algorithm constructs multiple decision trees by randomly sampling subsets of training instances and predictor variables at each node, reducing sensitivity to data quality and overfitting relative to other machine learning methods (Belgiu & Drăguţ, 2016). It performs robustly in hyperspectral classification, addressing the curse of dimensionality and multicollinearity among spectral bands.

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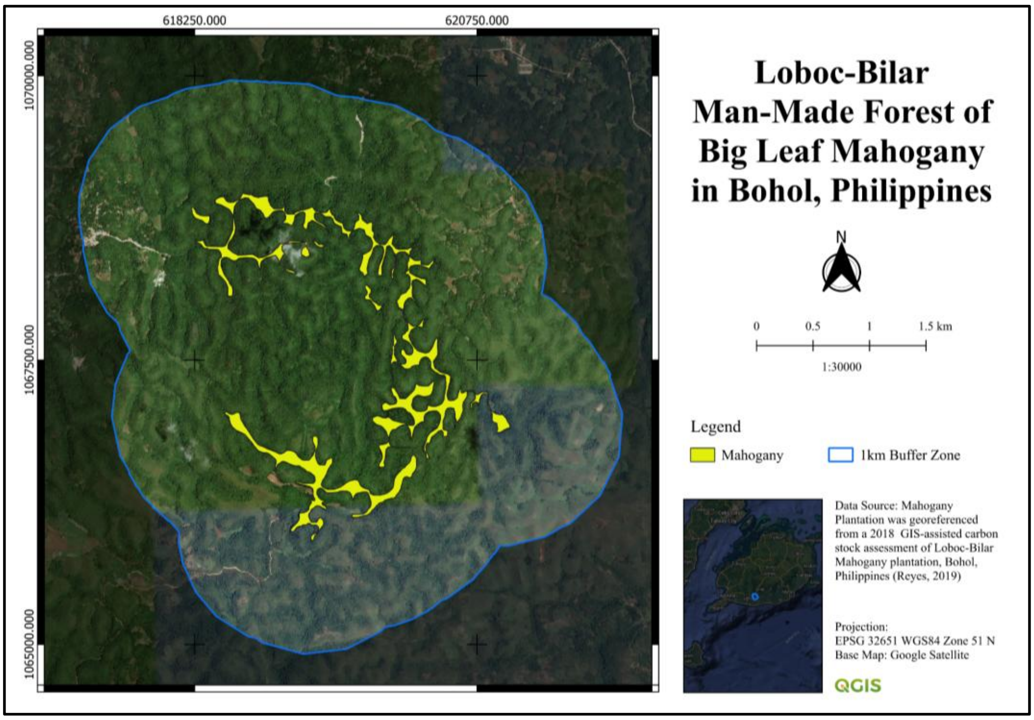

Figure 1. Study Area at Loboc-Bilar Man-Made Forest of Big Leaf Mahogany in Bohol, Philippines.

A Random Forest Classifier was applied each year through the GEE function, ee.Classifier.smileRandomForest(), which has decision trees set to a default of 1000, corresponding to the standard default number of decision trees. However, the maximum number of decision trees were explored to find the optimum number of decision trees that will give constant accuracy yet less processing space. The training input produced is used to train the Random Forest classifier. The resulting classifier was used to classify the images.

2.3.2 Accuracy Assessment: To assess the classification performed for each of the satellite images per year, 30% of the initial labeled sample points (Section 2.3.1) were randomly set aside as testing data, separate from the training set to prevent data leakage. Several accuracy metrics were calculated using different GEE functions which automatically calculate the confusion matrix, overall accuracy, kappa, consumer's accuracy, and the producer's accuracy for each of the classified images.

2.4 Change Detection

2.4.1 Classification Change Detection: To perform change detection using classified classes, pixel values and corresponding land cover classes were identified and compared. Multiplying the 2013 image with base 10 and adding the 2023 image thereafter resulted in a satellite image with pixel values where the tenth digit corresponds to its initial classification and the ones digit corresponds to its final classification after 10 years. These possible combinations were then described and visualized. Total area for each combination was computed to determine the most change happened in terms of class.

2.4.2 Indices Change Detection: Change detection for the spectral indices was done to identify the connection between the change in period as well as to determine the possible effects or changes in the spectral characteristics of the features. Comparisons of the values per index were executed through subtracting matching pixels and their indices. To quantify these changes, the mean differences per land cover classification were calculated. Bivariate choropleth maps were also used to visualize the spatial distribution of changes across the landscape.

3. Results and Discussion

3.1 Random Forest Classification

Figure 2 shows the classified land cover classes of the study area for 2013 and 2023. Five land cover classes, Mahogany, non-Mahogany vegetation, soil, water, and built-up, were identified for both years with varying area extents that illustrate their change of spread through time. The white portions signify the masked-out areas that were previously occupied by cloud features, excluded from the final satellite classification.

The result from 2013 shows that most of the study area is classified as non-Mahogany vegetation (green), with the second most populous class being Mahogany (yellow). Both years display the soil, water, and built-up classes to a relatively minimal extent, which is valid as the study site is well situated within a forest area. The major difference can be seen in 2023, however, where it is evident that the Mahogany (yellow) class spread in area, becoming larger and denser around the Mahogany cluster in the 2013 map. In a practical sense, this effectively illustrates the invasive nature of Swietenia macrophylla, showcasing its proliferation at the expense of the non-Mahogany vegetation it neighbors.

3.1.1 Accuracy Assessment: From Table 1, the highest and lowest overall accuracy, 90.77% and 91.36%, was seen in 2013 and 2023, respectively. This trend in accuracy was shown as well in the Kappa percentage of their classification except for 2018 having the highest Kappa coefficient of 89.26%. All overall accuracy values were deemed to be acceptable as it is more than 85% (Campbell, 2002; Adhikary et al., 2019 as cited by Dash et al., 2021).

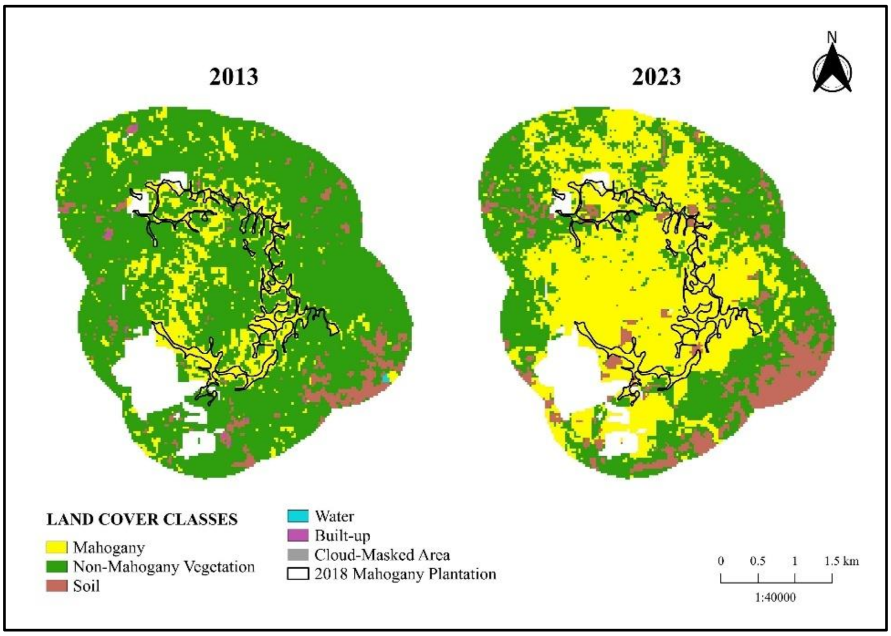

Figure 2. 2013 and 2023 Land Cover Classification using Random Forest.

Year	Overall Accuracy (%)	Kappa (%)	Consumer's Accuracy (%)					Producer's Accuracy (%)				
			Mahogany	*Non-Mahogany Vegetation*	*Soil*	*Water*	*Built-up*	*Mahogany*	*Non-Mahogany Vegetation*	*Soil*	*Water*	*Built-up*
2013	90.77	88.39	100.00	84.21	75.00	100.00	100.00	76.92	100.00	100.00	100.00	78.57
2018	91.43	89.26	100.00	85.71	78.57	100.00	93.33	84.62	85.71	91.67	100.00	93.33
2023	91.36	89.14	100.00	100.00	72.73	100.00	93.75	94.44	100.00	94.12	100.00	75.00

Table 1. Accuracy Assessment of Random Forest Classification for 2013 and 2023.

However, soil areas in all periods were below the 85% threshold of high accuracy. This would imply the least priority in the reliability and usefulness of the soil for classifying other data using the produced classification. Moreover, with this classification, consumer's validation for Mahogany and water were at most 100%. For the producer's accuracy, water areas remain to be at high accuracy while Mahogany and built-up had an accuracy lower than the 85% threshold. This high accuracy for water could be due to the distinct spectral signature and spatial homogeneity of the sea areas surrounding the island, where its samples came from. These stable coastal waters reduce spectral variability, minimizing classification errors and enhancing accuracy. On the other hand, despite having ground truth data of the Mahogany plantation, the producer could not make a higher accuracy from the samples.

These high accuracies, particularly for Mahogany, were influenced by a key limitation in the assessment, the assumption that Mahogany training points identified in 2018 remained unchanged in 2013 and 2023. This reliance on assumed static training data may have led to overestimated classification accuracy and reduced the reliability of detecting actual changes over time. Scenarios such as natural and environmental events including typhoons may have altered the ground truth from 2018, or these may have been subjected to harvesting of timber or land conversion for agriculture. Therefore, while our accuracy assessment yields high values, caution is advised when interpreting these results or applying them in future studies, as the underlying assumption must be viewed cautiously as proxies rather than actual validations.

3.2 Change Detection

Figure 3 illustrates the total land cover change from 2013 to 2023, revealing significant shifts in vegetation composition and land use within the study area. Mahogany experienced the most substantial positive change, increasing by 5.334 sq. km, from 2.821 sq. km in 2013 to 8.155 sq. km in 2023 (Table 2). This dramatic expansion underscores the invasive nature of Mahogany, whose allelopathic properties enable it to dominate and suppress neighboring plant communities, limiting the regeneration and growth of native vegetation. In contrast, non-Mahogany vegetation saw the largest decline, decreasing by 6.039 sq. km, from 12.347 sq. km to 6.308 sq. km over the same period. This inverse relationship between Mahogany gain and non-Mahogany loss highlights a likely displacement effect, were Mahogany either replaced or outcompeted existing native or diverse plant species.

A closer analysis of land cover class transitions provides deeper insight into the patterns observed in Figure 3. The most prominent change is the conversion of 5.609 sq. km (Table 3) from non-Mahogany vegetation to Mahogany, reflecting a strong invasion into areas previously dominated by native or mixed vegetation, as shown in Figure 4. This directional shift suggests that Mahogany has been expanding outward from its established stands, initially affecting neighboring non-Mahogany areas. Such a spread pattern reinforces Mahogany's invasive behavior, likely facilitated by its allelopathic properties and competitive advantage in disturbed or reforested environments.

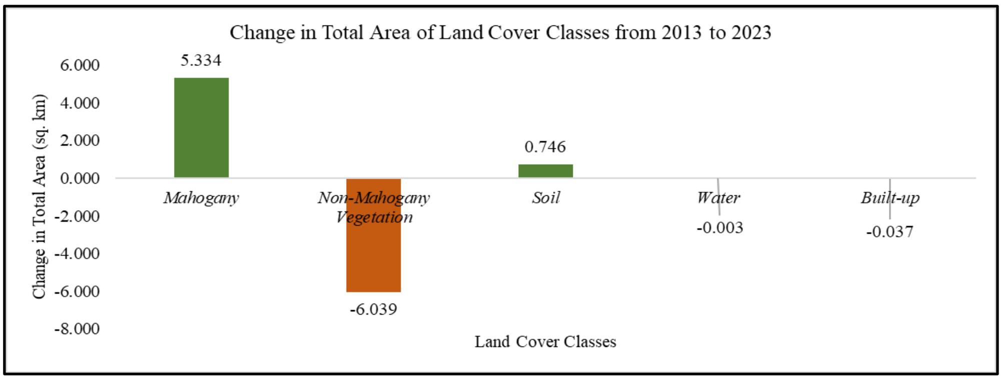

Figure 3. Change in Total Area of Land Cover Classes from 2013 to 2023.

Year	Total Area per Land Cover Class (sq. km)					Area (sq. km)
	Mahogany	*Non-Mahogany Vegetation*	*Soil*	*Water*	*Built-up*	
2013	2.821	12.347	0.751	0.007	0.037	15.963
2023	8.155	6.308	1.497	0.004	0.000	

Table 2. Total Area per Land Cover Class in 2013 and 2023.

In parallel, 2.457 sq. km of Mahogany remained unchanged, emphasizing the long-term persistence of established Mahogany populations. In contrast, only 0.284 sq. km transitioned from Mahogany back to non-Mahogany vegetation, and 0.08 sq. km shifted to bare soil. These minor reversals highlight Mahogany's resilience once it becomes dominant. The few patches where Mahogany reverted to non-Mahogany vegetation are likely due to environmental constraints, such as soil degradation or microclimatic stress, that reduced Mahogany's competitive edge and allowed nearby native vegetation to recolonize.

Interestingly, the largest unchanged land cover category was non-Mahogany vegetation, with 5.775 sq. km showing no transformation. This suggests a considerable portion of the landscape has remained ecologically stable and may currently exhibit resistance to the Mahogany invasion. As indicated in Figure 4, these areas are spatially distant from early Mahogany areas, supporting the idea that Mahogany's spread radiates outward and initially impacts nearby vegetation. The apparent isolation of these non-Mahogany patches may have temporarily shielded them from invasion. However, without proactive management, this stability may not persist as Mahogany continues to expand across the landscape.

Furthermore, 0.995 sq. km loss of non-Mahogany vegetation to bare soil points to potential degradation or land clearing, which could make these areas more vulnerable to future Mahogany invasion. Limited recovery is seen in transitions from soil to vegetation, with only 0.077 sq. km regenerating into Mahogany and 0.232 sq. km into non-Mahogany vegetation, indicating slow and uneven landscape recovery.

Given the forested nature of the area, transitions involving built-up and water classes were minimal, reflecting relatively stable patterns of human land use and hydrological features. However, the small observed shifts from built-up areas to Mahogany and non-Mahogany vegetation, each at 0.014 sq. km, may reflect vegetation regrowth in abandoned or marginally developed zones.

It is important to recognize that the reliability of the change detection results depends on the accuracy of the underlying image classification, and thus any classification uncertainties should be carefully considered when interpreting temporal changes.

Land Cover Change	Area (sq. km)
Mahogany to Mahogany	2.457
Mahogany to Non-Mahogany Vegetation	0.284
Mahogany to Soil	0.082
Non-Mahogany Vegetation to Non-Mahogany Vegetation	5.705
Non-Mahogany Vegetation to Mahogany	5.609
Non-Mahogany Vegetation to Soil	0.995
Soil to Non-Mahogany Vegetation	0.232
Soil to Soil	0.407
Soil to Mahogany	0.077
Soil to Built-up	0.002
Water to Soil	0.008
Built-up to Mahogany	0.014
Built-up to Non-Mahogany Vegetation	0.014
Built-up to Soil	0.008
Built-up to Built-up	0.002

Table 3. Land Cover Change Detection from 2013 to 2023.

3.3 Indices Change Detection

Mean changes in NDVI, MSI, and BSI across land cover transitions between 2013 and 2023 reveal clear spectral signatures associated with Mahogany expansion and allelopathic nature (Table 4). The most substantial positive shifts in NDVI (+0.222) and corresponding declines in MSI (−0.173) and BSI (−0.199) occurred in areas transitioning from soil to Mahogany, indicating significant increases in vegetation cover, reduced moisture stress, and decreased bare soil exposure, evidence of successful Mahogany establishment.

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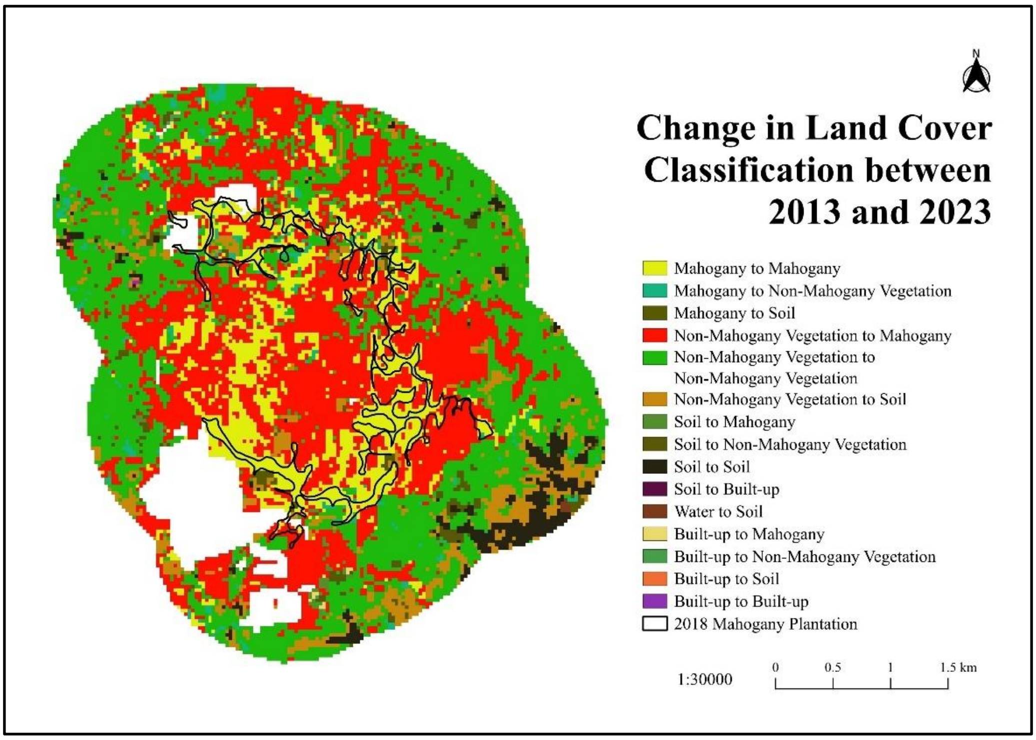

Figure 4. 2013 and 2023 Change in Land Cover Classification.

Land Cover Change	NDVI	MSI	BSI
Mahogany to Mahogany	-0.01499506	0.00194136	0.0105938
Mahogany to Non-Mahogany Vegetation	-0.03111103	0.0223177	0.03573325
Mahogany to Soil	-0.1855491	0.10961277	0.1535283
Non-Mahogany Vegetation to Mahogany	0.01548903	-0.03370593	-0.0359067
Non-Mahogany Vegetation to Non-Mahogany Vegetation	0.01798503	-0.03271809	-0.03331488
Non-Mahogany Vegetation to Soil	-0.05122952	0.02324055	0.03354106
Soil to Mahogany	0.22158037	-0.17345111	-0.19915205
Soil to Non-Mahogany Vegetation	0.18016641	-0.15861268	-0.16447396
Soil to Soil	0.01547367	-0.01510037	-0.01197728

Table 4. Mean changes in NDVI, MSI, and BSI values across land cover transitions from 2013 to 2023. Positive or negative values indicate the direction and magnitude of change.

Transitions from non-Mahogany vegetation to Mahogany also showed modest improvements across indices, reinforcing Mahogany's competitive advantage and canopy densification. In contrast, areas where Mahogany was replaced by soil exhibited the steepest NDVI decline (−0.186) and substantial increases in MSI (+0.110) and BSI (+0.154), suggesting degradation and exposure following canopy loss.

These quantitative trends are supported by the bivariate maps (Figure 5), which spatially illustrate Mahogany's impact on ecosystem structure. NDVI maps show increasing vegetation greenness in expanding Mahogany zones, while adjacent non-Mahogany areas frequently display declining NDVI, likely reflecting allelopathic suppression and competitive exclusion.

The MSI bivariate map further substantiates this trend. Mahogany zones exhibited stable or decreasing MSI values, indicating lower moisture stress due to the species' ability to maintain water access even under competitive conditions. Mahogany-dominated areas maintain or reduce stress levels, while surrounding vegetation experiences increased moisture stress, likely due to water competition. Similarly, BSI maps indicate consistently low bare soil exposure under Mahogany canopies, contrasting with elevated BSI values in neighboring areas, especially at plantation margins, where undergrowth suppression is most evident.

Collectively, the bivariate maps reinforce the interpretation that Mahogany's spatial expansion correlates with declining vegetation health, increased environmental stress, and suppressed regeneration in neighboring areas. These spectral patterns, when contextualized with land cover changes, provide robust evidence of Mahogany's invasive impact on the forest ecosystem over the decade. The consistency of these spectral indicators across multiple indices strengthens the conclusion that Mahogany is not merely persisting but actively altering the landscape in ecologically significant ways.

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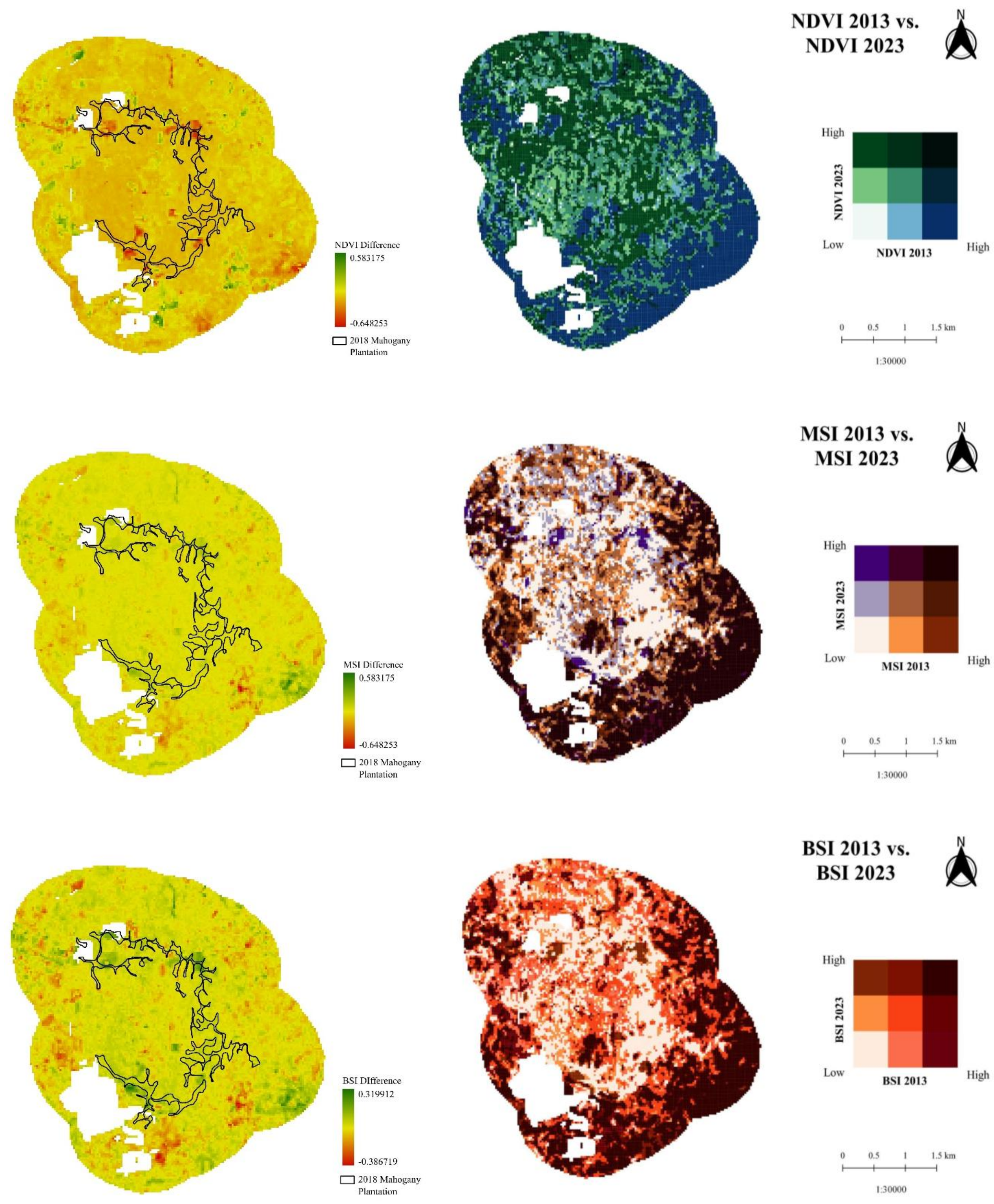

Figure 5. Difference and Bivariate Maps of Spectral Indices (NDVI, MSI, and BSI) between 2013 and 2023.

4. Conclusion

This study employed remote sensing techniques through Google Earth Engine to evaluate the ecological effects of Swietenia macrophylla (Mahogany) in the Bohol Man-Made Forest from 2013 to 2023.

Using Random Forest classification on Landsat 8 imagery, the study achieved overall classification accuracies exceeding 90%, above the commonly accepted 85% threshold. While the Mahogany class exhibited consistently high user's accuracy, the producer's accuracy was moderately lower, particularly due to limitations in training data.

A central limitation of this study was the reliance on 2018 ground truth data to represent Mahogany presence in both 2013 and 2023. This assumption, though based on the species' long lifespan and persistent growth habit, may have introduced classification biases and affected the accuracy of temporal comparisons. Despite this, the results strongly indicated that Mahogany exhibited the most significant positive land cover change, expanding by approximately 5.334 sq. km over the decade. This expansion came primarily at the cost of non-Mahogany vegetation, with over 5.609 sq. km of native or mixed vegetation transitioning to Mahogany, reinforcing its invasive and competitive nature.

Bivariate analysis of NDVI, MSI, and BSI confirmed Mahogany's ecological impact. NDVI values increased in Mahogany areas while declining in adjacent non-Mahogany zones, suggesting suppressed health and vigor in native vegetation. MSI results showed rising moisture stress in nearby vegetation, potentially caused by Mahogany's high-water uptake and allelopathic properties. BSI maps revealed increased soil exposure near Mahogany stands, further indicating the suppression of undergrowth and regeneration.

These findings illustrate a clear ecological trend that Mahogany not only expands spatially but also alters vegetation health, soil conditions, and forest structure. Its spread is spatially connected, primarily affecting adjacent native vegetation before reaching more isolated zones, suggesting that remaining native patches may only be temporarily resistant.

To enhance the robustness of future research, the study recommends the use of updated, year-specific ground truth data and higher-resolution satellite imagery. Hyperspectral remote sensing could offer deeper insights into species-level distinctions and structural impacts. Field validation is especially critical to calibrate remote sensing outputs and develop a spectral or phenological index specific to *S. macrophylla*.

Ultimately, this study contributes to the growing body of knowledge on invasive species dynamics in tropical forests and supports the urgent need for science-based management strategies. The findings underscore the extent of the allelopathic effects of Swietenia macrophylla and signify a call to action to improve the area's biodiversity. The results emphasize the importance of planting ecologically appropriate native species in reforestation programs and enforcing more stringent regulation of invasive tree plantations, especially in ecologically sensitive and protected areas. In the Philippine context, an effective localized management of invasive species will require sustained monitoring of IAPS with collaboration of different concerned organizations. Continuous monitoring of S. macrophylla species in Bohol Man-Made Forest, as well as of other invasive species in Philippine landscapes is significant for a deeper understanding of the dynamics of how these invasive species spread in a particular area, which could eventually contribute to stricter policies for IAPS. Without such interventions, Mahogany's continued expansion threatens to further degrade native biodiversity and forest resilience in Bohol and other affected landscapes in the Philippines.

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