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Detecting Vegetation Cover Change in Reforestation Sites from 2013 to 2019 in Central Visayas, Philippines Using Remotely Sensed Data

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Abstract

Assessment of reforestation success is indispensable to document the impact of the project and whether it has achieved the intended objectives. Globally, the use of remotely sensed data is a widely accepted method to track changes in reforestation sites. Hence, this study investigated the changes in Normalized Difference in Vegetation Index (NDVI) using LandSat 8 images to assess vegetation cover in National Greening Program reforestation sites in Central Visayas from 2013 to 2019. Results showed that there was a minimal increase of NDVI (0.002 to 0.07) and a 9% (286 ha) gain of dense vegetation cover in the sampling sites which may be attributed to the reforestation activity. Forest gain was highest in Negros Oriental (262 ha) while Cebu lost 29 ha of dense vegetation. Field data confirmed that tree biomass density (245 Mg/ha) was highest in Negros Oriental and lowest in Cebu (78 Mg/ha). Analysis of variance revealed that there was no significant change in forest cover between 2013 and 2019. The program reported a total of 42,000 ha as their accomplishment in the region which was planted with 500 fast-growing tree species per hectare. If the seedlings successfully survived, this could have increased considerably forest cover in the region by up to 60%. Thus, it is important to revisit the reforestation program's policies and processes to build on the strengths and avoid mistakes for future projects. It is also vital to integrate cost-effective, accurate, and real-time monitoring schemes that ensure the attainment of the key objectives.

***Keywords**:* change analysis, LandSat 8, Normalized Difference in Vegetation Index, reforestation

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1. Introduction

The forest ecosystem covers 30.8% of the global land area (Food and Agriculture Organization and United Nations Environmental Programme [FAO and UNEP], 2020). It provides vital services such as water storage and purification, flood control, climate regulation, carbon storage, and maintenance of biodiversity richness among others. However, heavy dependence on forest resources has led to the rapid loss of these resources over the past decades at an alarming rate. FAO and UNEP (2020) estimated that the net loss of forest area from 2010 to 2020 is at 4.7 M ha per year. The study of Hansen *et al.* (2013) showed that the largest forest loss occurs in the tropics which totaled almost 32% of the global total forest loss.

In the Philippines, forest resources suffered a continuous decline through the years due to exploitation. It was estimated to have reduced from 12 M ha in 1960 to about 6.8 M ha in 2010 or 23% of the country's overall land area (FAO, 2010). An assessment made by Department of Environment and Natural Resources – Forest Management Bureau (DENR-FMB) (2010), revealed that from 2003 to 2010 alone, there was an annual drop of 46,954 ha. The national decrease in forest cover was attributed to the decline taking place in several regions of the country.

Central Visayas is among the regions in the Philippines with low and declining forest cover from 74,869 ha in 2003 to 62,033 ha in 2010 (DENR-FMB, 2010). This status is partly attributed to the fact that it contains more alienable and disposable lands (65%) compared with forest lands (35%). Despite that, Central Visayas due to its distinct biogeographic characteristics (Fernando *et al.*, 2009) is home to several endemic species threatened with extinction (Posa *et al.*, 2008). It contains, as well, identified key priority areas for biodiversity conservation (Ambal *et al.*, 2012). In addition, about a quarter of the families in the region relied on forest resources for income (Chokkalingam *et al.*, 2006).

To compensate for forest loss and to rehabilitate denuded forestlands, Executive Order No. 26 created the National Greening Program (NGP) in February 2011. It targets to plant some 750 million to 1.5 billion trees in the public domain such as forestlands, protected areas, and ancestral domains for a period of six years from 2011 to 2016. This program received commendation among several sectors as it tries to harmonize efforts from the government and private sectors and has broader objectives not only to increase forest cover but also to reduce poverty and enhance food security.

At the end of the program in 2016, DENR-FMB (2016) reported that the program planted a total of around 1.37 billion seedlings in 1.66 M ha of land and created jobs for 4.02 M people. To sustain the success of the program, a new Executive Order No. 193 in 2015 was issued to expand the coverage of the NGP and to extend its implementation from 2016 to 2028. However, questions were asked as to how these accomplishment figures translate to changes in forest cover. While early establishment success measures in terms of the number of seedlings, total area planted, and survival rate within three years, may indicate future success, they do not warrant those objectives are met.

Reforestation success requires regular assessment of the outcomes if it has achieved the intended objectives. Assessment requires a sufficient budget which is not usually incorporated or integrated with reforestation projects as the allocated budget is normally limited and prioritized for implementation. However, assessment of success is also an indispensable process to reforestation to document the extent of the impact of the reforestation on the changes in forest cover. Globally, there is increasing utilization of modern technology such as remote sensing to assess forest change (Hansen *et al*., 2013). Given its advantages, being cost-effective in acquiring comprehensive spatial and temporal information and extracting the spectral features which have wide applications such as in analyzing vegetation density, forest cover, vegetation type, and land use changes (Jiang *et al*., 2008). Assessment by this method is widely adapted in global and regional studies as an alternative and cost-effective way to monitor continuously the impact of the project through time.

One of the frequently used indexes in vegetation studies to measure the state of health and vegetation vigor is the normalized difference vegetation index (NDVI) (Lyon *et al*., 1998; Ke *et al*., 2015). This index was found to be more sensitive in detecting the change in crown density than other vegetation indexes and a suitable indicator for analysis of changes resulting from degradation (Meneses-Tovar *et al*., 2011; Zaitunah *et al*., 2018). The measured value is influenced by the state of health and vigor of the vegetation observed. It may range from -1.0 to 1.0. Negative values are associated with water bodies. While very low positive values (between 0 and 0.2) correspond to bare soil or rock, moderate positive values represent shrub and grassland (0.2 to

0.5), and a high value indicates tropical rainforests (0.6 to 0.8) (Hassini *et al.*, 2006; Weier and Herring, 2008; Othman *et al*., 2018).

Hence, this study aimed to detect changes in vegetation cover in NGP sites in Central Visayas between the establishment phase and post-planting phase using NDVI. The remotely sensed data in this study can provide site-specific and reliable calculations on the temporal variation in the vegetation of NGP in Central Visayas which gives useful information to the outcome of the project.

2. Methodology

2.1 Research Environment

This study assessed the vegetation cover changes in the NGP sites in Central Visayas, Philippines using NDVI. Sampling sites in the study were identified based on the list of NGP grantees in the region from 2011 to 2013. Shapefiles of their corresponding reforestation sites were also obtained from the DENR-NGP office. Selection criteria for sampling sites include the type of the grantee, the type of commodity planted, and the area of the reforestation sites. The current study selected those reforestation sites managed by people's organizations (POs), planted with trees as the commodity, and with at least 10 ha reforestation area.

From the selection criteria, a total of 30 grantees were randomly selected from the four provinces in the region. Seven were chosen from Bohol, 11 were from Cebu, nine were from Negros Oriental, and three were from Siquijor (see Figure 1). This number is proportional to the number of grantees in each province and represents 15% of the total grantees in the region from 2011 to 2013. The sampling area covers a total of about 3,363 ha; 503 ha in Bohol, 1,608 ha in Cebu; 1086 ha in Negros Oriental; and 166 ha in Siquijor.

At least two LandSat 8 (OLI and TIRS) images were used to measure NDVI in each sampling site to compare vegetation cover. One image was selected during the establishment phase (between 2013 to 2015) as a baseline for the actual condition of the forest before the reforestation project. The second image was selected during the post-planting phase (between 2018 to 2019) to provide a comparison with the status of the forest.

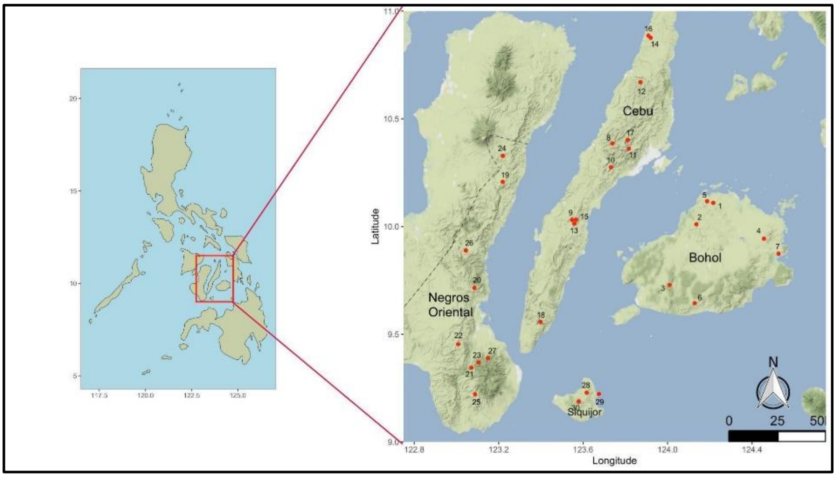

Figure 1. The Map of Central Visayas showing the location of the different sampling sites

Key-informant interviews revealed these sites were covered with annual and perennial crops, grasses, shrubs, and some bushes as remnants of farming and deforestation activities in the past before the reforestation activity. The reforestation project utilized varied tree species majority of which are fast-growing species based on preference and availability. These seedlings were planted in 4 by 5 m spacing with a target of 500 trees per hectare of land. In Bohol, Cebu and Siquijor, seedlings include fruit trees, fuelwood, mangium (*Acacia mangium*), mahogany (*Swietenia macrophylla*), auri (*Acacia auriculiformis*), gmelina (*Gmelina arborea*), narra (*Pterocarpus indicus*), molave (*Vitex parviflora*), and others. While in Negros Oriental, 90% of the sampling sites planted mangium (*A. mangium*) and mahogany (*S. macrophylla*).

With the characteristics of these species, the literature showed that successful growth and development of these trees in five years can render observable changes in NDVI results. Hence, a comparison of NDVI between these time frames will provide helpful insight regarding the outcome of the project.

2.2 Computing for the NDVI

LandSat 8 (OLI and TIRS) Collection 1 Level-2 atmospherically corrected scenes were selected (Table 1) and downloaded from the USGS/EROS data archive. Selection criteria include the year and the cloud cover (which is up to

30% only). As pointed out by Buitre *et al*. (2019), one of the major constraints of LandSat images in tropical countries such as the Philippines is the presence of lots of clouds which may affect the accuracy of the analysis. Hence, to ensure that only the image with the least clouds was used for analysis, several LandSat 8 images were compared and those that yielded the highest NDVI value for each sampling site were chosen in the study (Table 1). Perez and Comiso (2014) found that NDVI values calculated from cloud-free LandSat images were in good agreement with the values derived from satellite imaging, the Moderate Resolution Imaging Spectroradiometer (MODIS). Similar findings were also revealed in the study of Ke *et al*. (2015) using multiple satellite sensors and in-situ observations.

Table 1. LandSat 8 (OLI and TIRS) C1 L-2 scenes downloaded from the USGS data archive

	Landsat 8 OLI/TIRS C1 level 2				
Year	Path: 113 Row: 53	Path: 113 Row: 54	Path: 114 Row: 52	Path: 114 Row: 53	Path: 114 Row: 54
2013	5/22; 07/09; 08/10	11/14			
2014	02/18; 03/06			02/25; 11/08; 12/10	02/25
2015				03/16; 10/26	
2018				03/08	05/11
2019	08/11; 11/15	11/15	02/07	02/07	

LandSat 8 (OLI and TIRS) emits 11 bands (Table 2) but only 2 bands, band 4 (RED) and 5 (NIR) both with 30-m resolution were used to compute the vegetation index. NDVI was calculated using the QGIS 2.18.17 (QGIS.org., 2018) raster calculator using the formula:

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

This step was followed by clipping the shapefiles of the study areas obtained from DENR-Region-VII to extract the NDVI values. Calculated NDVI values were compared using analysis of variance.

Considering the tropical climate condition in the Philippines, Perez and Comiso (2014) highlighted that NDVI in forested areas does not significantly change throughout the year unlike in agricultural areas, thus, seasonality was not taken into consideration in image selection.

Table 2. Different bands in Landsat 8 (OLI and TIRS) and their corresponding wavelengths and resolution

Bands	Wavelength (μm)	Resolution (m)
1 – Coastal aerosol	0.43 - 0.45	30
2 – Blue	0.45 – 0.51	30
3 – Green	0.53 – 0.59	30
4 – Red	0.64 – 0.67	30
5 – Near Infrared (NIR)	0.85 – 0.88	30
6 – Shortwave Infrared (SWIR 1	1.57 – 1.65	30
7 – Shortwave Infrared (SWIR) 2	2.11 – 2.29	30
8 – Panchromatic	0.50 – 0.68	15
9 – Cirrus	1.36 – 1.38	30
10 – Thermal Infrared (TIRS) 1	10.60 – 11.19	100 * (30)
11 – Thermal Infrared (TIRS) 2	11.50 – 12.51	100 * (30)

Calculated NDVI values from sampling sites were then categorized into six classes adapted from Aquino and Oliveira (2012) for ease in analysis and visualization of the results (Table 3). The area for each NDVI category was then estimated using R studio (R Core Team, 2020).

Table 3. NDVI class interval for the vegetation cover

Category	NDVI value range	
1	< 0.10	Bare soil
2	0.10-0.19	Very Low
3	0.20-0.39	Low
4	0.40-0.59	Moderately Low
5	0.60-0.79	Moderately High
6	> 0.80	High

3. Results and Discussion

The NDVI has been used widely to examine the relation between spectral variability and the changes in vegetation both in global and regional studies. It is calculated as the ratio difference between red and near-infrared bands in remotely sensed data. The data are highly useful to reforestation program implementers and policymakers in making important decisions to improve the status of the forest.

The values of NDVI in vegetated landscapes may vary depending on plant morphology, health, and density of the vegetation. High positive values (> 0.8) are associated with dense, healthy, and live vegetation in tropical forests. On the other hand, moderate values (0.2 to 0.5) represent shrubland and grassland while very low positive values correspond to barren areas (Hassini *et al.*, 2006; Weier and Herring, 2008; Othman *et al*., 2018).

Figure 2 compares the NDVI values of representative sampling sites from the four provinces in the region at the establishment phase and post-planting phase. At the same time, it also shows the NDVI change between the two periods. In the establishment stage, NDVI values in the region ranged from 0.11 to 0.94 with an average of 0.72. While on the later stage NDVI ranged from 0.30 to 0.92 and had an average value of 0.76. Results showed that net NDVI change was positive, ranging from 0.07 (10%) in Negros Oriental, 0.05 (9%) in Siquijor, 0.03 (5%) in Bohol, and the least from Cebu with 0.002 (0.35%) on the average.

This change in NDVI is consistent with the data presented in Table 4 comparing the relative size of the sampling sites per NDVI category between the establishment phase and the post-planting phase in each province. Negros Oriental showed a consistent decrease of the area for NDVI category 1 to 5 from 740 ha to 478 ha with very low vegetation cover to moderately high vegetation cover but gained 262 ha (from 345 to 607 ha) for category 6 with high vegetation cover. A similar trend was observed in Bohol and Siquijor (see Figure 3). Bohol gained around 140 ha for its moderately high and high vegetation cover (from 302 to 442 ha) while Siquijor obtained 17 ha of high vegetation (from 137 to 154 ha). On the contrary, Cebu showed a different trend. It lost about 83 ha (from 1,545 to 1,462 ha) of its moderately high and high vegetation cover and 15 ha of its very low to low vegetation cover but gained 98 ha of its moderately low vegetation cover.

Results of this study showed a total of 9% (286 hectares) gain in vegetation densities with more than 0.8 NDVI which may be attributed to the reforestation activity. Negros Oriental contributed more than 90% (262 ha) of the forest gain. On the other hand, Cebu lost about 8% (54 ha) of its dense vegetation and 4% (29 ha) of its moderately high vegetation. This result coincided with the field sampling data where tree biomass density (245 Mg/ha) was highest in Negros Oriental and lowest in Cebu (78 Mg/ha) with *A. mangium* and *Swietenia* sp. as the dominant species, respectively. Overall, the increase in vegetation cover in the sampling sites between establishment phase and post-planting phase was positive but minimal.

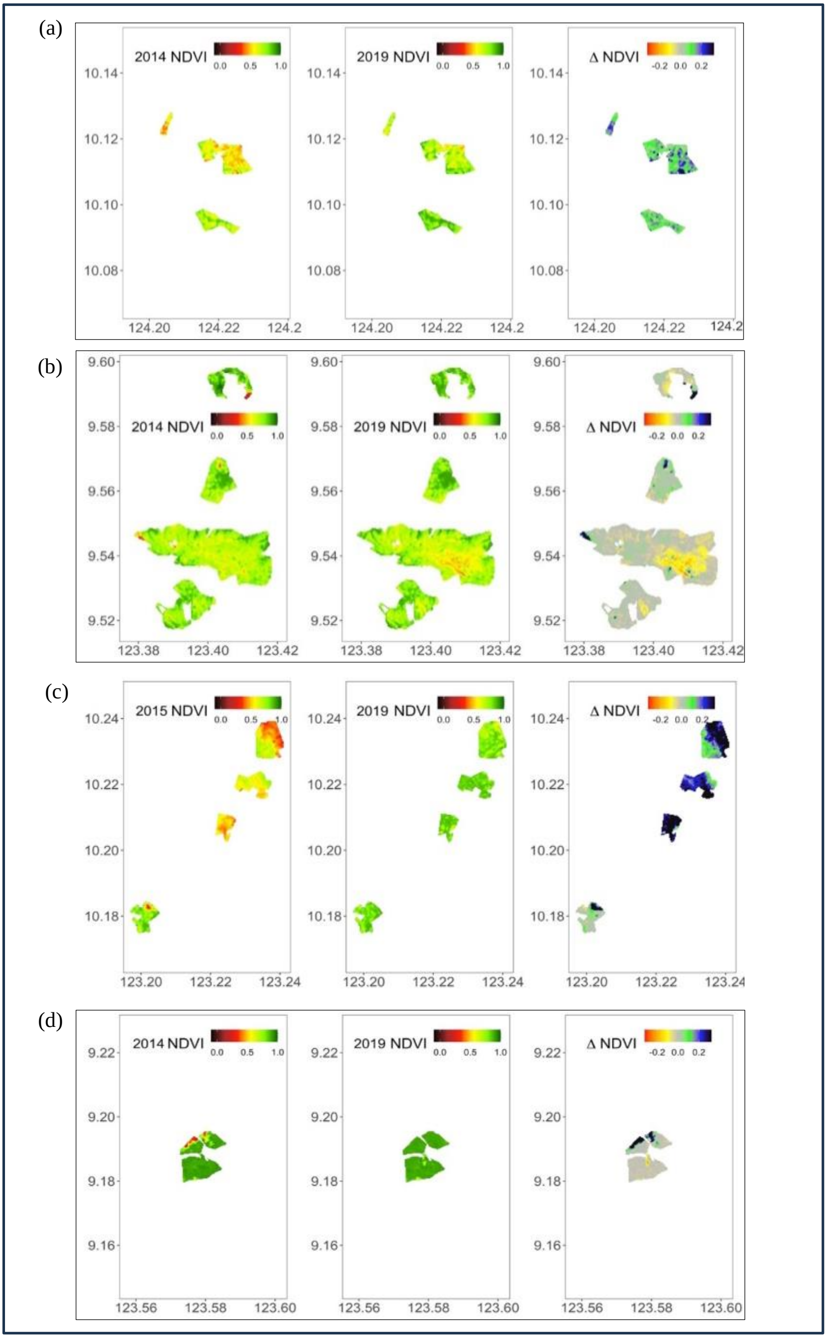

Figure 2. Color-coded shapefiles of representative NGP sites in Central Visayas and their NDVI values and NDVI differences: Site 1, Bohol (a); site 18, Cebu (b); site 19, Negros Oriental (c); and site 30, Siquijor (d)

Table 4. Comparison of the area (ha) in each province per NDVI category and the changes that occur between establishment phase and post-planting phase

NDVI category	Year	Bohol	Cebu	Negros Oriental	Siquijor	Total
1	P-P Phase	0.00	0.00	0.00	0.00	0.00
(< 0.10)	E Phase	0.00	0.63	2.07	0.00	2.70
	Change	0.00	-0.63	-2.07	0.00	-2.70
2	P-P Phase	0.00	0.00	2.25	0.00	2.25
(0.10-0.19)	E Phase	0.00	2.61	20.07	0.09	22.77
	Change	0.00	-2.61	-17.82	-0.09	-20.52
3	P-P Phase	0.09	0.99	9.36	0.27	10.71
(0.20-0.39)	E Phase	5.31	12.69	66.33	4.59	88.92
	Change	-5.22	-11.70	-56.97	-4.32	-78.21
4	P-P Phase	60.48	145.35	75.60	2.52	283.95
(0.40-0.59)	E Phase	195.03	47.70	194.67	6.39	443.79
	Change	-134.55	97.65	-119.07	-3.87	-159.84
5	P-P Phase	317.79	806.85	391.14	9.27	1525.05
(0.60-0.79)	E Phase	238.77	835.47	457.29	18.00	1549.53
	Change	79.02	-28.62	-66.15	-8.73	-24.48
6	P-P Phase	124.47	655.29	607.50	154.08	1541.34
(> 0.80)	E Phase	63.72	709.38	345.42	137.07	1255.59
	Change	60.75	-54.09	262.08	17.01	285.75

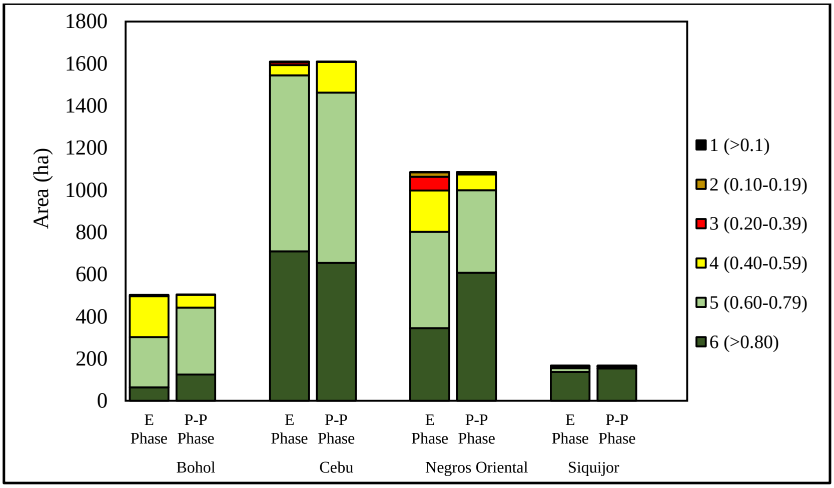

Figure 3. The relative area of the sampling sites per NDVI category in the provinces of Central Visayas at establishment (E) phase and post-planting (PP) phase

Analysis of variance (see Table 5) revealed that sampling site, province, and NDVI category significantly predicted forest cover (F (1, 355) = 16.11, 14.43, 58.04, P-value = 0.000, 0.000, 0.000, respectively). However, time exhibited no significant effect on forest cover (*F* (1, 355) = 0.00, *P*-value = 1.000). The determinants of forest cover also explained a significant proportion of variance in the forest cover (r^2 = 17.42%, *F* (4, 355) = 18.54, *p* = 0.000). This implies that forest cover in Central Visayas has not significantly increased between 2013 and 2019.

Table 5. Analysis of Variance results for factors affecting forest cover in Central Visayas

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	4	171554	171554	42889	18.5397	0.00000
Time	1	0	0	0	0.0000^{ns}	1.00000
Sampling Site	1	3895	37273	37273	16.1121*	0.00007
Province	1	33382	33382	33382	14.4304*	0.00017
NDVI Category	1	134277	134277	134277	58.0449*	0.00000
Error	355	821233	821233	2313		
Total	359	992788				

p-value < 0.05 – Significant at α = 0.05 (*); *p*-value > 0.05 – Not Significant at α = 0.05 (^{ns})

Summary of Model

S = 48.0971 R-Sq = 17.28% R-Sq (adj) = 16.35%
PRESS = 848484 R-Sq (pred) = 14.54%

Despite the reported DENR-NGP accomplishment in Central Visayas from 2011 to 2013, reforestation activity created a negligible improvement in forest cover. If majority of the seedlings planted in 42,000 ha of forest land successfully survived this could have increased forest cover in the region which was 62,033 ha in 2010 by 60%. The reforestation project utilized fast-growing tree species such as the *A. mangium*, *A. auriculiformis*, *Swietenia* spp., and *Gmelina arborea*. Published studies showed that these species can achieve the mean annual increment (MAI) in DBH of 5 cm/year and MAI for height ranges from 5 m/year in the first four or five years (Krisnawati *et al*. 2011). Growth of these trees may have considerably contributed to the increase in vegetation cover in the region.

This finding is similar to the study of Perez *et al*. (2020) in NGP sites in the greater Luzon region. Implementation of NGP brought a minimal contribution to improving forest cover in the region. Better results may have been attained if the reforestation project ensured the survival of the seedlings by providing proper care (water, fertilizer, and protection against grazers), implemented species-site matching, mitigated fire occurrences, enforced the law against the illegal conversion of forest land to agriculture and tourism-related development, and effectively organized the community.

On the other hand, in terms of poverty alleviation, NGP is perceived to have helped increase income and provide livelihood opportunities among the impoverished local people (Israel and Lintag, 2013). Similar claims were expressed among key informants in the region who were involved in the NGP project. However, this claim needs further verification.

4. Conclusion and Recommendation

The NGP received commendation among several sectors as it tries to harmonize efforts from the government and private sectors and has broader objectives not only to increase forest cover but also to reduce poverty and enhance food security. It is a timely response to the urgent need to rehabilitate the continuously degrading forest and the worsening poverty condition of the Filipino people who depend on this resource. With these objectives, the government invested a considerable amount of resources (budget allocation for the six-year implementation in 2011-2016 is Php 28.8 billion). This program raises hopes and high expectations for the recovery of the state of the forest in the country.

The program reported a high degree of success in terms of the number of seedlings planted, the percentage of the area planted compared to the target area, and the survival rates. In Central Visayas, the report showed that NGP exceeded its target based on the above indicators. Data revealed a total of more than 42,000 ha planted in highly denuded forestland as their accomplishment in the region between 2011 to 2013. Most of the seedlings planted were fast-growing species including mangium (*A. mangium*), mahogany (*S. macrophylla*), auri (*A. auriculiformis*), gmelina (*G. arborea*), and others.

These species can achieve the MAI in DBH of 5 cm/year and MAI for height ranges from 5 m/year in the first four or five years in favorable environmental conditions. Seedlings were planted at a target density of 500 trees per hectare. If these seedlings successfully survived and the total area accomplishment is translated to forest cover, this could have increased considerably forest cover in the region which was 62,033 ha in 2010 by up to 60%.

Despite the accomplishment data, results from the current study in Central Visayas revealed that there was no significant effect on forest cover between 2013 and 2019. NDVI change calculated from LandSat 8 images between the establishment phase and post-planting phase in the sampling sites was minimal, ranging from 0.07 in Negros Oriental and the least from Cebu with 0.002. Dense vegetation cover increased by 9% (286 ha) in the region. Negros Oriental contributed more than 90% (262 ha) of the forest gain. On the contrary, Cebu lost about 8% (54 ha) of its dense vegetation. This result concurred with the data from field sampling where tree biomass density (245 Mg/ha) was highest in Negros Oriental and lowest in Cebu (78 Mg/ha). Among the factors observed in the sampling sites that may partially explain the case of Cebu province included low survival of the reforested trees, conversion of reforestation sites for tourism-related development from private claimants, expansion of agricultural lands, and continued illegal logging activities.

These results confirmed that early establishment indicators cannot predict the long-term outcome of the program. Hence, there is a need to integrate an accurate, cost-effective, and real-time monitoring scheme such as the use of remotely sensed data of useful indicators throughout the project cycle to track the outcome and whether it is attaining its key objectives. Accurate and real-time data is valuable in monitoring the progress of the project to analyze strengths and identify problems encountered on-site, and employ changes that ensure success. Future implementation of the reforestation project should also consider revisiting policies related to the choice of species for reforestation, strategies and funding related to plantation maintenance, and partnership with institutions, and law enforcement for a more sustainable forest conservation and management.

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