ANALYSIS OF CLOUD-BASED NDVI TRENDS OF A COUNTRY-WIDE FOREST RESTORATION PROGRAM

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ABSTRACT

The Philippine government embarked on a country-wide forest restoration program in 2011 targeting 1.5 billion trees in 1.5 million hectares of public lands over a six-year period, from 2011 to 2016. The program aimed at poverty reduction, sustainable management of natural resources, provision of food, goods, and services, promote public awareness on importance of forests and watershed, climate change alleviation. The program was expanded with the goal of rehabilitating all the remaining unproductive, denuded, and degraded forest lands, estimated at 7.1 million hectares, from 2016 to 2028.

This paper makes use of satellite imagery in measuring the success of the program in terms of planting trees in the selected areas. Vegetation indices derived from remotely sensed data were used in validating ground measurements and observing the temporal trends in the growth of vegetation.

Considering the large volume of data required for the analysis, we used Google Earth Engine, a web-based platform for cloud-based processing. We used several regions of interest to determine levels of success in order to elucidate what particular policy interventions show greater success in forest rehabilitation. We compared the NDVI values of the planted areas in protected areas, ancestral domain areas, local government units. Results reveal that forest restoration perform better in partnership with local governments although silvicultural treatments and logistical provisions were identified as key elements of success.

Background

The forest cover in the Philippines has been recorded to be decreasing dramatically for the past hundreds of years. From covering 27,500,000 hectares or 92% of the land mass in 1565 (IBON, 2000) to about 14,814,800 hectares or 50% in 1950 (Kummer, 1993). According to the Asia-Pacific Forestry Sector Outlook Study of the Food and Agriculture Organization of the United Nations (FAO, 1997) the forest area of the Philippines was estimated to have declined from 12 million hectares in 1960 to about 5.7 million hectares in 1995, which includes not greater than a million hectares of virgin forest located in very steep and inaccessible areas.

Several reforestation initiatives were employed by the government to increase forest cover. The National Integrated Protected Areas System (NIPAS) Act was passed to law in 1992 and expanded (ENIPAS) in 2018 to manage protected areas. Meanwhile, under the Indigenous Peoples Rights Act of 1997, the rights of Indigenous People (IPs) to their ancestral domain by virtue of Native Title shall be respected and formally given recognition, which is embodied in a Certificate of Ancestral Domain Title. The National Greening Program was implemented in 2011 aimed at poverty reduction, sustainable management of natural resources, provision of food, goods, and services, promote public awareness on importance of forests and watershed, climate change alleviation. It was expanded in 2016, targeting the rehabilitation of ll the remaining unproductive, denuded, and degraded forest lands.

Data obtained from satellites have been useful in forest cover studies in the regional and global scales ((Song, et al., 2018); (Hansen, et al., 2013); (Turner, et al., 2007); (Foley, et al., 2005). Satellite data, with it being comprehensive and capable of providing continuous and consistent service, is vital in the assessment of seasonal, interannual, and relatively long-term changes (Perez et al., 2020). Time-series data derived from Landsat are favorable for vegetation change detection due to their high spatio-temporal resolution. In terms of image processing, the high density of Landsat data limits data computation and storage. Also, the high temporal frequency of clear observations improves detection accuracy (Zhu & Woodcock, 2014).

Vegetation Indices derived from remote sensing-based canopies are straightforward and effective algorithms for assessing vegetation cover, vigor, and growth dynamics, among other things. The most widely used vegetation index is the Normalized Difference Vegetation Index (NDVI). Rouse Jr. et al. proposed it, which can be expressed as

$$NDVI = (NIR - Red)/(NIR + Red)$$

With the use of Google Earth Engine, analysis of country-wide data will be more efficient and optimal.

The main objective of this study is to make use of satellite imagery to measure the success of the reforestation programs. Specifically, the study aims to generate country wide NDVI data each year from 1990 to 2021 and to compare NDVI trends among reforestation programs established within the country.

Materials and Methodology

Site Description

The Philippine archipelago, which consists of 7,641 islands (NAMRIA, 2017) is in Southeast Asia. The Philippines covers an area of 1,850 kilometers (1,150 miles) in length, stretching from the fifth to the twentieth parallels north latitude. There are 300,000 square kilometers of land in total (Boquet, 2017)It is situated between the longitudes of 116° 40' and 126° 34' E, and the latitudes of 4° 40' and 21° 10' N.

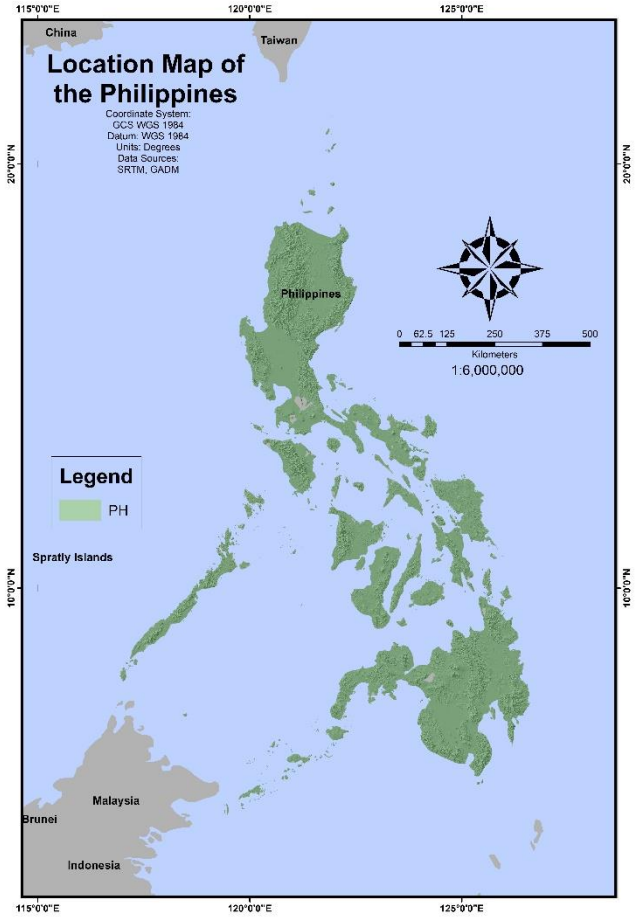


Figure 1. Location Map of the Philippines

The Philippines' topography is quite varied. Most the Philippines' major islands are volcanic in origin. As a result, the country is very mountainous. Slopes of 18 percent or steeper make up nearly half of the country (Espiritu et al 2010).

Large areas become unsuitable for agriculture unless terraces are built, causing circulation problems, and increasing the risk of landslides. Figure below shows the location map of the Philippines.

Data Acquisition

Google Earth Engine was used to generate NDVI rasters covering the whole country for each year from 1990 to 2021. Clouds were masked out and annual median NDVI values were used in each mosaic. These mosaic rasters were then exported at 90-m spatial resolution and downloaded for use in GIS software.

For measuring the NDVI trends, 400 random points were generated to obtain a sample of pixel values of the rasters (Bantayan, et al., 2015). The boundaries for the National Greening Program areas were acquired from the Forest Management Bureau of the Department of Environment and Natural Resources. Meanwhile, the data for Protected Areas were obtained from the Protected Planet: The World Database on Protected Areas (WDPA) and World Database on Other Effective Area-based Conservation Measures (WD-OECM) (UNEP-WCMC & IUCN , 2021).

On the other hand, the extent for the areas with Certificate of Ancestral Domain Title were secured from the National Commission on Indigenous Peoples. Out of the 400 random points, 100 were produced within each of the following program (NGP, CADT, PA) and 100 for areas with no reforestation program. NDVI values were extracted to each of the random points per classification and were compared to observe yearly trends in NDVI. The figure below shows the location of the sample points generated. The extracted values in the points were tabulated and averaged annually. Graphical comparisons of the *annual averages were generated to observe performance of different programs.*

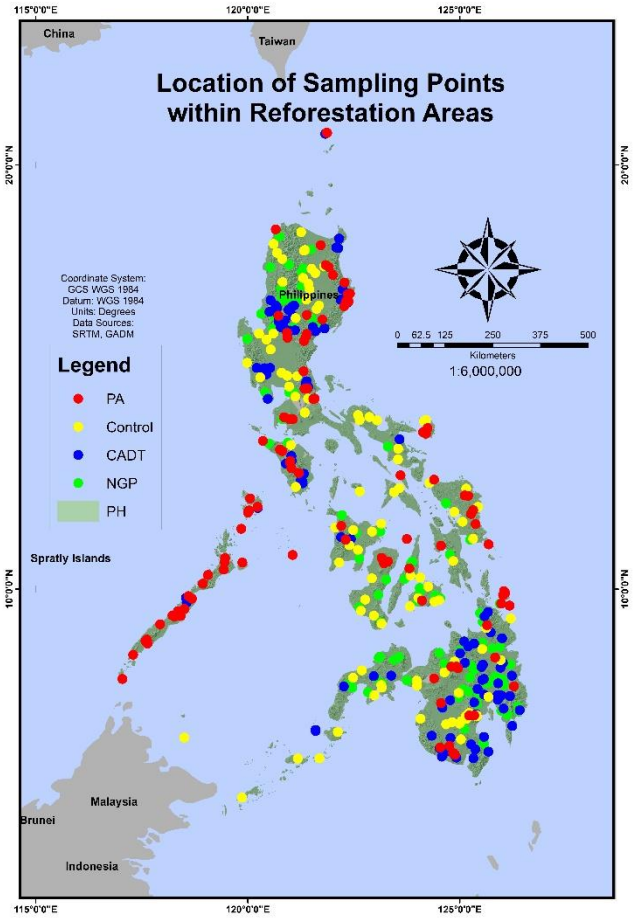


Figure 2. Location of sampling points

Results

It was observed that Protected Areas and areas with Certificate of Ancestral Domain Titles had relatively higher mean annual NDVI values compared to areas with no reforestation program implemented. Lowest values for all years were observed in 1992, with mean NDVI for PAs at 0.536 and for CADTs at 0.544. Tables below show the tabulated mean annual NDVI values for each program observed.

Table 1. Mean NDVI values for extracted points within reforestation programs (1990-1999)

Class	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CADT	0.633	0.572	0.544	0.653	0.689	0.662	0.694	0.713	0.629	0.701
PA	0.687	0.640	0.536	0.686	0.711	0.668	0.717	0.711	0.674	0.711
Control	0.536	0.526	0.499	0.594	0.652	0.634	0.670	0.640	0.598	0.645
NGP	0.593	0.585	0.465	0.597	0.657	0.636	0.670	0.654	0.593	0.669

Table 2. Mean NDVI values for extracted points within reforestation programs (2000-2009)

Class	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CADT	0.718	0.621	0.742	0.714	0.731	0.722	0.765	0.753	0.730	0.754
PA	0.693	0.708	0.727	0.703	0.718	0.740	0.754	0.734	0.724	0.755
Control	0.646	0.646	0.657	0.649	0.666	0.634	0.698	0.665	0.680	0.703
NGP	0.639	0.664	0.701	0.672	0.690	0.678	0.715	0.679	0.701	0.717

Table 3. Mean NDVI values for extracted points within reforestation programs (2010-2021)

Class	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
CADT	0.735	0.752	0.757	0.782	0.783	0.778	0.775	0.792	0.779	0.787	0.795	0.798
PA	0.715	0.760	0.768	0.801	0.788	0.791	0.780	0.800	0.816	0.807	0.797	0.797
Control	0.651	0.712	0.704	0.744	0.732	0.735	0.734	0.750	0.736	0.730	0.742	0.750
NGP	0.677	0.677	0.722	0.755	0.750	0.748	0.741	0.772	0.769	0.756	0.763	0.773

Before the implementation of the National Greening Program, the mean NDVI for the areas bound by the program were performing similarly with the areas with no reforestation program implemented. It was at 2012 when the mean NDVI for NGP areas were observed to be higher than those of the areas with no reforestation implemented, with 2021 having the highest mean NDVI value at 0.773. The graph below shows the annual NDVI trends for the reforestation programs.

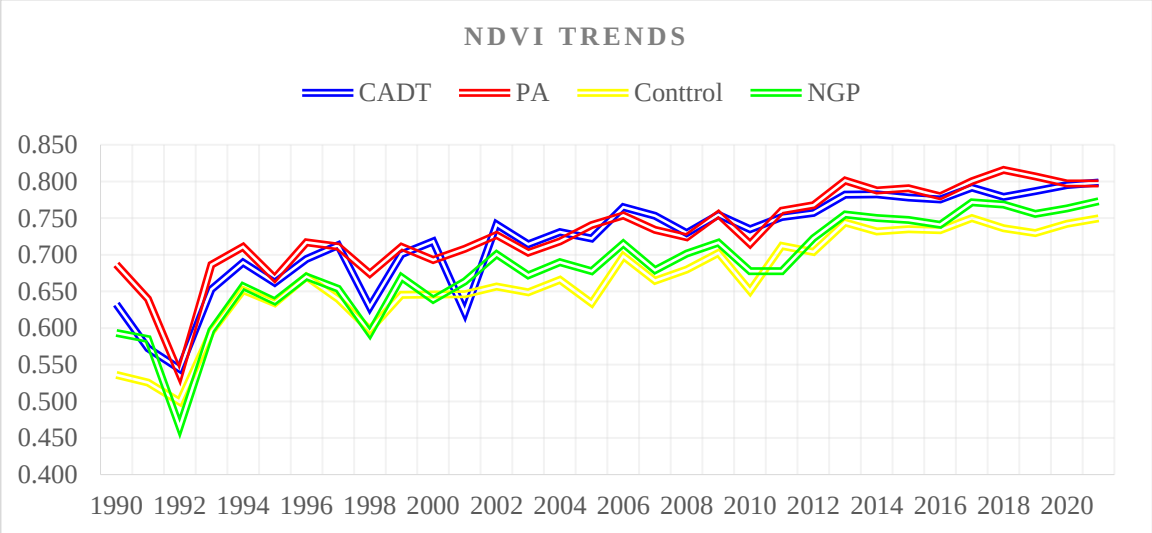


Figure 1. Mean annual NDVI trends for different reforestation program

After 1992, trends for all observations seemed to have a similar behavior, with all of them dipping in 1992 and then gradually increasing up to the recent years. Increases in mean NDVI data for NGP areas were observed on starting 2011, one year after the implementation of the program. It has been increasing since then and its values are approaching those of the PAs and the CADTs. Overall, the reforestation programs in the country have positive linear trends. Figures below show visual evidence of increase of vegetation in certain NGP sites.

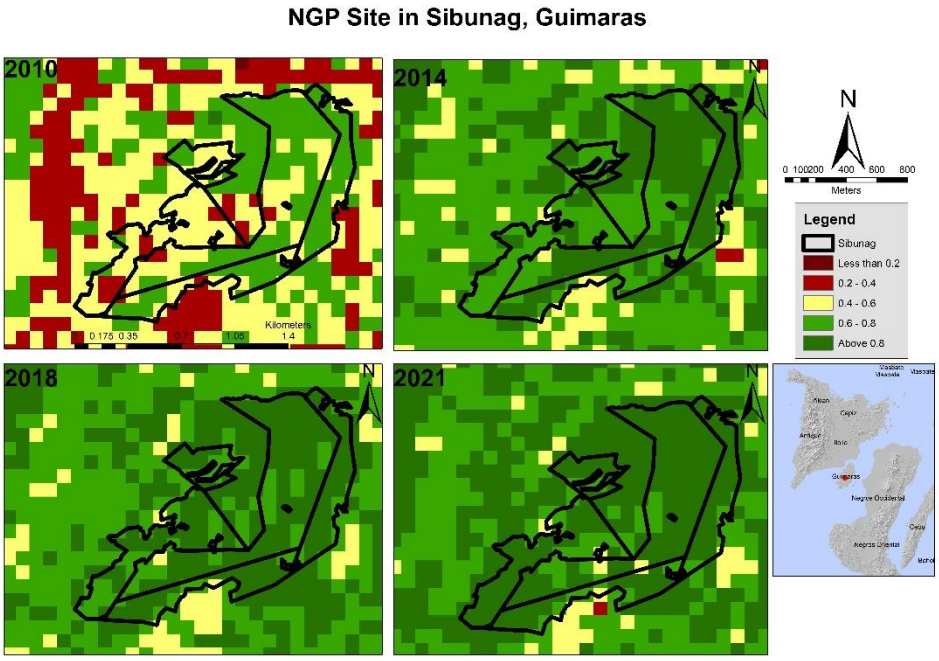


Figure 4. Vegetation growth in NGP site in Sibunag, Guimaras

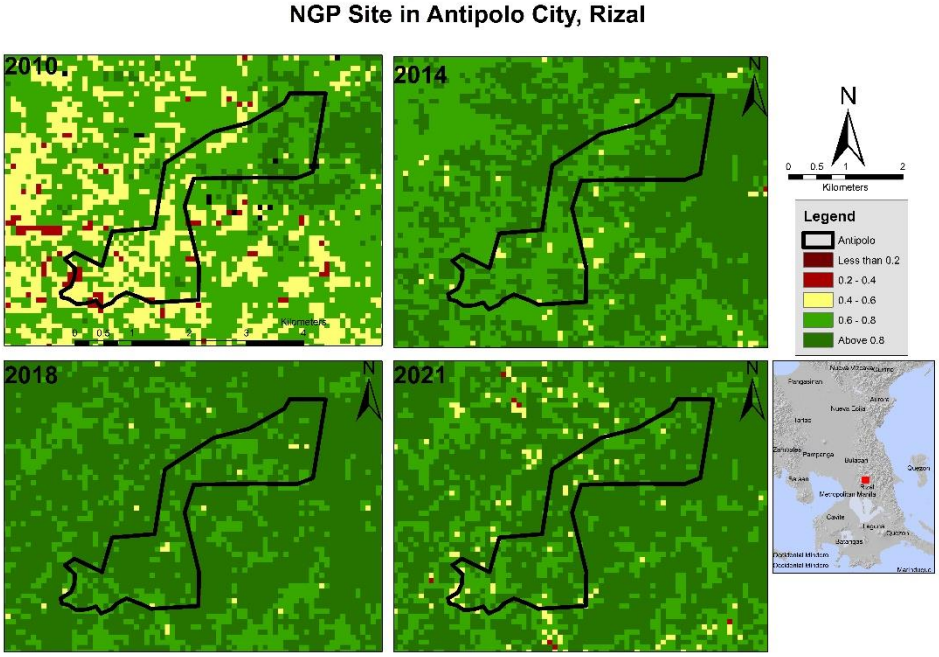


Figure 5. Vegetation growth in NGP site in Antipolo City, Rizal

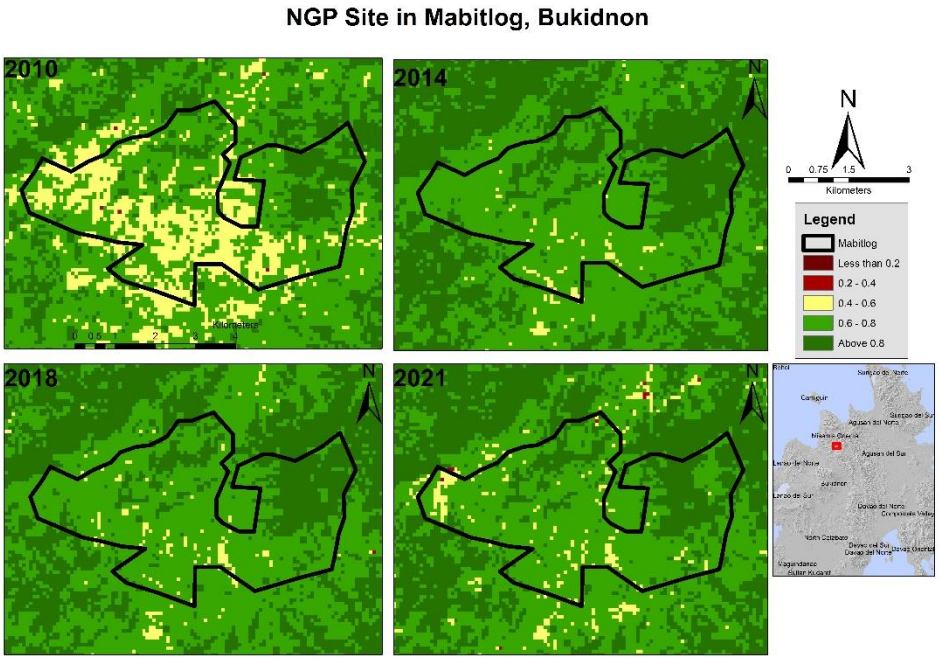
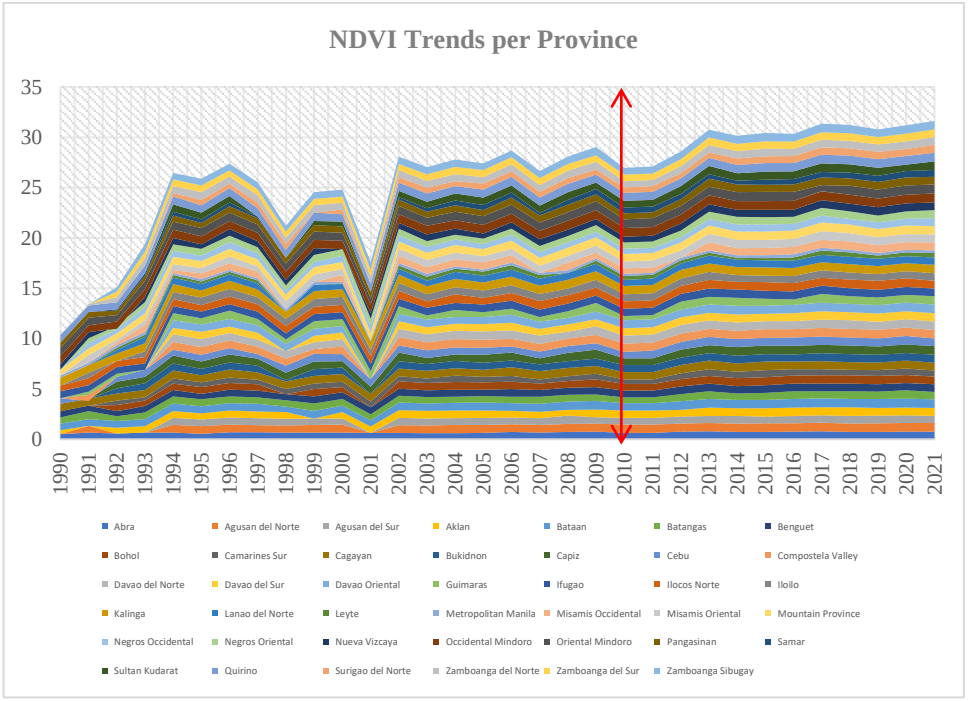


Figure 6. Vegetation growth in NGP site in Mabitlog, Bukidnon

NGP sites from Local Government Units (LGUs) in Luzon, Visayas, and Mindanao were observed and evidence of vegetation growth within the sites were found. The site in Luzon is found in Antipolo City, Rizal. In 2010, majority of the area was observed to have an NDVI range within 0.4 to 0.6. As the NGP continues, a large portion of the area seemed to have an increase in NDVI values.

Similarly, the site in Mabitlog, Bukidnon had a portion of its area with NDVI ranging from 0.4 to 0.6. Four years after the implementation of the NGP, only a small fraction of the area had the same NDVI range, while majority was found to have increased in value.

On the other hand, the NGP site in Sibunag, Guimaras and its surrounding area were found to have portions with NDVI ranging from 0.2 to 0.4. Later years were shown to have lesser areas with this NDVI range and areas with NDVI greater than 0.8 were found to be increasing. Generally, visual evidences of vegetation growth are present for the reforestation projects. The graph below shows the stacked area for NDVI trends for several provinces in the country. A red line is shown when the NGP was implemented.



A red line is shown when the NGP was implemented. The 100 random points were found to be in the jurisdiction of 41 provinces. Provinces with multiple points had their representative values averaged to account for all sample points. Provinces with one point were carried over and plotted. A gradual increase in the NDVI trend for the provinces were observed in years 2011 onwards, and the trends have been going positively since then. The graph supports the visual evidence of vegetation growth within the NGP areas.

Conclusion

Using Google Earth Engine to generate NDVI mosaics for the whole country makes data processing more efficient. Generating country-wide cloud-free mosaics is possible within seconds in the cloud, compared to the conventional remote sensing software processing. It also eliminates some of the pre-processing methods, thus optimizing work and resources.

Sampling of random points within the reforestation areas was made possible with the availability of data from the Forest Management Bureau for the National Greening Program site, the National Commission for Indigenous People for the areas with Certificate of Ancestral Domain Title, and the UNEP-WCMC and IUCN for the Protected Areas.

Overall, the reforestation programs showed positive linear trends. Mean NDVI values were found to increase from 1992 and are increasing since then. Protected areas and areas with Certificate of Ancestral Domain Title were found to have relatively higher mean NDVI values but as the National Greening Program continues, it shows that more areas are now having healthier vegetation. Continuous implementation of these reforestation programs will further improve the forest cover of the country.

Acknowledgement

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