Tempo-Spatial Analysis and mapping of stored carbon in vegetation using remote sensing technique in Palawan, Philippines

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Abstract— Quantifying the carbon storage and its changes through time is vital in understanding the role of vegetation as carbon sources and sink. The temporal and spatial changes in carbon storage in Palawan was computed and plotted using the gross and net primary production in a time sequence from 2003 to 2014. Remote sensing technique was used to calculate and monitor GPP and NPP changes in the Province through the Moderate Resolution Imaging Spectroradiometer (MODIS) by evaluating spatial patterns in productivity as well as annual variations and long-term trends. It was found out that it has significantly declined from 2003 with 0.0281 kg/m2 of stored Carbon to 0.0175 kg/m2 in 2014 with the majority of loss concentrated in southern part Palawan. Through this assessment, a map showing the changes in carbon storage in Palawan was generated. Results demonstrated the cost-effective and rapid capability of remote sensing-based quantitative change detection in monitoring carbon storage.

Index Terms— Carbon storage, Gross Primary Productivity, Vegetation Loss, Remote Sensing

1 Introduction

Carbon storage is a measurement of the amount of carbon that is incorporated the ecosystem. It is assimilated in the carbon sink through the carbon cycle. Which serves as an essential and highly dynamic system that incorporates the path of organic matter as it moves around. Carbon storage includes several pools such as soil, detritus, black carbon residue, and vegetation. The capacity of regions for carbon storage varies and carbon stored plays a major role in the global carbon budget. A decline in carbon storage generally indicates a reduction in the quality of habitat health or even loss, as such stored carbon is a function of the health and primary productivity of ecosystem through time (Dong et al., 2003).

Among the different terrestrial ecosystem, forest vegetation is the first major form that plays a dominant role in the global carbon cycle (Xu et al., 2007). Carbon cycle is an essential and highly dynamic system that incorporates the path of organic matter as it moves around a system. This includes several storage pools such as soil, detritus, black carbon residue, and vegetation. The capacity of different region and locations that have the capacity to store carbon varies and can be generally attributed to vegetation and forest cover. Carbon stored plays a major role in the global carbon budget. Stored carbon is also a function of a productivity and health of ecosystem through time. A decline in carbon storage generally indicates a reduction of a health habitat or even loss (Dong et al., 2003).

Primary productivity of vegetation is the main force driving the processes and functions of terrestrial ecosystems. It is represented by the amount of carbon dioxide (CO2) fixed by plants during the process of photosynthesis which is commonly attributed as gross primary production and net primary production (Zhao & Zhou, 2003). Gross primary production (GPP) is the total amount of carbon dioxide fixed by land plants per unit time through the photosynthetic reduction of CO2 into organic compounds while net primary production (NPP) is the amount of carbon uptake after all the energy has been used by the system (Gough, 2011). The GPP of terrestrial ecosystem is the largest global CO2 flux and a measure of the amount of CO2 removed from the atmosphere by plants annually ((Zhao & Zhou, 2003).

Gross primary production (GPP) and net primary production (NPP) can be used to have an estimate of the total carbon pool. The capacity of vegetation to capture energy and carbon thus may help in maintaining the ecosystem's stability is represented by GPP, while NPP represents the net carbon stored as plant material for resources. A method that utilizes NPP and GPP has significant implications for determining whether the terrestrial ecosystem is a carbon source or sink as given by its carbon storage, as such, it is used as a basis in quantifying carbon storage in an area.

In this study, the carbon storage in Palawan was analyzed through a remote sensing technique. Remote sensing has been used to calculate and monitor GPP and NPP changes at the regional and global scale. Estimates of daily GPP and NPP are now produced operationally for the terrestrial surface. The Moderate Resolution Imaging Spectroradiometer (MODIS) provides a mean of evaluating spatial patterns in productivity as well as annual variations and long-term trends. It is also considered as one of the most reliable data sources at the global scale (Zhang et al., 2009). This paper quantified the amount of carbon storage in Palawan and was able to assess and map the significant change in the storage from year 2003 to 2014.

2 Methodologies

Remote sensing technique was utilized in this study in order

to analyze the stored carbon in vegetation in Palawan, Philippines. The gross primary productivity (GPP) and net primary productivity (NPP) of the vegetation in the region were calculated over time in order to generate a carbon storage map of the research locale.

2.1 Study Site

This study focused on Palawan as the whole area in calculating carbon storage and changes both temporally and spatially. Palawan is located in the westernmost portion of the Republic of the Philippines. The island of Palawan is located between 8° 30′ and 12° 45′ North latitude and 117° 30′ to 121° 45′ East longitude with a total land area of 17,030.75 km2. It has 13 mainland municipalities and 11 island municipalities (Hara & Cayron, 2001).

Palawan is dubbed as the "last ecological frontier" because of its high biodiversity and ecological importance harboring the highest terrestrial forest cover in the country which makes up 46% of the Palawan Province's land area and highest mangrove assemblage in the country that account for roughly 42% of the total remaining mangroves in the Philippines (Fuentes et al., 2015).

2.2 Data and Data Processing

This study made use of level 4 datasets both with 500-m spatial resolution obtained from MODIS; the Global annual net primary production as derived from the sum of the 45, 8-day Net Photosynthesis (PSN) products, and the 8-day gross primary productivity based on the radiation-use efficiency concept. The MODIS dataset provides the first operational, near real-time calculation of global GPP and NPP and it has been validated across various biomes and climate regimes, and found to be consistent with the GPP from ground flux tower and field observed NPP estimates (Zhang et al., 2009). The images were first filtered to obtain the desired location and time frame and carbon storage was computed as a function of ratio of GPP and NPP using the Google Earth Engine API.

The data obtained from the ratio between GPP and NPP were then used and plotted order to generate a map of the whole region of Palawan showing the changes as depicted in the gradient on the region in the amount of stored carbon.

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3 Result and Discussions

The amount of stored carbon in Palawan was calculated as a function of the ratio between the Net primary production and gross primary production. As depicted in Figure 1 below, there is a significant decrease in the amount of carbon stored in Palawan from year 2003 to 2014.

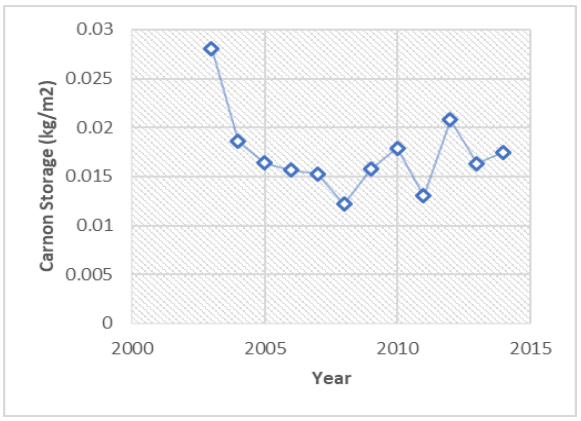
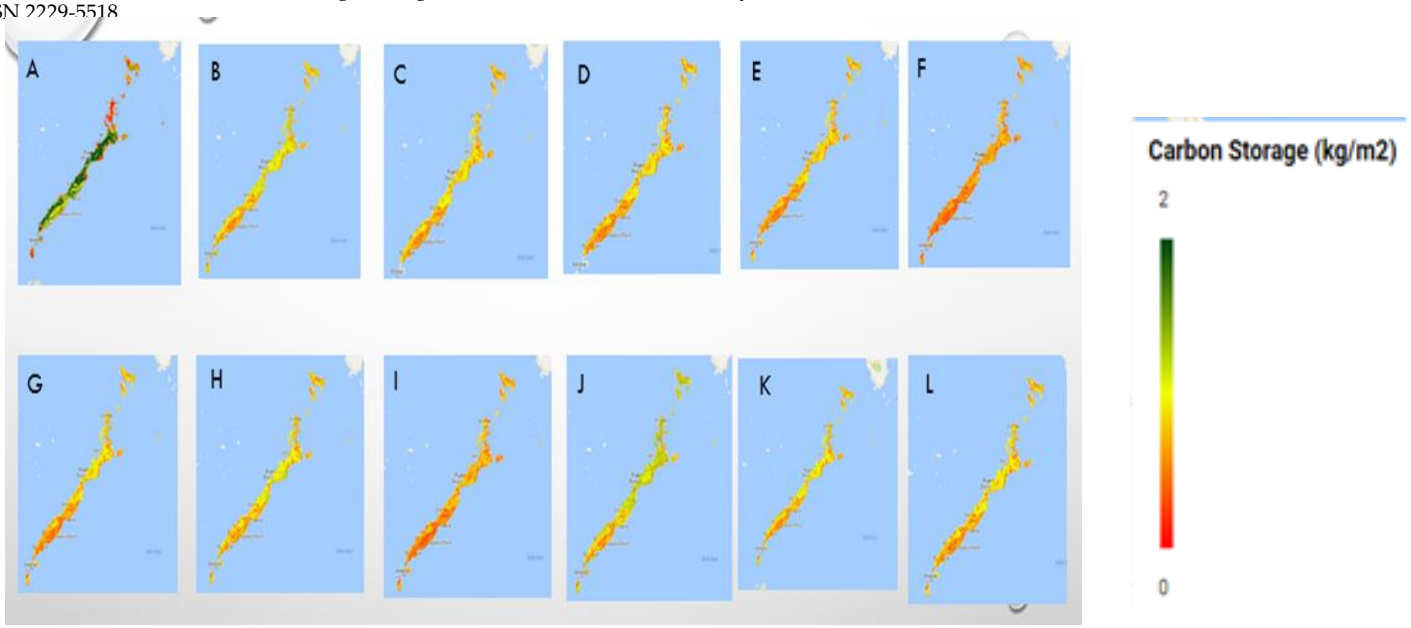


Fig. 1. Change in the Carbon Storage from 2003 to 2014 in Palawan,Philippines obtained from vegetation gross primary productivity and net primary productivity.

From 2003 to 2014, there is a significant decrease in the amount of stored carbon in the area of Palawan. As calculated, the average amount of annual stored carbon from 2003 to 2014 were as follows: 0.0281,0.0186, 0.0164, 0.0156, 0.0153, 0.0122,0.0157, 0.0179, 0.0130, 0.0208, 0.0163, 0.0175. From 2003 to 2008, there is a continuous loss in the carbon storage, and it was noted that it rise a little during 2009 and 2010. It declined again in year 2011. Though there is a minimal change in the annual carbon storage, a significant loss was still attributed when the over-all carbon storage was mapped.

A carbon storage map was generated from the study (Figure 2). It shows that year 2003 have the highest amount of stored carbon and the lowest was recorded at 2008.Further, it can be seen from the map that the highest degree and extent of carbon storage decline was concentrated in the southern portion of Palawan.

Vegetation account for the great part of the carbon exchange have the ability to mitigate carbon dioxide emissions. Thus, they ability to store carbon is very vital in battling pollution (Turner et al., 2006). The stored carbon in an area may vary from time to time, but in permanently maintained vegetation sinks, it can lower atmospheric CO_2 concentrations. This will be efficient if but this can be done most effectively if sequestration occurs close to the time when atmospheric concentrations are to be lowered, as such changes or decline in carbon storage from time to time is very significant (Kirschbaum, 2003).



The decrease in the amount of stored carbon may be attributed primarily to vegetation loss. As validated through the use of remote sensing imagery from Hansen Global Forest Change v1.2 (2000-2014), Palawan has lost approximately 908,543 m2 of forest area. Forest degradation in Palawan has been rampant brought upon by land cover change and deforestation that is primarily brought upon by population growth (Angelsen & Kaimowitz, 2001). Other anthropogenic activities that pose negative impacts to the province's vegetation is agricultural and industrial development, overexploitation of resources, and mining (Fuentes et al., 2015).

It was also noted that the concentration of decline in carbon storage is located in Southern portion of Palawan. This region of Palawan includes Puerto Princesa City which is classified as a highly urbanized city, and thus has the most industrial development. The loss of carbon storage can be attributed to this development. Another factor that can also be taken into account are the mining operations mostly located in Southern Palawan (Fuentes et. al, 2015), but further studies must still be conducted to verify these findings. Previous studies have also shown that the carbon sequestration ability of forest ecosystems is interactively driven by abiotic and biotic factors such as forest origin, forest age, forest type, geography, and soil environment (Xu et al., 2018), as such future studies regarding this matter should also be conducted.

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