Assessing the economic value of carbon sequestration in Taman Negara Pahang

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Abstract. Aesthetic benefits are not enough. Authorities need to be presented with economic benefits as well to make decisions in favour of forests and help them conserved or expanded. Thus, this paper aims to evaluate the economic value of carbon sequestration in Taman Negara Pahang (TNP), Malaysia, a national park with an extensive forest area. The study area covers 247,700 hectares of the Pahang State. The study uses a Geographic Information System (GIS) method of Normalized Difference Vegetation Index (NDVI) to identify the density of the forest across the study area. Consequently, by using the NDVI results, the carbon sequestration in TNP and its economic value were calculated. As a result, the research found that the potential of carbon storage or sequestration in TNP was 142,560,513 tonnes CO₂. The economic value of which was worth RM2,637,369,490.50. The results of the GIS calculation were more accurate than the conventional method. It was due to the reason that they were based on evaluating density on a smaller scale of 900m x 900m (81ha). The results were aligned with previous studies pointing out higher density areas holding higher economic values. The study results can be used to convince Malaysian authorities to make wise decisions about such forests as they worth billions of Ringgit Malaysia.

Keywords: NDVI, GIS, Forest, Protected areas, Economic valuation

1. Introduction

Taman Negara (also known as National Park) is one of the most popular ecotourism destinations in Malaysia. The total area of the park covers 4,343km² [1]. Around 4000km² of which is covered by forest [2]. The park is situated across three states, namely Pahang, Kelantan and Terengganu [1]. Taman Negara Pahang (TNP) comprises the majority of the forest as it makes 57% of the total area of the park followed by Kelantan (24%) and Terengganu (19%) [3].

Forest holds the capacity to absorb carbon and play a vital role in decreasing its negative effect in the atmosphere. To be precise, forest stores a large amount of carbon in the wood and roots of its trees [4]. Besides many other aesthetic benefits of Taman Negara, specifically, TNP is providing to the tourists, the vegetation or forest in the park absorbs a huge amount of carbon [5]. Thus, playing its role in decreasing air pollution and greenhouse gas emissions [4]. This absorption is called carbon sequestration [6].
Economically, carbon sequestration by forests, like TNP, can help decrease the consumption of energy for cooling [7]. Moreover, the right to emit each ton of carbon dioxide to the atmosphere needs to be purchased [8]. Thus, the lower level of carbon dioxide in the air caused by carbon sequestration can give a chance to the developing countries to protect their industries from the sanctions of global climate change organizations [9]. As a result, the employment rate would remain higher, and no economic crises raised by relevant factors would threat the countries. Forests considered as sustainable carbon sequestration element also avoid the huge cost of using artificial technology for this purpose [9]. Half of the dry wood mass is made of carbon. Hence, the Harvested Wood Products (HWPs) such as furniture can not only store atmosphere carbon for a long time but also support the economy of the countries through local use and exports [10]. These services provided by forests are considered their economic values. Estimating of which is called economic valuation [8].

The economic value (value in currency) of carbon sequestration by forests has been estimated by several studies [6, 8, 11, 12]. They have also illustrated the techniques through which the value can be assessed, e.g. Hedonic Price Method (HPM) and Normalized Difference Vegetation Index (NDVI). HPM is mostly used in the housing market [13]. With the advancement of the technologies like the introduction of Remote Sensing (RS) and Geographic Information System (GIS), it is now easy to evaluate the potentials of the surfaces with ease [14]. Thus, the GIS technique of NDVI was deemed effective, easy and affordable for evaluating the economic value of carbon sequestration in forests [12].

As far as TNP is concerned, the economic value of carbon sequestration for this valuable national park has not been evaluated and mapped out so far. Therefore, by using NDVI technique, this study aims to assess and map the economic value of carbon sequestration across TNP. This study is important in terms of exploring the potential of TNP, thus, making way for its further conservation.

2. Method

2.1. Study area

TNP is located in the central part of Malaysian Peninsular covering 2,477 km$^2$ (247,700 hectares) of the Pahang state [15]. TNP provides a living environment for hundreds of types of fauna and flora [2, 16]. Figure 1 shows TNP as the study area for the current research.

2.2. Analysis of the economic value of carbon sequestration

Carbon sequestration analysis was conducted using Geographic Information System (GIS). GIS is a platform that allows data collection, data management and data analysis. It has different applications used for various purposes, one of which is the ArcGIS tool which is used to view, edit, create, and analyse geospatial data. ArcGIS is equipped with a lot of useful tools, such as Raster Calculator, which can be used to calculate and analyse raw geospatial data.

NDVI is a GIS tool-formula performed under Raster Calculator which can be used to determine the density of green on a patch of land. NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). NDVI is a standardized way to measure vegetation cover or density where high NDVI values show higher density vegetation cover and low NDVI values indicate lower or no vegetation cover.

Listed below are the main steps to perform NDVI and calculate the economic value of carbon sequestration in Taman Negara Pahang:

2.2.1 Acquisition of Landsat imageries for the study area: As per the requirement of the study, Landsat 8 imageries were collected and downloaded from the USGS (United States Geological Survey) online source. Two patches of imageries were downloaded that cover the entire study area with the least cloud on them: (126057_20160626) and (127057_20140511). The different year imageries were chosen to make sure the imageries have the least cloud cover since the cloud would affect the NDVI value.
2.2.2 Software and tools: ArcGIS 10.5 software was used to reference the raw imageries to the site, run NDVI analysis, mosaic the separate imageries, clip them, and mask the few clouds existed. ERDAS IMAGINE and GEOMATICA software were also used to make sure the results are consistent and accurate. After running NDVI for density analysis, No-value areas of the mosaic raster were removed by overlaying the base maps for Taman Negara Pahang.

2.2.3 NDVI calculation: Since NDVI uses the near-infrared (NIR) and red channels in its formula, spectral Band 4 and Band 5 of each imagery were used in the calculation to detect the density of vegetation covers. The formula used to calculate NDVI for this study site is stated as below:

\[
\text{NDVI} = \frac{\text{NIR} - \text{VIS}}{\text{NIR} + \text{VIS}} \\
\text{NDVI} = \frac{\text{band5} - \text{band4}}{\text{band5} + \text{band4}}
\]

The result of this formula generates a value between -1 and +1. Low reflectance (or low values) in the red channel and high reflectance in the NIR channel will yield a high NDVI value and vice versa. After carrying out the NDVI analysis, the imageries were mosaicked, followed by clipping and masking.

2.2.4 Fishnet and assigning NDVI results to that: After the NDVI results were available, there was a need to calculate and analyse the density on a smaller scale of 900m x 900m (81ha). For this purpose, a Fishnet of the same size was created and overlaid with the NDVI raster result. Then, the mean value for each of the cell was calculated, which indicated the value of vegetation density.

2.2.5 Economic valuation of carbon sequestration: Carbon sequestration was calculated based on the result of NDVI mean values. This calculation is more accurate due to the reason that the computation of
carbon sequestration (tonne CO$_2$), and its economic value were based on the density of vegetation for each grid size of 900m x 900m (81ha.).

The amount of carbon emitted into or removed from the atmosphere was computed based on the default values from the Intergovernmental Panel on Climate Change (IPCC) Guidelines. The present forest type at the TNP is mixed dipterocarp forest with 350 tons above-ground biomass dry matter per hectare. Since the forest is natural and assumed to be in a steady state, an annual increment in biomass from natural regeneration was assumed as zero. Hence the carbon content is estimated using Table 4.7, page 453, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use [17]. The Carbon fraction of biomass dry matter is 0.5 (IPCC default value). Thus, a hectare of the natural forest has 175 tonnes of C or 642.25 tonnes of carbon dioxide (CO$_2$). The equation or formula used, in a GIS environment-Raster Calculator, was as stated below:

\[
\text{Carbon sequestration} = \frac{\text{Mean value of NDVI} \times 642.25 \text{ tonnes CO}_2}{\text{Mean final (NDVI)}} \times 81 \text{ha}
\]

The economic value of carbon sequestration
\[
= \text{Carbon sequestration value per pixel} \times \text{RM18.50 (the price of carbon per CO}_2\text{ tonne)}
\]

3. Results and Discussion

The TNP with a total area of 247,700 ha shows that it is capable of sequestering a huge amount of CO$_2$ per year. Conceptually, the value of CO$_2$ is the cost of avoiding the damage with the same amount of CO$_2$. This gas released into the atmosphere has to be valued using the abovementioned valuation approach when there are no official markets for the trading of carbon. Since a market has already existed for carbon emission trading, initially, it was important to evaluate the economic value of carbon sequestration in TNP by conventional way using the market price and amount of CO$_2$ that can be sequestered by each hectare. Later, the results were compared with the ones achieved by NDVI method.

There are few active trading programs in greenhouse gases. The largest is the European Union Emission Trading Scheme [18]. Historically the price per tonne of carbon has been fluctuating at around RM45 to RM125 per CO$_2$ tonne. However, during early 2013, the United States and European economic crises, carbon emission prices had fallen to between RM12 to RM25 per CO$_2$ tonne. For the current study, the average rate of RM18.50 per CO$_2$ tonne was used to assess the economic impact upon CO$_2$ emission. The same value has been used by a previous study [19]. As a result of the calculation, the total amount of carbon storage in TNP was 159,085,325 tonnes CO$_2$. As far as the economic value of carbon sequestration is concerned, it was estimated at RM2,943,078,512.50 (Table 1).

Carbon sequestration calculation using conventional formula
Total value of carbon sequestration
\[
= 247,700 \text{ ha} \times 642.25 \text{ tonnes CO}_2/\text{ha}
\]
\[
= 159,085,325 \text{ tonne CO}_2
\]

Economic value of carbon sequestration
\[
= 159,085,000 \times \text{RM18.50}
\]
\[
= \text{RM2,943,078,512.50}
\]

The total amount of carbon storage or sequestration in TNP using GIS method of NDVI was 142,560,513 tonnes CO$_2$. This amount of storage is lower than that calculated by the conventional formula. Since NDVI calculates the storage of carbon based on the density of the vegetation, the results for storage were shown lower in the low-density areas and which is more accurate than the conventional method (Figure 2). Moreover, the calculation was based on a smaller scale of 900m x 900m (81ha). Thus, playing its role in creating more accurate results. The total economic value of carbon sequestration
was estimated at RM2,637,369,490.50. This amount was similarly lower when compared with the calculation of the conventional method. The reason being is a lower density of forest in some parts resulting in lower sequestration; thus achieving lower economic value (Figure 3). These results are aligned with some previous studies on economic valuation of forests [9, 12, 20].

Carbon storage calculation using GIS method of NDVI

Carbon Sequestration

= [Mean value of NDVI * 642.25 tonnes CO$_2$ / Mean final (NDVI)] * 81ha

= 142,560,513 tonnes CO$_2$

Economic value of carbon sequestration

= Carbon sequestration per pixel * RM18.50 (price of carbon per CO$_2$ tonne)

= RM2,637,369,490.50

| Forest reserves | Area (ha) | Method of calculation | Carbon sequestration (Tonne/year) | The economic value of carbon sequestration (RM/year) |
|-----------------|-----------|-----------------------|---------------------------------|-----------------------------------------------|
| TNP             | 247,700   | Conventional          | 159,085,325 tonnes CO$_2$        | RM2,943,078,512.50                           |
|                 |           | GIS method of NDVI    | 142,560,513 tonnes CO$_2$        | RM2,637,369,490.50                           |

Figure 2. Map of carbon sequestration.
4. Conclusion
The study found that Taman Negara Pahang sequesters the amount of carbon per CO\textsubscript{2} tonne worth more than RM2.5 billion in a year. This study also concluded that higher density forest areas in TNP are worth more than that with lower density in terms of carbon sequestration. The study also established that the conventional calculation does not consider the density of the forest as accurate as the NDVI method does. Looking at the lower density areas in TNP, the study identifies the potential for further afforestation which would result in additional storage of carbon from the atmosphere. This study would help authorities to understand the economic value of forests, thus, convincing them further to conserve such forests in Malaysia and other countries. Further studies can be conducted to assess the economic value of carbon sequestration in the remaining parts of this national park.

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