Carbon stock and carbon emission estimation in Java’s North Coast National Road (Jalur Pantura) within Karawang Regency using high resolution satellite image

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ABSTRACT. Java’s North Coast National Road also known as Jalur Pantura is a primary transportation corridor connecting Indonesian capital city of Jakarta and eastern part of Java Island. Interestingly, the road’s greenbelt is located in Karawang Regency planted with various trees. From its diameter breast height (DBH) and height, above ground biomass (ABG) from these trees were estimated and then compared with four vegetation indices namely NDVI, SAVI, EVI and tasseled cap extracted from SPOT-7 satellite image. Furthermore, this study used predicted ABG values to generate carbon stock and carbon absorption ability. In addition, data from daily vehicle traffic observation will be employed to predict carbon emission. Estimated vehicle carbon emission then compared with carbon absorption ability for each road segment to observe how big trees can store carbon emission from vehicle. The information of carbon balance in each road segment, in form of comparison between carbon absorption ability with vehicle carbon emission, can be useful for road authority to increase vegetation especially in the areas of low carbon absorption.

1. Introduction
One of the approaches in climate change control is by decreasing greenhouse effect, such as CO2 reduction and maintaining forest conservation. Recently, research in carbon stock has increased as climate change issue grows. Carbon stock is the amount of carbon which stored in terrestrial ecosystem consists of biomass in living and dead vegetation, both in soil surface and sub-surface. Moreover, carbon storage is measured in Mg/hectare or ton/hectare [1]. According to Intergovernmental Panel on Climate Change (IPCC), carbon source can be classified into 5 namely, above ground biomass (AGB), below ground biomass, dead wood, litter, and soil [2]. Stored carbon above the surface or AGB is the highest among 5 classes.

Trees have function as carbon absorber. In photosynthesis process, trees absorb carbon dioxide (CO2) from atmosphere, then release oxygen (O2) and finally keep CO2. In trees, most of carbon are stored in wood forms [1], which represent number of carbon in atmosphere absorbed by vegetation.

Nowadays, National Road Route 1 or also known as Jalur Pantai Utara (Pantura) located in Karawang Regency connects Indonesian capital city of Jakarta and cities in West Java Province such as Cirebon and Bandung. This makes Karawang Regency as pivotal in accessibility, not to mention that it has 121,062 kilometres of road which can be classified into provincial, toll, arterial, and collector roads [3]. This situation becomes wary, since high intensity of traffic volume indicates high number of carbon emission.
Therefore, this paper has two objectives which the first is to estimate carbon stock and carbon absorption from AGB by using high resolution satellite images. The second objective is to assess carbon emission in each road segment by comparing its carbon absorption capability.

2. Study area
This research was performed in national road corridor located in Karawang Regency. The national road in Karawang Regency has 54.16 km long, and situated geographically within 107°02'-107°40' East and 05°56'-06°34' South. In the north, Karawang Regency has boundary with Java Sea, while in the south with Bogor Regency [3].

Figure 1. Study area
West of Karawang Regency is Bogor Regency and in the east is Subang Regency (Figure 1). Study area is in Karawang Regency National Road part of National Route 1 also known as Jalur Pantai Utara (Pantura). Based on Indonesian Land Transportation Directorate General Regulation Pantura national road includes roads namely, Tanjung Pura, A. Yani, Tuparev, Suroto Kunto, Klari, Kosambi, Cikampek-Pamanukan and By Pass Jomin.

3. Methods
Broadly speaking, the method used to estimate the vegetation indices was using SPOT-7 images. Three vegetation indices were then correlated with AGB from the trees along the road within sampling locations. The most significant correlation from three different vegetation indices with AGB then chosen to map the overall AGB regarded as carbon stock value along Pantura road. The selected vegetation indices then used. The second objective in this paper was achieved by measuring the traffic volume within sampling location and converted into carbon emission estimation. More detail on overall method can be seen in Figure 2.
3.1 Normalized Difference Vegetation Index (NDVI)
NDVI is one of the most common vegetation indices used in research about biomass and carbon stock. NDVI can be employed to measure vegetation relative condition, which possible to estimate biomass, leaf area index (LAI), and photosynthetically active radiation (PAR) absorbed by vegetation [4]. NDVI value is between -1 and 1, where 0 value frequently associated as the border line between vegetated and un-vegetated pixel. Healthy vegetation cover is represented with NDVI value located within range of 0.1 and 0.7 [5]. NDVI equation can be observed as follow:

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

3.2 Enhanced Vegetation Index (EVI)
EVI was developed as a product from MODIS satellite image. EVI has high sensitivity level detection of biomass by reducing atmosphere and soil value in blue band [6]. EVI has value range between -1 and 1. EVI algorithm can be observed in Equation (2):

$$EVI = G \cdot \frac{(NIR-Red)}{(NIR + C_1 Red - C_2 Blue + L)} \cdot (1+L)$$  (2)

Where G is Gain Factor with 2.5, C_1=6, C_2=7.5 and L is Soil Adjustment value equal with 1.

3.3 Soil Adjusted Vegetation Index (SAVI)
SAVI used to reduce soil spectral value by using Soil Adjustment Factor (L) in NDVI. In general, L value is 0.5 since it can consider area with densely or sparsely vegetation [7]. SAVI algorithm can be observed in Equation (3):

$$SAVI = \frac{(NIR-Red)}{(NIR+Red+L)} \cdot (1+L)$$  (3)
3.4 **Tasseled Cap Greenness (TCG)**

Tasseled cap with greenness index was used to observe the relationship between greenness index and AGB value within sampling locations. This paper used tasselled cap function in ERDAS software to compute tasselled cap greenness index based on SPOT-7 data. Though used function of ERDAS had no algorithm for SPOT-7, however, it was assumed that tasselled cap for Quickbird image within ERDAS software could be selected as the characteristics of bands in both Quickbird and SPOT-7 almost similar.

3.5 **Field Biomass Value Estimation**

In this study, non-destructive sampling was performed to measure height and diameter of trees and then inserted the values into allometric equation to estimate biomass. Allometric data of trees were measured approximately 130 cm from soil surface. In addition, based on this measurement the diameter of every tree can be predicted through circular perimeter calculation. Furthermore, trees height measured by using clinometer device. To convert diameter and height of trees into estimated AGB, couple of equation which came from previous study were employed (Table 1).

Table 1. Allometric equation for AGB based on different tree type

| No. | Tree type               | Allometric equation                     | Source              |
|-----|-------------------------|-----------------------------------------|---------------------|
| 1.  | Woody                   | AGB = 0.0002 H^{2.4071}                 | Berry, 2008         |
| 2.  | Tree with branch        | AGB = 0.11 \rho D^{2.62}                 | Ketterings, 2001    |
| 3.  | Tree without branch     | AGB = \pi \rho H D^{2.62}               | Hairiah et al, 1999 |

Remarks, H= height, D=diameter

3.6 **Carbon stock estimation and carbon absorption capability**

To select which of the vegetation index will be used to map the carbon stock estimation, preliminary simple regression will be performed for each vegetation index as independent variable while carbon stock estimation as dependent variable. Furthermore, to derive carbon stock value, following Equation (4) will be used:

\[
\text{Carbon stock} = \text{Biomass Value (m}^3\text{)} \times 0.50 \text{ (ton/ha)}
\]  

In addition, to convert carbon stock value into carbon absorption capability, Equation (6) will be employed (Waryono, 2013):

\[
\text{Carbon stock absorption} = \text{carbon stock} \times 3.6667 \text{ (ton/ha)}
\]

3.7 **Carbon emission estimation**

To get carbon emission value, traffic volume which crossed Pantura road was observed within two weeks period. Equation (7) was employed to convert traffic volume into carbon emission value [2007].

\[
Q = n \times FE \times K \times L
\]

Where Q is vehicle born emission (gram/hour), n is number of vehicle crossed the road (vehicle equivalent factor/hour), FE is CO2 emission factor merupakan faktor emisi CO2 (gram/liter), K is vehicle fuel consumption per 100 km (liter/km), L is road length (km).

In addition, vehicle equivalent factor was derived by multiplying number of vehicle from observation with conversion factor (Table 2).
VEGETATION CLASSIFICATION BASED ON NDVI VALUE

Table 2. Vehicle equivalent factor [8]

| No. | Vehicle type                  | Vehicle equivalent factor |
|-----|-------------------------------|---------------------------|
| 1.  | Light vehicle (van and pick-up) | 1.0                       |
| 2.  | Heavy vehicle (truck and bus)  | 1.3                       |
| 3.  | Motor cycle                   | 2                         |

Based on previous studies, the relationship between fuel consumption and carbon emission can be used to predict carbon emission in each vehicle (Table 3).

Table 3. Carbon emission conversion factor based on fuel consumption [9]

| No. | Vehicle type | Fuel Type | Specific energy consumption (liter/100 km) | CO2 emission factor (gr/liter) |
|-----|--------------|-----------|-------------------------------------------|-------------------------------|
| 1.  | Van          | gasoline  | 11.79                                     | 2597.86                       |
| 2.  | Pick-up truck| gasoline  | 8.11                                      | 2597.86                       |
| 3.  | Big truck    | diesel    | 15.82                                     | 2924.90                       |
| 4.  | Bus          | diesel    | 16.82                                     | 2924.90                       |
| 5.  | Motor cycle  | gasoline  | 2.66                                      | 2597.86                       |

4. Results and Discussions
4.1 Vegetation classification based on NDVI
Vegetation classes on the Pantura Road can be divided into 3 classes, namely low, medium, and high. The area with NDVI value of 0.3 was classified as low, where mostly located on the following roads namely, Tanjung Pura, Kosambi, Ahmad Yani and Cikampek Pamanukan. While the moderate class of NDVI value had reflectance between 0.30-0.50, mostly located in Jenderal Sudirman road. In addition, area with NDVI value more than 0.50 was classified as high, located on Tanjung Pura and a small portion of Ahmad Yani road (Figure 3).
4.2 Vegetation classification based on SAVI
For area with low class of vegetation based on SAVI value (<0.32), was scattered in whole Pantura Road namely, Tanjung Pura, Kosambi, Cikampek Pamanukan and By Pass Jomin. Meanwhile, for moderate classification of SAVI value (0.32-0.5), it was located mostly in part of Kosambi and Ahmad Yani (Figure 4).

4.3 Vegetation classification based on EVI
Area within the class of low EVI (<0.325), were located along Tanjung Pura, Suroto Kunto, Kosambi, dan Cikampek-Pamanukan. Surprisingly, vegetation class with high EVI (>0.428) was only positioned in small parts of Sudirman and Tang Pura (Figure 5).

4.4 Vegetation classification based on tasselled cap greenness
Based on image processing by using TCG algorithm, it can be observed in Figure 6 that greener colour correspond with vegetation while black colour indicates paddy field. On the other hand, white colour indicates housing and human settlements.
4.5 Relationship between trees characteristics and vegetation classification

Based on simple regression analysis, EVI shows the biggest correlation coefficient among other (Table 4). This indicates that EVI can be used to predict biomass.
Table 4. Models of vegetation indices relationship with AGB

| Vegetation Indices | Model                        | R   | R²   |
|--------------------|------------------------------|-----|------|
| NDVI               | $Y = -1.556 + 10.305 \text{NDVI}$ | 0.423 | 0.179 |
| SAVI               | $Y = 1.034 + 1.499 \text{SAVI}$   | 0.160 | 0.026 |
| EVI                | $Y = -0.639 + 17.453 \text{EVI}$  | 0.460 | 0.212 |
| TCG                | $Y = -0.19 + 4.47 \text{TCG}$     | 0.056 | 0.03  |

4.6 Carbon stock estimation
EVI was used to estimate overall value of AGB in the study area and then using Equation (5) and (6), carbon stock and carbon absorption capability can be predicted. It can be observed from Table 5, Sudirman Road has the biggest AGB and carbon stock estimation. This can be due to the length of the road which affects the increase of trees along the road. On the other hand, Klari Road was the lowest AGB and carbon stock estimation.

Table 5. Models of vegetation indices relationship with AGB

| Road name        | AGB (ton/hectare) | Carbon stock estimation (ton/hectare) | Carbon absorption capability (ton/hectare) |
|------------------|-------------------|--------------------------------------|-------------------------------------------|
| Tanjung Pura     | 1073.43           | 536.72                               | 1,967.97                                  |
| Ahmad Yani       | 686.86            | 343.43                               | 3,759.55                                  |
| Tuparev          | 376.40            | 188.20                               | 690                                        |
| Suroto Kunto     | 1,080.88          | 540.44                               | 1,981.63                                  |
| Klari            | 545               | 272.5                                | 999.17                                     |
| Kosambi          | 1,942.99          | 971.50                               | 3,562.19                                  |
| Tamelang         | 394.45            | 197.22                               | 723.17                                     |
| Cikampek Pamanukan | 3,081.16        | 1,900.58                             | 6,968.86                                  |
| By Pass Jomin    | 884.59            | 442.28                               | 1,621.71                                  |
| Sudirman         | 4,397.84          | 2,198.92                             | 8,062                                      |

4.7 Carbon emission
Based on field observation, average traffic volume in nasional route could reach 18,499 vehicles per hour, and surprisingly up to 23,946 vehicles in holidays. It becomes more clearly, that the highest carbon emission resulted from vehicle in Suroto Kunto- Kosambi road segment. Meanwhile, the lowest carbon emission came from By Pass Joman road section (Figure 7).
In addition, all carbon emission level in each road still below the carbon absorption capability. However, to anticipate the increasing traffic volume in the future, it can be recommended for Pantura national road management to increase trees planting especially in roads where traffic volume are high and carbon stock is low such as Tuparev, Tamelang, Klari and Ahmad Yani.

5. Conclusion
It can be concluded, based on the result within the study area EVI from SPOT-7 is the most suitable index to estimate AGB, carbon stock, and carbon absorption capability. Total AGB and carbon stock in Pantura National Road within Karawang Regency was estimated 18,902 ton/hectare and 9,406 ton/hectare, respectively. Highest carbon emission estimation was in the area of Suroto Kunto Road which located near industrial areas.

6. References
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