Estimation of carbon emission from peatland fires using Landsat-8 OLI imagery in Siak District, Riau Province

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Abstract. The study was conducted in three land cover conditions (secondary peat forest, shrub land, and palm plantation) that were burned in the Siak District, Riau Province, Indonesia year 2015. Measurement and calculation carbon emission from soil and vegetation of peatland should be done accurately to be implemented on climate change mitigation or greenhouse gases mitigation. The objective of the study was to estimate the carbon emission caused peatland fires in the Siak District, Riau Province, Indonesia year 2015. Estimated carbon emissions were performed using visual method and digital method. The visual method was a method that uses on-screen digitization assisted by hotspot data, the presence of smoke, and fire suppression data. The digital method was a method that uses the Normalized Burn Ratio (NBR) index. The estimated carbon emissions were calculated using the equation that was developed from IPCC 2006 in Verified Carbon Standard 2015. The results showed that the estimation of carbon emissions from fires from above the peat soil surface were higher than the carbon emissions from the peat soil. Carbon emissions above the peat soil surface of 1376.51 ton C/ha were obtained by visual method while 3984.33 ton C/ha were obtained by digital method. Peatland carbon emissions of 6.6 x 10^-4 ton C/ha were obtained by visual method, whereas 2.84 x 10^-3 ton C/ha was obtained by digital method. Visual method and digital method using remote sensing must be combined and developed in order to carbon emission values will be more accurate.

1. Introduction
Peatland ecosystem plays an important role in maintaining environmental balance, including preventing floods during the rainy season and releasing moisture back into the air during the dry season, however, this ecosystem is very fragile. Peatland ecosystems disturbed by particular factors such as drying with the canalization system will gradually dry up and have vulnerability to fire. Organic materials in peatland ecosystems have a great potential in triggering the fires when it is supported by the suitable weather/climate conditions.

Peatland fire is categorized in the most dangerous types of fires [1]. Peatland fires are a major contributor to Indonesia’s greenhouse gas (GHG) emissions. About 500 billion tons of carbon are stored in the vegetation that exists worldwide. The carbon element is the dominant compound in peatland fires, almost 45% of the plant's dry matter is carbon [2]. The increasing carbon compounds as greenhouse gases, the greenhouse effect is also increasing.
The emission calculations for tropical peatlands in relation to fires been based upon limited field data. A study of the West and East Kalimantan region conducted by the Forestry Research and Development Team and the Directorate General of Plants (2009) states that there are obstacles in implementing the IPCC guideline 2006, particularly the data limitations that result in low levels of detail. Data needed to calculate emissions using IPCC guideline 2006 are activity data and emission factor data or absorption. Activity data such as peatland fires are required in hectares, so that accuracy of peatland fires are urgently needed to produce accurate carbon emissions data.

Remote sensing and Geographic Information Systems (GIS) play an important role in the study of factors affecting fire occurrence and understanding fire behavior [6]. Previous studies have used satellite-based sensors AWiFS, LISS-III, ETM +, SPOT, AATSR, AVHRR, and MODIS [7]. Images from MODIS and Landsat TM /ETM + satellites are common sources of data and have the potential to monitor forest fires [7]. Several studies have studied the topic related to the use of remote sensing satellite imagery to identify forest and land fires, including the identification of burned areas, however, the research has not been widely developed in Indonesia. Researchers in Indonesia have been detection using Landsat TM multi-time satellite imagery, MOS-MESSR, and Landsat TM multisensor images, and using SPOT images [3], [4], [5]. Therefore, it is necessary to conduct the study on burned areas with the aim was to test the reliability of quantitative methods (digital) and qualitative (visual) methods in order to estimate the burned area.

2. Research method

2.1. Study area
The research was conducted on May 2016 to April 2017. The study was conducted in Siak Regency. Data processing and analysis of imagery data were performed in Remote Sensing Laboratory and GIS, Forestry Faculty of IPB, Bogor, and Utilization Center of Remote Sensing LAPAN.

2.2. Tools and materials
The tools used in this study were a set of computers with some software such as Microsoft Excel 2016 for tabulation and graphics processing, digital camera, GPS (Global Positioning System), compass, oven, trash bag, plastic straps, phi band, tally sheet. The materials used in this study was primary and secondary data, namely: (1) top surface plat conditions (trees, poles, stakes, seedlings, necromass, dead woods) and peat soils, (2) the preliminary research data (burned area and land cover) [8]

2.3. Method and data analysis

2.3.1. Determination and preparation of research plots.

Where:
A : tree plot (20m × 20m);
B : pole plot (10m × 10m);
C : stake plot (5m × 5m);
D : seedling plot (2m × 2m).
The plot distance is 50 m.

Figure 1. Research plot design.

The sampling technique used is a randomly sampled from SNI 7724 year 2011 on measurement and calculation of carbon stock. The size of the largest plot is 20 m × 20 m (figure 1), whereas the plot
size for vegetation are: (a) seedling with a minimum area of 4 m$^2$, (b) stake with a minimum area of 25 m$^2$, (c) pole with a minimum area of 100 m$^2$, and (d) tree with a minimum area of 400 m$^2$.

2.3.2. Biomass data collection. The biomass data were collected in each plot. All sections were collected in each collection plot, then weighed the total wet weight and sampled each of ± 300 grams wet weight. The biomass samples were dried by oven in the laboratory with a temperature range of 70°C to 85°C until it reached a constant weight for 2 × 24 hours. Thus will be obtained dry weight (biomass).

2.3.3. Soil sampling. The soil samples were taken in a disturbed and intact soil. The disturbed soil was weighed to obtain the net weight while the intact soil was taken using a ring sampler to obtain the bulk density. Soil samples were taken as many as 3 samples in each plot 20 m × 20 m.

2.3.4. Calculation of biomass carbon stock. The tree biomass was estimated using allometric equations depending on DBH (Diameter at Breast Height) in cm and WD (Wood Density) in g cm$^{-3}$ [9]:

$$\text{AGB}_{\text{est}} = 0.242 \times \text{DBH}^{2.473} \times \text{WD}^{0.736}$$  \hspace{1cm} (1)

Other biomass data were calculated based on SNI 7724 year 2011. Then, these biomass data were converted to carbon stock data.

2.3.5. Estimation of carbon emissions. Estimating carbon emissions from peatland fires used the IPCC 2006 method in the Verified Carbon Standards 2015 [10]. Estimating can be used the following equations:

$$E_{\text{biomassburn}, i, t} = \sum_{g=1}^{G} \left( (A_{\text{burn}, i, t} \times B_{i, t} \times \text{COMF}_i \times G_{g, i} \times 10^{-3}) \times \text{GWP}_g \right)$$  \hspace{1cm} (2)

Where:
- $E_{\text{biomassburn}, i, t}$ Greenhouse gas emissions due to biomass burning as part of deforestation activities in stratum i in year t of each GHG (CO$_2$, CH$_4$, CO) (t CO$_2$e)
- $A_{\text{burn}, i, t}$ Area burnt for stratum i in year t (ha)
- $B_{i, t}$ Average aboveground biomass stock before burning stratum i, year (t d.m. ha$^{-1}$)
- COMF$_i$ Combustion factor for stratum i (unitless)
- $G_{g, i}$ Emission factor for gas g in stratum i for gas g (kg t$^{-1}$ d.m. burnt)
- GWP$_g$ Global warming potential for gas g (t CO$_2$/t gas g)

$$E_{\text{peatburn}, i, t} = \sum_{g=1}^{G} \left( (A_{\text{peatburn}, i, t} \times P_{i, t} \times G_{\text{peat}, g, i} \times 10^{-3}) \times \text{GWP}_g \right)$$  \hspace{1cm} (3)

Where:
- $E_{\text{peatburn}, i, t}$ Greenhouse emissions due to peat burning in stratum i in year t of each GHG (CO$_2$, CH$_4$, CO) (t CO$_2$e)
- $A_{\text{peatburn}, i, t}$ Area peat burnt in stratum i in year t (ha)
- $P_{i, t}$ Average mass of peat burnt in stratum i, year t (t d.m. ha$^{-1}$)
- $G_{\text{peat}, g, i}$ Emission factor in stratum i for gas g (kg t$^{-1}$ d.m. burnt)
- GWP$_g$ Global warming potential for gas g (t CO$_2$/t g)

1, 2, 3 ... G greenhouse gases (unitless)
3 Result and discussion

3.1. Condition of measurement location for carbon stock

Map of research object in Dayun Village Dayun Subdistrict and Kotoringin Village Mempura Subdistrict of Siak District can be seen in figure 2. These locations are quite far from Siak City, which is about 15–30 km and could be reached by two-wheeled or four wheels vehicles. Mileage to the location of research about 1 hour. The location’s coordinate of this measurement is the UTM 48 N (table 1).

Table 1. The Coordinate of sampling location.

| Land Cover              | Plot | Latitude (°LU) | Longitude (°BT) |
|------------------------|------|---------------|-----------------|
| Shrub                  | 1    | 0.66724       | 102.10985       |
| Shrub                  | 2    | 0.66681       | 102.11005       |
| Shrub                  | 3    | 0.66624       | 102.11015       |
| Oil palm plantation    | 1    | 0.87683       | 102.07080       |
| Oil palm plantation    | 2    | 0.87666       | 102.07136       |
| Oil palm plantation    | 3    | 0.87655       | 102.07176       |
| Secondary forest       | 1    | 0.66904       | 102.09885       |
| Secondary forest       | 2    | 0.66887       | 102.09888       |
| Secondary forest       | 3    | 0.66880       | 102.09891       |

The location of carbon stock measurement is land under the control of Natural Resources Conservation Center (BBKSDA) of Riau Province. The condition of burning area consisted of 3 types of land cover namely shrub, oil palm plantation, and secondary forest. The topography of the three types of land cover is relatively flat. The thickness of peat in 3 land types was categorized as medium (1–2 m) for oil palm plantation and very deep category (>3 m) for shrub and secondary forest. Types of land cover are frequent fires due to dry or non-flooded peat conditions and the presence of many artificial canals nearby.

3.2. Carbon stock at above ground of the burned area

This research used the allometric equation of Manuri et al. [9], Lubis [11], Hairiah et al. [12]. These equations were used to determine the carbon content at above ground. The results of carbon (ton/ha) contents calculations of the 9 sample plots consisting of different levels of regeneration, litter, and necromass are presented in table 2 and table 3.
Tables 2 and 3 show that the carbon content in secondary forest (104.72 ton/ha) was higher than that of oil palm plantation (42.47 ton/ha) and shrub (54.69 ton/ha). Carbon content in the swamp secondary forest area suggests the highest carbon content compared to other land cover types due to the highest tree density in the area in each diameter class. According to Syam’ami et al. [13], the amount of carbon stock in a region is closely related to the diameter growth and the quantity of tree biomass since most of the biomass is contained in tree trunks. The tree component has the largest percentage because the stem is the woody part and the largest storage of photosynthesis for growth. In secondary forest areas, it was obtained stands with a diameter almost 60 cm, this condition was not found in shrubs. The results of Indrajaya’s research [14] showed that trees with stem diameters >60 cm, although the percentage was only 4.93%, has contributed 67% in storing carbon in the above-ground biomass.

**Table 2. Total carbon content at above and below ground for the observation site of secondary forest and shrub.**

| Plot | Carbon of litter (ton/ha) | Carbon of understory Plants (ton/ha) | Carbon of dead tree (ton/ha) | Carbon of trees, poles, stakes (ton/ha) | Carbon of root (ton/ha) | Total carbon content (ton/ha) |
|------|--------------------------|-------------------------------------|-----------------------------|----------------------------------------|------------------------|-----------------------------|
| **Secondary forest** | | | | | | |
| I | 3.02 | 0.41 | 0.45 | 82.93 | 11.35 | 98.16 |
| II | 1.13 | 0.28 | 0.62 | 137.14 | 18.77 | 157.95 |
| III | 2.69 | 0.06 | 0.66 | 48.08 | 6.58 | 58.06 |
| **Average** | 2.28 | 0.25 | 0.58 | 89.38 | 12.24 | 104.72 |
| **Shrub** | | | | | | |
| I | 2.05 | 0.11 | 0.45 | 27.35 | 3.74 | 33.70 |
| II | 2.81 | 0.04 | 1.10 | 96.86 | 13.26 | 114.07 |
| III | 2.71 | 0.03 | 0.98 | 11.06 | 1.51 | 16.29 |
| **Average** | 2.52 | 0.06 | 0.84 | 45.09 | 6.17 | 54.69 |

**Table 3. Total carbon content at the observation site of oil palm plantation.**

| Plot | Carbon of litter (ton/ha) | Carbon of understory plants (ton/ha) | Carbon of fronds (ton/ha) | Carbon of dead tree (ton/ha) | Carbon of tree (ton/ha) | Total carbon content (ton/ha) |
|------|--------------------------|-------------------------------------|--------------------------|-----------------------------|------------------------|-----------------------------|
| I | 0.00 | 2.09 | 57.26 | 0.00 | 4.16 | 63.51 |
| II | 7.34 | 1.99 | 0.00 | 0.00 | 9.48 | 18.82 |
| III | 0.59 | 1.63 | 37.84 | 0.73 | 4.30 | 45.09 |
| **Average** | 3.97 | 1.90 | 18.92 | 0.73 | 5.98 | 42.47 |

The root of tree was the second largest carbon stock after the tree trunk. Root carbon stocks are directly proportional to the above-ground carbon stocks [15]. The percentages of tree root biomass in secondary forest and shrubs were respectively by 14%. This result is in line with Indrajaya [14] research results in the protected forest in Ketrok Malinau District. Areas with healthy stands condition will be able to optimally store carbon at above and below ground.

Litter carbon stocks on land cover types of secondary forests and shrubs were smaller than that finding by Wahyuni et al. [16] but larger than Mahfud et al. [17]. This difference is caused by differences in the physical condition of the area and also the measurement time which conducted during the dry season. According to Liao et al. [18], litter production in the rainy and autumn seasons is high while that is moderate to low out of the seasons. However, the high litter production during the rainy season cannot survive for a long time on the forest floor due to the rain flows.

The carbon stock of understory plants was similar to Ariani et al. [19] result that is 0.13–0.53 tons C/ha but much lower than Azham [20] research results. The carbon stock of understory plants in this study is considered low due to human activity and canopy factor. The shrubs are frequently disturbed.
by surrounding communities in the form of land clearing for planting preparation or as an accessibility area, moreover, the secondary forest has a more dense canopy so the carbon stock is relatively low.

The carbon stock of small diameter dead tree was relatively low, this is also lower than that found by Wahyuni et al. [16], amounted to 1.64 tons C/ha. Carbon stock of dead tree is an indicator of low illegal logging and the relative good of stands health conditions.

The largest total carbon stocks from table 2 and 3 if sorted on each of the existing land covers were obtained in the secondary forest of 104.72 ton/ha, shrub of 54.69 ton/ha, then palm plantation of 42.47 ton/ha. The results of the previous research indicated that secondary forest carbon stocks are 83.49 ton/ha [21], shrub carbon stocks of 55.19 ton/ha [22], carbon stocks of oil palm plantation with age between 6–10 year of 34.16 ton/ha [23]. Several results of the previous research were not much different with the results of carbon stocks in this study. Furthermore, according to Hairiah et al. [24], the differences of carbon stocks amounts between types of land cover depend on the diversity and density of existing plants, type of soil, and management method of land. The more diverse plants provide larger carbon stocks.

3.3. Physical and chemical properties of peat soil

The results of physical and chemical properties analysis of peat soil prior to burning are presented in table 4. The bulk density of secondary forest (0.22 g/cm³) was lower than that of shrubs (0.26 g/cm³) and oil palm plantation (0.30 g/cm³). The bulk density is affected by the depth of the groundwater level and affects the decomposition process. The difference of groundwater depth is caused by the land processing system, which is drainage or canalization channel. Differences in the value of bulk density are also influenced by the level of peat maturity. In addition, the bulk density also has a reciprocal relationship with porosity [25], in which soils with a relatively low bulk density generally have high porosity. Furthermore, oil palm plantations have high bulk density value compared to other types of land. This condition might be caused by the land preparation before planting in the form of drainage, soil grinding, and organic or inorganic fertilization which can change the nature of peat [26].

Above ground Organic-C of peat soils in secondary forests was higher than in other land types. The lower organic-C values on oil palm plantation cover due to decomposition activities by soil microorganisms, erosion, and subsidence. Drained peatland conditions will change the condition of peat from anaerobes to aerobes. Moreover, the results of Nugroho et al. [26] suggested that the c-organic value of peat soils will be degraded since the conversion of secondary peat forests into oil palm plantations.

### Table 4. Physical and chemical properties of peat soil before burning in various types of land cover.

| Variable       | Secondary forest | Shrub       | Oil palm plantation |
|----------------|-----------------|-------------|---------------------|
| Bulk density (g/cm³) | 0.22 ± 0.02     | 0.26 ± 0.02 | 0.30 ± 0.02         |
| Organic-C (%)  | 49.26 ± 0.40    | 49.22 ± 0.44| 45.79 ± 0.11        |

Note: The numbers written after the ± sign are the standard deviations.

3.4. Carbon stock in top layer of peat soil

Carbon stock in the top layer of Peat Soil (10 cm) is interpreted from bulk density and c-organic content of peatland (table 5). The highest carbon stock in the top of peat soil (10 cm) on oil palm plantation (138.542 ton/ha) was higher than that of secondary forest (108.63 ton/ha) and shrub (126.712 ton/ha). The carbon stock in the top of peat soil (10 cm) in land covered oil palm plantation is influenced by the value of bulk density which is relatively higher than other land covers.

In this study, sampling was done at the same depth because the data related the top layer of peat soil is required for the calculation of carbon emissions from peatland fires. The calculation of this carbon stock cannot be equated with the overall peat soil carbon stocks using peat thickness variables. Aswandi
et al. [27] stated that the peat soil carbon stock in secondary forest is higher than that of oil palm plantations. This is due to variations of peat thickness variable and secondary forest land cover that have a deeper peat thickness than that in oil palm plantations. The results of Safitri’s research [28] stated that peat soil carbon in oil palm plantation with a depth of 28 cm, 34 cm, and 146 cm were 266 tons/ha, 341 tons/ha and 2050 tons/ha respectively. The results of Safitri’s research [28] can also be compared with the results of this study which suggested that the carbon stock of peat soil with a depth of 10 cm automatically lower than 266 tons/ha, this is in line with the results of the calculations presented in table 5.

3.5. Carbon emission from peatland fires

The forest and land fires cause biodiversity loss and will also affect the amount of carbon emissions generated from the burning areas. Lu et al. [29] stated that forest and land fires result in the release of carbonaceous compounds into the air. Subsequently, the increasing carbon compounds as greenhouse gases raise the greenhouse effect. The carbon is the dominant compound in forest fires since nearly 45% of the plant's dry matter is carbon [2]. Most of the carbon emitted into the air is in the form of CO$_2$, the excess is CO$_2$ and hydrocarbons (mainly CH$_4$ and smoke), while sulfur will be left as smoke and slightly formed into SO$_2$ and chlorine elements form the CH$_3$Cl compounds [30]. Carbon emissions from fires cause carbon stocks decline. Thus, an approach based on carbon stocks in the land that is assumed for unburnt is expected to provide information on carbon emissions occurred in burning areas.

The carbon stock of each land cover will be different, therefore in case of forest and land fires with high biomass to low biomass contents will impact on less carbon content and furtherly contribute to the value of carbon emissions. The data of Carbon stock is partly obtained from the result of previous research through a direct measurement in the field.

Table 5. Carbon stock in the top layer of peat soil in research location of secondary forest, shrub, and oil palm plantation.

| Land cover [8] | The depth of soil sample (cm) | Bulk density (g cm$^{-3}$) | % C-Organic soil content | Carbon stock (ton/ha) |
|---------------|------------------------------|-----------------------------|--------------------------|----------------------|
| Secondary forest | 10 | 0.219 | 0.493 | 108.363 |
| Shrub | 10 | 0.258 | 0.492 | 126.712 |
| Oil palm plantation | 10 | 0.302 | 0.458 | 138.542 |

Table 6. The depth and mass of the peat burn.

| Land cover [8] | The depth of peat burn (cm) | The mass of the peat burn (ton/ha) |
|---------------|-----------------------------|-----------------------------------|
| Secondary forest | 33.17 ± 3.65 | 73 x 10$^{-7}$ |
| Oil palm plantation | 25.00 ± 2.89 | 65 x 10$^{-7}$ |
| Shrub | 52.57 ± 2.25 | 158 x 10$^{-7}$ |

The calculation of carbon emissions from peat fires used the data of bulk density and the surface depth of the burning peat. Table 6 shows that the highest average of burning peat depth is found on the land cover of shrub. The highest level of peat depth in shrubs is caused by higher fire intensity than others. The depth of the peat burned in the secondary forest was about 15–74 cm, in the oil palm plantation of 15–30 cm, and in the shrub of about 30–72 cm.

According to Utami et al. [31], Indonesia has different fire patterns from other regions in Southeast Asia. Indonesia contributes to open burning biomass emissions resulting from burning of rice stem or straw, forest, and peatland fires. Indonesia contributes the fourth largest emissions of open burning biomass in Southeast Asia, however, considering the amount of emissions in peatlands, Indonesia contributes for about 84% of carbon dioxide emissions.
Table 7. Carbon emissions from forest and peatland fires.

| Land cover                  | Carbon emission (ton C/ha) | Finding result | Reference [33] |
|----------------------------|----------------------------|----------------|----------------|
|                            | Visual Method[^[8]]        | Digital Method (NBR model)[^[8]] | Visual Method                                      | Digital Method (NBR model) |
| Carbon emission at above ground of peat soil (A) |                          |                |                |
| Shrub                      | 524.84                     | 3024.09        |                |
| Secondary forest           | 230.69                     | 553.67         |                |
| Forest Plantation          | 381.81                     | -              |                |
| Oil palm plantation        | 239.16                     | 406.58         |                |
| Total                      | 1376.51                    | 3984.33        |                |
| Carbon emission of peat (B)|                            |                |                |
| Shrub                      | $4.5 \times 10^{-4}$       | $2.57 \times 10^{-3}$ | $4.3 \times 10^{-4}$ | $2.45 \times 10^{-3}$ |
| Secondary forest           | $5.0 \times 10^{-5}$       | $1.20 \times 10^{-4}$ | $4.7 \times 10^{-5}$ | $1.12 \times 10^{-4}$ |
| Forest Plantation          | $8.0 \times 10^{-5}$       | -              | $7.5 \times 10^{-5}$ | - |
| Oil palm plantation        | $9.0 \times 10^{-5}$       | $1.50 \times 10^{-4}$ | $8.4 \times 10^{-5}$ | $1.42 \times 10^{-4}$ |
| Total                      | $6.6 \times 10^{-4}$       | $2.84 \times 10^{-3}$ | $6.3 \times 10^{-4}$ | $2.70 \times 10^{-3}$ |
| Total carbon emission (A + B)| 1376.51                    | 3984.33        |                |

Carbon emissions from peat fires can be seen in table 7. This carbon emission calculation is performed on the different land cover and is generated from CO₂, CO, and CH₄ emissions. However, carbon emissions from peat fires are not known in detail. The results of Anita et al. [32], used a gas analyzer and gas chromatography, stated that CO₂ emissions from shrubs, oil palm plantation, and secondary forest were 497.4 ppm; 523.2 ppm; 457.2 ppm respectively. In contrast to this study that used the Verified Carbon Standard [10], the results of this study showed that carbon emissions in the shrub were higher than others since the severity of the fires is also high. Peat soil carbon emission value was considered very low, however, a relatively high value of carbon emissions at above ground of peat soil is also obtained. The total carbon emissions resulting from the visual method are different from those of the digital method due to some constraints already mentioned in the previous chapter.

Stockwell et al. [33] stated that changes in the value of emission factors used in the calculation of greenhouse gas emissions from peat soil fires in tropical countries need to be obtained. This is because the default emission factor value published in IPCC 2003 is the result of a laboratory study which used only single samples. Furthermore, the CO₂ emission factor value changed from 464 g / kg to 1564 ± 77 g / kg, the CO changed from 210 g/kg to 291 ± 49 g/kg, and CH₄ changed from 21 g/kg to 9.51 ± 4.74 g/kg. Table 7 presents the differences between peatland carbon emissions calculations using IPCC [34] and emissions factor of Stockwell et al. [33]. The result of the final calculation for peat soil carbon emission from fire was 0.05% lower than using the value of emission factor of Stockwell et al. [33].

4 Conclusion
The estimation of carbon emissions from fires from above the peat soil surface were higher than the carbon emissions from the peat soil. Carbon emissions above the peat soil surface of 1376.51 ton C/ha were obtained by visual method while 3984.33 ton C/ha were obtained by digital method. Peatland carbon emissions of $6.6 \times 10^{-4}$ ton C/ha were obtained by visual method, whereas $2.84 \times 10^{-3}$ ton C/ha was obtained by digital method. Visual method and digital method using remote sensing must be combined and developed in order to carbon emission values will be more accurate.
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