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CARBON STOCK ESTIMATION IN SMALL-SCALE PEAT ECOSYSTEMS BASED ON THE NDVI VEGETATION INDEX ON THE GOOGLE EARTH ENGINE CLOUD COMPUTING PLATFORM

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Abstract: Peatlands are wetland ecosystems that originate from piles of rotting organic material on the surface of the soil. Peatlands have unique conditions that are not found in other land system units, these conditions include having a high biomass value and carbon storage capacity. Jambu Baru Village is one of the villages located on a peatland unit with ecosystem conditions that have not experienced major changes or conversion of function. Field measurements aim to test and validate the value of soil biomass and carbon content in peatlands. The greenness index model from Sentinel 2A satellite imagery is used as the main basis for determining sampling plots for biomass measurements in each class of greenness index for each land cover in the field. The research results showed that the greater the diameter and height of the plant, the higher the biomass content and carbon stock, high stands obtained a biomass value of 14.95 kg with a carbon stock of 20.36 kg; medium stands obtained a biomass value of 9.08 kg with a carbon stock of 7.33 kg and low stands obtained a biomass value of 0.89 kg with a carbon stock of 0.42 kg. In this research, results were also obtained which showed that the tree and pole sources had the highest biomass among the other sources, 24.04 kg with 27.68 kg of carbon. The results of calculating biomass and carbon stock values for the wetland ecosystem in Jambu Baru Village are presented in spatial modeling in the form of a map of estimated biomass and carbon stock values.

Keywords: biomass; carbon stock; peat ecosystem; google earth engine

INTRODUCTION

Climate change is a major problem in the world today. In Indonesia, this is exacerbated by the trend of deforestation and degradation of tropical forest land which is getting worse from year to year. Deforestation and forest land degradation cause the release of carbon and emissions into the atmosphere. It is one of the factors that contributes to increasing carbon dioxide emissions and global warming

The climate change phenomenon whose impact is directly felt is during the El Nino and La Nina cycles. El Nino climate and La Nina climate are forms of climate change that occur throughout Indonesia. It was recorded that in 1997-1998 there was a prolonged dry season (El

Nino climate) and in 2020-2021 there was an extreme rainy season, causing almost all of Indonesia to be affected by flooding. Barito Kuala Regency is one of the areas affected by these two climate changes.

Barito Kuala (Batola) Regency is one of the regions in South Kalimantan has peatland, covering 40% of its area (Bapedda, 2013), peatlands in Batola Regency almost always experience fires every year. Jambu Baru Village is one of the villages experiencing forest fires (karhutla) in 2022 (BNPB, 2022). Forest and land fires are caused by various factors, natural factors and anthropogenic factors. According to Rosalina et al, (2019), forest and land fires in Barito Kuala Regency are caused by the lack of peat water content and rainwater which makes the peat land dry and easy to catch fire.

It is strongly suspected that the lack of water content plays a role in the El Nino climate phenomenon, which has become more frequent in recent years. El Nino increases the risk of forest fires, where these fires then increase carbon dioxide emissions and increase climate change. Climate change will ultimately give rise to a vicious circle that further worsens the conditions of the macro and micro environment and ecosystems, which are uninterrupted and interconnected with each other. According to the 2019 IPCC report, tropical forests store 25% of the world's total carbon and absorb around 2 billion tons of carbon dioxide every year.

Indonesia as a country with a tropical climate has very extensive forests. Data from the Indonesian Ministry of Environment and Forestry shows that the forest area in Indonesia in 2022 will be 125,795,306 ha. This large carbon reserve also causes a high amount of carbon released into the atmosphere when peatlands in Indonesia burn. The high amount of carbon released into the atmosphere causes increased carbon dioxide emissions and warming.

The first step in conserving forest land is to monitor biomass value, carbon stock, and CO^2 emission absorption capacity. This monitoring can be done by combining remote sensing methods and measurements in the field (Jauhari et al, 2021; Arini et al, 2020).

LITERATURE REVIEW

Peat Ecosystem Management

Peat ecosystem management is influenced by the perspective of the peat ecosystem. In this case, the developmentalism paradigm views peat ecosystems as marginal land. It is said to be marginal land because not all types of plants can grow on peat land, and its management for agriculture requires special approaches, techniques, and technology. Masganti et al (2014), explained that the characteristics of peatlands are vulnerable to adverse changes. Care is needed in management to avoid a decrease in productivity due to changes in land characteristics. In response to global warming and the increasingly worsening impacts of climate change, peatland management is becoming a big concern. Wahyuni et al (2021), stated that if the amount of peat decreases, the result will be uncontrolled climate change.

Therefore, sustainable peatland management and participatory peatland conservation are needed as a form of climate change mitigation (Fatkhullah et al, 2021).

Peatland Conservation

In response to global warming and the increasingly worsening impacts of climate change, peatland management is becoming a big concern. Wahyuni et al (2021), stated that if the amount of peat decreases, the result will be uncontrolled climate change. Therefore, sustainable peatland management and participatory peatland conservation are needed as a form of climate change mitigation (Fatkhullah et al, 2021).

Land conservation is an action or effort to protect, maintain, and improve the quality of land so that it functions optimally in supporting human survival and ecosystem sustainability. Land conservation includes the management and preservation of the natural resources contained in land, water, air, and biodiversity. Land conservation aim is to avoid land damage which can cause natural disasters, environmental damage, and loss of biodiversity (KLHK, 2018).

Biomass and Carbon Stocks

Biomass is all organic material obtained from biological sources, such as plants or animals. Biomass can be obtained from various sources, such as biomass from forests, agricultural waste, food waste, industrial waste, and others (Radhiana et al, 2023). Biomass has the potential as a renewable energy source that can be used as an alternative to fossil fuels. Through photosynthesis carbon dioxide is absorbed and converted by plants into organic carbon in the form of biomass. Biomass is an energy absorption that can be converted into carbon, alcohol, or wood. The absolute carbon content or the amount of carbon stored in a biomass is known as carbon stock.

Carbon stocks can be expressed in terms of mass or volume of carbon, such as tons of carbon or kilograms of carbon per hectare. Carbon stocks can change due to changes in resource availability or environmental conditions, such as deforestation or land degradation (Siamti et al, 2021). Each plant and vegetation has a different carbon stock. The more solar energy you absorb, the greater the carbon stock. Indonesia as a tropical country has two seasons, dry and rainy, making it one of the largest carbon stock storage areas. Even though it is one of the largest stores of carbon stocks, many people still do not understand the impact of burning their agricultural products or cutting down forests illegally. As a result, carbon stocks are released into the air and become carbon emissions.

RESEARCH METHODS

Research methods

The method used in this research is a quantitative method with a spatial approach and field observations. The data used is secondary data in the form of satellite images Sentinel 2A was released by the Copernicus satellite operated by the European Space Agency (ESA). Having a spatial resolution of 10 m per pixel, the Sentinel-2 Satellite has a single multi-spectral sensor instrument (MSI) with 13 spectral channels in the visible/near-infrared (VNIR) and shortwave infrared (SWIR) spectral ranges. In 13 bands.

The greenness index in vegetation then becomes a reference in determining sample plot points using the allometric block method. Block division is a determinant in field observations which aim to determine the number and types of dominant plants, as well as the diameter and height of the plants selected for sampling. Data collected through field measurements will be processed to determine the value of above-ground biomass and the value of carbon stocks. Figure 1 presents the framework for this research.

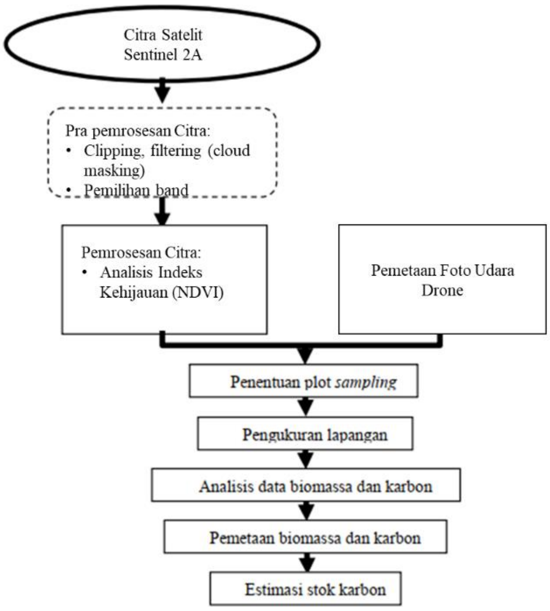

Figure 1. Research Framework

Research sites

This research was carried out in Jambu Baru Village, Kuripan District, Barito Kuala Regency (Figure 2). The time for carrying out this research is April – November 2023.

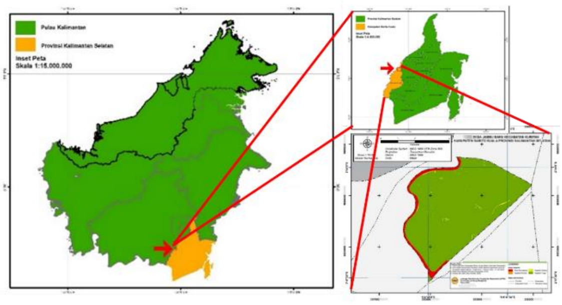

Figure 2. Research sites

Research Stages

1. Identify the Greenness Index

NDVI (Normalized Difference Vegetation Index) is an index used to measure the amount and quality of vegetation in an area. NDVI classification involves dividing areas or images based on NDVI values obtained from remote sensing or satellite imagery. In general, NDVI classification is divided into 5 categories.

Table 1. Greenness index class

No	NDVI Class	Information
1	NDVI > 0.8	(very high vegetation)
2	0.6 < NDVI < 0.8	(high vegetation)
3	0.4 < NDVI < 0.6	(medium vegetation)
4	0.2 < NDVI < 0.4	(low vegetation)
5	NDVI < 0.2	(very low vegetation)

Source: processed from primary data

2. Calculation of Biomass Value in Greenness Class

The formula for calculating plant biomass using the Normalized Regional Vegetation Index (NDVI) is as follows:

$$\text{Biomass} = A * \text{NDVI} + B$$

3. Biomass Measurement

Biomass calculations use allometric equations (Chave, 2005). To calculate biomass in secondary natural forests, the average specific gravity of the wood used is 0.68 gr/cm3. The allometric equation used is;

$$Y = 0.509\ xpx\ DBH^2\ x\ T$$

Information:

Y = Total Biomass
P = Specific gravity of wood 0.68 gr/cm³
DBH = Diameter at chest height (m)
Q = Free height of branches (m)

4. Carbon Stock Calculation

Aboveground carbon stock: AGC *(T/Ha) = Biomass (Kg/Ha) X Carbon Factor (0.5)*

Information:

A	Area of planted land with biomass in hectares (ha)
B.D	Biomass produced by plants in tonnes/ha
C	Carbon conversion factor (in units of tons of carbon per ton of biomass)
D	Carbon absorption capacity factor (in years)

RESULTS AND DISCUSSION

Satellite Image Processing to Identify Greenness Index Values

Satellite image data is used to create sampling plots for measuring biomass and carbon stock values. Making measurement sampling plots was carried out by dividing the peat ecosystem in Jambu Baru village into three classes of vegetation density and greenness. Access and processing of Sentinel 2A satellite image data is carried out on the Google Earth Engine (GEE) satellite image data provider and processing platform.

1. Data Pre-process

Using the GEE platform as a server platform to provide satellite imagery data needed for research. The GEE platform is script and command-based programming, to carry out the required functions, users use a Javascript-based programming language. The script used in this stage is:

```
var dataset =
ee.ImageCollection('COPERNICUS/S2_SR_HARMONIZED')
          .filterDate('2022-01-01', '2023-6-30')

.filter(ee.Filter.lt('CLOUDY_PIXEL_PERCENTAGE',20))
          .map(maskS2clouds)
          .median()
          .clip(Village);
```

Figure 3. Sentinel 2A Satellite Image Data Acquisition Process

The first line functions to determine the database used. The second row determines the time series of the data. The third to fifth lines function as a cloud correction tool, with cloud correction by 20%. The sixth line functions as location selection.

```
function maskS2clouds(image) {
var qa = image.select('QA60');
var cloudBitMask = 1 << 10;
var cirrusBitMask = 1 << 11;
var mask = qa.bitwiseAnd(cloudBitMask).eq(0)
.and(qa.bitwiseAnd(cirrusBitMask).eq(0));
return image.updateMask(mask).divide(1);
}
```

Figure 4. Satellite Image cropping process and cloud cover correction

The script above functions as a cloud correction tool, it also functions as a continuation of cloud correction.

```
var rgb = dataset.select(['B4', 'B3', 'B2']);
var RGBparam = {min: 0, max:3000,};
 Map.addLayer(rgb, RGBparam, 'RGB');
```

Figure 5. Band selection process for Greenness Index analysis

The first line functions as band selection from the database, in the database selected bands 4, 3, and 2. The second line functions to render the visualization. The third line functions to display data.

2. NDVI Greenness Index Processing

```
var nir = dataset.select('B8');
var red = dataset.select('B3');
var ndvi = nir.subtract(red).divide(nir.add(red)).rename('NDVI
dataset');

var NDVIparam = {min: -1, max: 1, palette:['blue', 'white',
'green']};
 Map.addLayer(ndvi, NDVIparam, 'NDVI Banjarmasin 2022')
```

Figure 6. The process of identifying the NDVI greenness index

The first and second rows function as band selections from the database, and the third row functions as the NDVI formula. The fourth and fifth lines function to display and organize the data display.

```
Export.image.toDrive({
image:dataset.float(),
description:('Sentinel_2A_New_Guava'),
folder: 'Mapping Data',
region:Village,
scale:30,
maxPixels:1e9
 })
```

Figure 7. The export process of the NDVI greenness index results

The first and second lines function for selecting the data storage location, and the third line functions for naming the data. The fourth line is for the folder to be selected on the drivea and the fifth line is for location selection. Then the sixth and seventh lines are for determining scale and pixels.

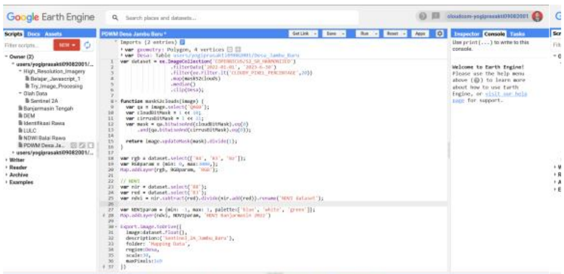

Figure 8. Implementation of scripting and commands on the GEE Platform

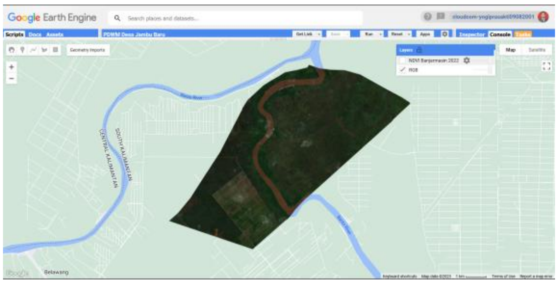

Figure 9. Capture the location of Jambu Baru Village on the GEE Platform

NDVI Greenness Index Classification

The distribution of NDVI vegetation index values is divided into 5 classes where the values consist of -1 – 0, 0 – 0.2, 0.2 – 0.5, 0.5 – 1. This shows that the vegetation in the Village wetland ecosystem Jambu Baru has a variation in NDVI values that is not very diverse and is dominated by the high vegetation density class with a percentage of 93.69%. This high vegetation density indicates that the wetland ecosystem is still dominated by natural peatland vegetation. Low NDVI values in wetland ecosystems identify shadows from trees and buildings. Based on Table 5.1. referring to Franklin (2001) in Putra et al., (2017) an area of 154.45 ha is included in the non-vegetated category because it is a residential area of Jambu Baru village.

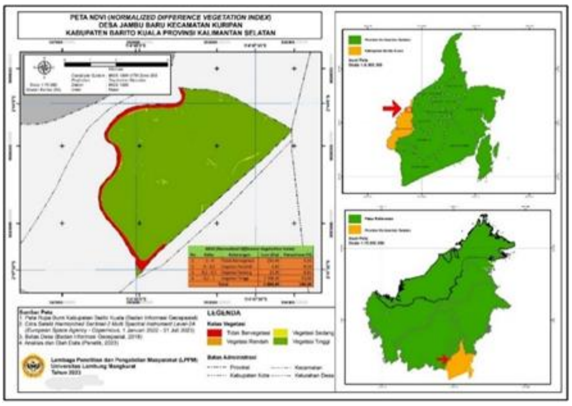

Figure 10. NDVI greenness index classification map in the Peat Ecosystem of Jambu Baru Village.

Field Measurement of Aboveground Biomass Values

Aboveground biomass refers to the total amount of biomass contained in organisms that live above the ground surface, especially in terrestrial ecosystems such as forests, grasslands, and various other types of dry land and wetlands. Measurement of biomass above the surface is carried out by estimating the height and diameter of plants and biomass calculations are also based on the use of allometrics which are adjusted to the type of forest and also the specific gravity of wood, biomass analysis in Peatlands is based on selected local methods with allometric Y=0.061 (DBHxpxT) 1.464, using a reference for the general density of wood, 0.68 gr/cm3.

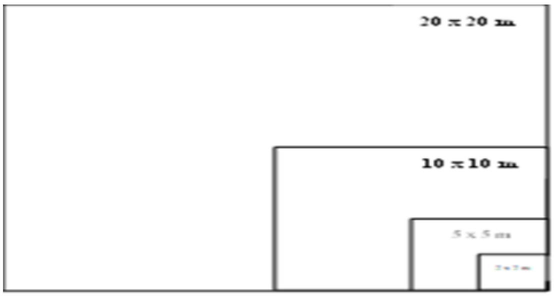

Figure 11. Plotting plan for biomass measurement samples

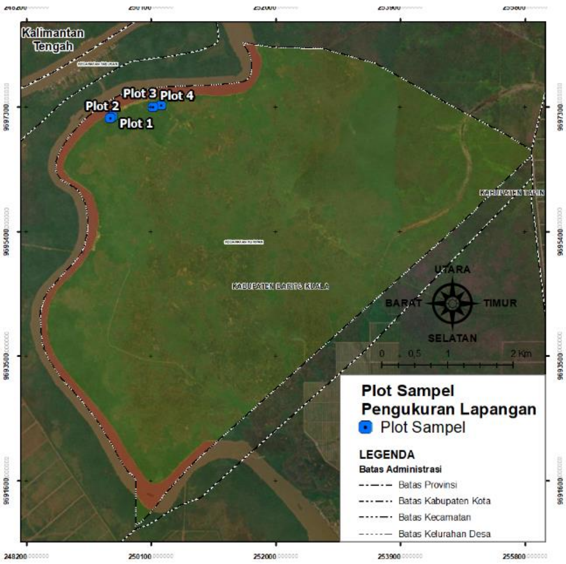

Figure 12. Scatter Plot of Biomass Measurement Samples

Data collection was carried out at three research location points based on stand density classification; low, medium, and high through the identification of NDVI results at the Jambu Baru Village location, data taken starting from recording the level of seedlings, saplings, poles and trees found at the research location, as well as considered to represent three classes of stand density. The first measuring plot measuring 20x20 meters with a medium stand classification the accumulated biomass value was 4,547 Kg, and the second plot with a high stand classification obtained a biomass value of 5,762 Kg. The third plot with a medium stand classification had a biomass value a total of a 4,536 Kg, and in the fourth plot with a high classification, the total biomass value was 9,193 Kg. The average growth rate found in the four plots was the growth rate of poles and trees.

The greater the diameter and height of the plant, the higher the biomass content. This is because trees with a larger diameter contain cellulose and extractive substances as well as other polysaccharide compounds stored in the trunk. The tree trunk is the woody part where the largest reserves of photosynthesis results are stored, so this shows that diameter growth is related to an increase in biomass.

Table 1. Aboveground biomass value in each sample plot

Plots	NDVI Class	Area	Biomass
1	-1 - 0	154.45	4.55
2	0 - 0.2	4.62	5.76
3	0.2 - 0.5	23.3	4.54
4	0.5 - 1	2706.32	9.19
	Total	**2889.69**	**24.04**

Source: research data processing, 2023

Estimated Carbon Stock Value

Based on the results of ground check research and field measurements to measure carbon stocks in the peatlands of Jambu Baru Village, Kuripan District, Barito Kuala Regency. Data sources that must be needed are standing trees and poles, undergrowth, litter, and woody necromass. This research uses low, medium, and high classifications.

Table 2. Aboveground biomass value in each sample plot

NDVI Class	Area	Biomass	Carbon	%
-1 - 0	154.45	4.55	2.14	7.72
0 - 0.2	4.62	5.76	6.45	23.31
0.2 - 0.5	23.3	4.54	5.20	18.77
0.5 - 1	2706.32	9.19	13.90	50.21

Source: research data processing, 2023

The research results showed that carbon stock calculation results in the peatlands of Jambu Baru village from each data source used were trees and poles of 27.68 kg with a percentage of 98.5; undergrowth 0.09 kg with a percentage of 0.3; litter 0.17 kg with a percentage of 0.6; necromass 0.34 with a percentage of 0.6

The results of the calculation table above show the carbon stock of peatlands in Jambu Baru village purposive sampling method and the large amount of data obtained will obtain complete data results from the results of this research and provide information on the carbon content in the Jambu Baru peatland Village.

Table 3. Biomass and carbon values in tree stands and poles, biomass and necromass

Source	Biomass	Carbon	%
Trees and Poles	4.55	2.14	7.72
Undergrowth	5.76	6.45	23.31
Litter	4.54	5.20	18.77
Woody Necromass	9.19	13.90	50.21

Source: research data processing, 2023

DISCUSSION

Peatlands are carbon-rich ecosystems because the peat layer consists of plant remains that decompose over time. This slow decomposition process causes significant carbon buildup in peat soil. Peatlands are known as "carbon blue chips" because of their capacity to store carbon. This carbon storage capability prevents the release of CO2 into the atmosphere. Therefore, peatlands act as natural carbon stores that can help control CO2 levels in the atmosphere, which contribute to climate change.

Research conducted by Prayitno (2013), found that carbon stores in peatlands in South Sumatra ranged from 56.3 – 58.31%, while the results of research by Dharmawan (2013), showed carbon stores in peatlands after 8 years of burning and 3 years of burning in Central Kalimantan in general was 45.29%. This amount is almost the same as the carbon storage in peat soil in Malaysia of 45.7%, which was measured in three types of land cover; forests, sago plantations, and oil palm plantations (Melling, et al., 2015).

From several of these studies, it can be concluded that carbon storage in peatlands, besides being high, is also influenced by several differentiating factors, including the type of land cover vegetation (peat forest, mangrove forest, or dry land) (Krisnawati et., al, 2015; Qirom et., al. 2015). The high potential for carbon storage in peatlands has implications for adjusting peatland management approaches, which of course differ from land management on non-peatlands, for example on mineral soils). On mineral soils, generally the largest carbon stores are in surface biomass (Krisnawati, et. al, 2015), which is different from peatlands.

Peatlands are vulnerable to degradation and damage. Human activities such as clearing land for agriculture, forest encroachment, and creating irrigation canals can dry out peatlands. When peatlands dry out, the decomposition process can accelerate, causing massive releases of carbon into the atmosphere as CO2. Peatland fires, often caused by humans, are a significant source of carbon emissions. When peat burns, the carbon trapped is released in the form of smoke and greenhouse gases, such as CO2 and methane (CH4). Peatland fires can cause environmental disasters and exacerbate global climate change.

CONCLUSION

Peatlands are known as "carbon blue chips" because of their capacity to store carbon. Carbon is trapped in layers of peat, preventing it from being released into the atmosphere as carbon dioxide (CO2). On the other hand, peatlands are vulnerable to degradation and damage. Human activities such as clearing land for agriculture, forest encroachment, and creating irrigation canals can dry out peatlands. When peatlands dry out, the decomposition process can accelerate, causing massive releases of carbon into the atmosphere as CO2. Peatland fires are a significant source of carbon emissions. When peat burns, the carbon trapped is released in the form of smoke and greenhouse gases, such as CO2 and methane (CH4). Peatland fires can cause environmental disasters, exacerbating global climate change.

Protection and restoration of peatlands is very important to mitigate the climate change. Efforts involve stopping peatland clearing, sustainable management, restoring degraded peatlands, and controlling fires. Peatland protection is not only a local responsibility but also a global task. In discussing carbon in peatlands, it is important to emphasize how vital the protection, restoration, and sustainable management of peatlands is to mitigate climate change and maintain the carbon balance on Earth.

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