Effect of canopy cover level on solar radiation for conservation plant photosynthesis under the stand of cocoa plants

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Abstract. Land degradation, which is caused by erosion, is one of the causes of the decline in the quality of cocoa plants. Vegetative soil conservation technology is one of the solutions to soil conservation on land that already has plants. The obstacle to conservation plant cultivation is its existence under the stand of plants so that solar radiation is limited for photosynthesis. This study aims to determine the level of canopy cover that can pass solar radiation for photosynthesis in conservation plants under the stand of cocoa plants. Retrieval of canopy cover data obtained through direct measurement using photo images and processed using MATLAB Image Processing Toolbox with closure approach. Solar radiation measured using the NHGH09BU Photosynthetic Active Radiation (PAR) sensor. The sensor is connected to the Arduino UNO microcontroller module. The results showed that the smaller the canopy cover, the duration of radiation that can support photosynthesis is longer. Likewise, the total active radiation for photosynthesis is inversely proportional to the percentage of canopy closure, which is the effect of the duration of active radiation. Radiation above 300 Watt/m² occurs between 10.30 AM - 01.00 PM with the highest value 483 Watt/m² which occurs at 11.00 AM. Total solar energy is inversely proportional to the percentage of canopy closure and is a linear relationship with R² > 0.9.

1. Introduction
Erosion causes a decrease in soil quality, which in turn causes a decrease in the quality of the cocoa plants, this is due to the decrease in soil capacity to retain water due to rapid surface runoff and reduce soil organic matter [1]. Vegetative soil conservation technology is one of the solutions to soil conservation on land that already has plants. One of the most widely used plants for soil conservation is the vetiver plant which is recommended because it can increase soil fertility and reduce erosion [2]. At certain rainfall intensities, this plant has a good performance in terms of reducing surface runoff and soil erosion compared to using rice straw [3]. The application method is to plant vetiver plants as conservation plants under the stand of cocoa plants using a planting system that follows contour strips because, in addition to preventing soil erosion, it also reduces surface runoff and increases infiltration [4]. The constraint of cultivating such conservation plants is limited to solar radiation for photosynthesis, while the accumulation of the amount of solar radiation received by plants has a significant effect on the formation of plant biomass [5]. Thus it is necessary to conduct studies to
determine the effect of canopy closure on the amount of solar radiation that can be transmitted for photosynthesis. The purpose of this study was to determine the effect of the level of canopy closure on the amount of solar radiation that can transmit to the conservation plants under the stand of cocoa for photosynthesis.

2. Materials and Methods
Retrieval of canopy closure data is obtained through direct measurement by taking photographic images. The camera placed under the stand of the cocoa plant in a straight line towards conservation plants and facing the sky to find out the maximum solar radiation that can be received by conservation plants that exist in the daytime. Longer daytime radiation has been proved that it can be increasing the efficiency of energy use, due to the convex form of radiation from photosynthetic light responses [6]. Image data is processed using MATLAB Image Processing Toolbox where the percentage of canopy closure is determined using the closure approach, this method used as in previous studies using the closure approach with the efficient use of solar radiation [7][8]. Solar radiation measured using the NHGH09BU Photosynthetic Active Radiation (PAR) sensor which is connected to the Arduino UNO microcontroller module [9]. The collected data is presented in graphical form to see the large changes in solar radiation for every minute. The solar radiation data for each collection point linked to determine the tendency of total radiation to the percentage of canopy closure.

3. Result and Discussion
3.1. Canopy Closure
Canopy closure data collection is performed at 3 locations that have different levels of cover. Based on the results of image data processing using MATLAB Image Processing Toolbox obtained the level of closure with the closure approach of 82, 64 and 54 percent. The image was taken upright of conservation plants so that we can determine the effect of the amount of solar radiation that is transmitted during the day which is the most efficient use of solar energy for photosynthesis because of the convex radiation from the photosynthetic light response [6].
3.2. Effect of canopy closure on the duration and magnitude of solar radiation

The results showed that the smaller the canopy cover, the longer duration of radiation that could support photosynthesis. It is because the irradiation process occurs earlier and lasts the longest. This long lapse of solar radiation is caused by the entry of sunlight through the canopy of plants that are more wide open. General description of this condition can be seen in figure 2 to 4:

**Figure 1.** Canopy closure at (a) observation 1, (b) observation 2, and (c) observation 3

**Figure 2.** Solar radiation at observation 1 (Canopy closure 82 %)
In addition to the different durations, differences in canopy closure also affect the maximum radiation that can be transmitted. This difference is due to differences in cover conditions that cause the spatial distribution of solar radiation is also different, as the results of research on cotton plants [5]. The results of solar radiation measurements show that the highest maximum radiation occurs in the smallest percentage of canopy closure that is 54%. In general, solar radiation greater than 300 Watt/m² occurs between 10.30 AM - 01.00 PM and the largest radiation is 483 Watt/m², which occurs at 11.00 AM.

3.3. Relationship of canopy closure to total solar radiation
The relationship between canopy closure and total radiation that can be received by conservation plants is inversely proportional. The closure of a small canopy has longer solar radiation time to be transmitted to conservation plants and vice versa. Another cause is that the highest maximum radiation is greater. The tendency of the relationship between the two parameters is a linear relationship and is very significant with the coefficient of determination ($R^2$) > 0.9.
Another tendency is the smaller the canopy closure, the greater the total energy, which is shown by the larger linear function gradient coefficient (negative value). That is shown in figure 6.

The graph above shows that the greater the total radiation, the difference in total radiation for each difference in canopy cover will be even greater. This difference occurs because of the different duration and intensity of the radiation.

4. Conclusions
The conclusions of this research are the Canopy closure of cocoa plant affect the duration of solar radiation and it’s the intensity for the plant under the trees. Smaller the canopy closure, longer the duration of solar radiation intensity to achieve the photosynthesis process. Radiation above 300 Watt/m² occurs between 10.30 AM - 01.00 PM with the highest value 483 Watt/m² which occurs at 11.00 AM. The total solar radiation received under the canopy of the cocoa plant is inversely proportional to the closure of the canopy with a trendline in the form of a very significant linear relationship with a value of $R^2 > 0.9$.

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