THE ANALYSIS OF VEGETATION CHANGE AND RAINFALL VARIABILITY IN LORE LINDU NATIONAL PARK CENTRAL SULAWESI, INDONESIA

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ABSTRACT

Lore Lindu National Park is one of the National Parks in Indonesia located in Central Sulawesi Province which is one of the biological protection sites in Sulawesi. This National Park consists mostly of mountain and sub-mountain forest (± 90%) and a small part of lowland forest (± 10%). Climate change and variability is one of the global, regional and local problems that have a major impact on vegetation changes in a region. The purpose of this research is to analyze NDVI (Normalize Difference Vegetation Index) correlation with rainfall variability in Lore Lindu National Park. The data used are rainfall data from 2015 to 2017 in several rain stations around Lore Lindu National Park, and NDVI satellite data taken from NOAA satellites using AVHRR (Advanced Very High Resolution Radiometer) sensor. This research uses Pearson correlation method between Rainfall and NDVI vegetation index which is used to find out how big the effect of rainfall on vegetation changes that happened in Lore Lindu National Park Bariri. The results of this study indicate that rainfall is positively correlated to NDVI which means rainfall change followed by NDVI changes regularly in same directions. The rainfall which has the highest average rainfall correlation value to the average vegetation changes in the Lore Lindu National Park area is the Doda rainfall post which has a correlation of 77%.

***Keywords* :** *Lore Lindu National Park, NDVI, Central Sulawesi, Pearson Correlation*

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1. Introduction

Lore Lindu National Park in Central Sulawesi Province is one of the largest tropical forests in Indonesia with a total forest area of 217,991 hectares that is consisting of lowland wet rain forests and mountainous areas. Lore Lindu National Park is located in the Poso and Donggala districts (Mansur, 2003). Various species of flora and fauna live in the Lore Lindu National Park. Because of its status as a National Park, Lore Lindu has a tropical rain forest that is still very much preserved. Lore Lindu National Park area is also the largest Conservation Area in Central Sulawesi which is one of the best places in the World to study biodiversity that is very unique and varied (Pitopang, 2012).

Vegetation is the most important element of the forest. Dense vegetation shows fertile and protected forests, while bare vegetation shows the condition of damaged forests. Data on the distribution of vegetation in a forest is the most important element for examining forest quality because, vegetation also directly influences the flora and fauna in the forest (Pettorelli et al., 2005).

One way to see the changes in a vegetation area is by using remote sensing data. The most commonly used method is the Normalize Difference Vegetation Index (NDVI). NDVI has been widely used by researchers and proved to be very effective way to see the changes in vegetation in an area. This method was first introduced by Tucker (1979) to see the difference between reflected light from the Near Infrared (NIR) and Red (R) spectrum bands. NDVI vegetation index that was developed by Tucker (1979) is calculated by using the following equation:

$$NDVI = NIR - R / NIR \qquad (1.1)$$

Note:

- *NIR* is the value of the Near Infrared channel image

- *R*is the value of the Red channel image.

Holben (1986) classified the output value of the calculation results into several classification classes, among others as follows:

No	Land Cover Type	NDVI
1	Solid Vegetation	>= 0.5
2	Medium Vegetation	0.140 – 0.499
3	Rare Vegetation	0.09 – 0.139
4	Barren Land	0.025 – 0.089
5	Cloud	0.002 – 0.0249
6	Snow and Ice	-0.046 – 0.0019
7	Water	-0.257 – 0.0459

Table 1.1 NDVI Classifications According to Holben (1986).

Rainfall is the element of weather and climate that has quite high variability and can also affect the growth of various plant species. Water is one of the most important limiting factors and is the most important source for the growth and development of plants that fall from the sky in the form of rain drops (Ayu et al., 2013). Plants carry out photosynthesis which is influenced by the element of CO^2 (carbon dioxide) in the air. Rainfall and fog can increase CO^2 content in the air because reduced air movement and fog during the rainy season prevents the loss of CO^2 (carbon dioxide) from the forest (Utomo, 2006).

Rainfall can also affect the availability and groundwater content in an area. Groundwater availability can directly affect the good and poor growth of trees and other flora species. Groundwater availability is an important element that is very closely related and have the strong relationship between soil, plants, and the atmosphere (Taufik and Setiawan, 2012).

Calculation of land water balance is a method that can be used to see the groundwater availability in the research area. Land water balance is closely related to research on plant growth and development. Plant water demand is indicated by the potential of water resources in an area from the results of the calculation of land water balance conducted (Sipayung, 2005).

One of method to calculate land water balance that is often used is by using a method developed by Thornthwaite-Mather (1975) which explains that the ability of soils to absorb water is strongly influenced by soil type and vegetation.

The purpose of this study is to search for the relationship and correlation between the variability of rainfall and groundwater availability changes in a vegetation by using the Normalize Difference Vegetation Index (NDVI) method.

2. Data and Method

2.1 Data

The data that is used to support this research is Rainfall and Temperature data in several rain gauge posts in Central Sulawesi Province, located in Poso District and in the Lore Lindu National Park area. The available rainfall data is a 3-year period from 2015, 2016, and 2017. The rain gauge post data used include the following:

No	Rain Gauge Post	Latitude	Longitude	Elevation (mdpl)
1	Lore Utara	-1.42633	120.3248	1103.9
2	Maholo	-1.47429	120.3682	1103.681
3	Doda	-1.7272	120.252	1214.93
4	Lore Peore	-1.52997	120.3283	1123.798
5	Sedoa	-1.35394	120.3397	1196.035
6	Tangkura	-1.493	120.63	82.296

Table 2.1 Rain Gauge Posts in the Region Research.

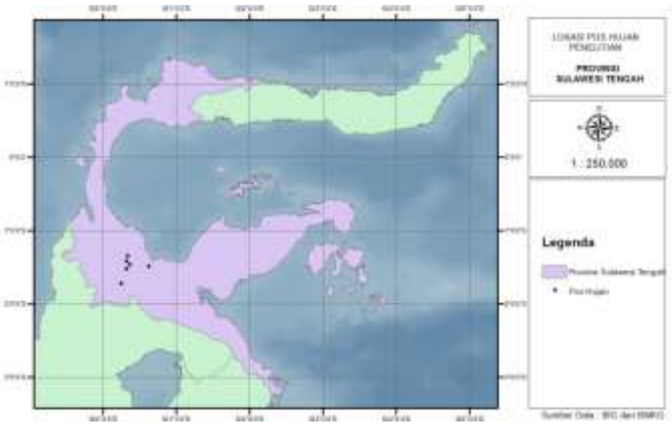


Figure 2.1 Distribution of Rain Gauge Posts in the Research Region.

The Rain Gauge Post only observes daily rainfall. Therefore, to obtain air temperature data used the Mock equation (1973) as follows:

$$\Delta t = 0{,}006 \; X \; (Z1 - Z2) \qquad (2.1)$$

Note :

- $\Delta\ t$ is the difference in temperature between the measured rainposts against the analyzed rainposts.
- Z1 is the elevation of the station used as a reference (m).
- Z2 is the elevation of the rain gauge post to be analyzed (m).

In calculating the daily air temperature the Mock equation (1973) can be derived as follows:

$$T_h = T_{ho} - ((0{,}6/100)*h) \qquad (2.2)$$

Note :

- T_h is the temperature of the rain gauge post to be analyzed (^{o} Celcius).
- T_{ho} is the temperature of the reference station.
- h is the difference between the height of the rain station and the reference station.

2.2 Method

In carrying out this research, several methods were carried out including the linear regression method and Pearson correlation method which was used to calculate the regression value and correlation to analyze the relationship between the two variables namely rainfall and NDVI and Thornwaite-Matter method for groundwater availability and NDVI. In addition this study also uses the Thronwaite-Matter method to calculate the availability of ground water. To get valid data NDVI values are taken in highly densely vegetated areas in the Lore Lindu National Park area. The selection of these locations using the Google Earth application, which then gets the location geographically located at 1o28 'South Latitude and 120o11' East Long as shown below:

Figure 2.1 Research Areas Source (Google Earth).

Pearson correlation value which has a value (+) indicates a positive relationship between two variables, which means an increase in the number of variables x followed by an increase in the number of variables y, whereas if the correlation value indicates the value (-) it indicates that there is a negative relationship between two variables that means that if the number of variable x increases then that will be followed by a reduction in the number of variables y and vice versa. The greater the correlation value or the closer to number 1 indicates that the correlation between the two variables the better. The correlation equation is formulated as follows:

Note:

- r is correlation.
- n s the large amount of x and y data.
- Σx is the total number of variables x.
- Σx^2 is the result of the square of the total number of variables x.
- Σy is the total number of variables y.
- Σy^2 is the sum of squares of the total number of variables y.

The analysis conducted using simple linear regression method aims to calculate the regression equation that will explain the two variables, namely x and y. The formula of the regression equation can be written as follows:

$$Y = a + bX \quad (2.4)$$

Note:

- Y is a bound variable.
- X is an independent variable.
- *A*is intercept.
- b is the regression coefficient or slope.

Calculation of groundwater availability in this study uses the Thornthwaite-Matter (1957) method, the process of calculating groundwater availability uses the following steps:

- Input monthly rainfall data from the station or rain gauge post to be analyzed;
- Calculating the value of Potential Evapotranspiration (ETP) from a station or rain gauge post;
- Calculating the difference in the value of Rainfall and ETP;
- Calculating the value of the Accumulated Potential Loss of Water for Evaporation (APWL);
- Calculate the value of Soil Moisture (KAT) with the following formula:

$$KAT=TLP+[[1,00041-(1,07381/AT)]|APWL|xAT \quad (2.4)$$

$$r = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{\{n\Sigma x^2 - (\Sigma x)^2\}\{n\Sigma y^2 - (\Sigma y)^2\}}} \quad (2.3)$$

Note:

- *TLP* is permanent withering point;
- *KL* is field capacity;
- Calculate dKAT value, value dKAT is calculated by finding the value of KAT in the month to be analyzed with the value of KAT in the previous month;
- Calculating Actual Evapotranspiration rates (ETA) If the Rainfall is greater than ETP then, ETA reaches its maximum value. If the Rainfall is smaller than the ETP value, the ETA value is obtained from the sum of CH and dKAT, where dKAT is absolute because all CH and dKAT will be evaporated;
- Calculating the Deficit value obtained from the difference in Potential Evapotranspiration (ETP) with Actual Evapotranspiration;
- Calculate Surplus value which is an excess of ground water which generally occurs during the rainy season. For the calculation of surplus is to use the formula S = CH - ETP - dKAT;
- Calculate the value of Groundwater Availability (ATS) with the following equation:

$$ATS = \frac{(KAT - TLP) / (KL - TLP)}{100\ \%} \quad (2.5)$$

Note:

- *ATS* is groundwater availability.
- *TLP* is permanent wilting point.
- *KL is* field capacity.

Thornthwaite-Mather (1957) classifies ATS values into several categories, including the following:

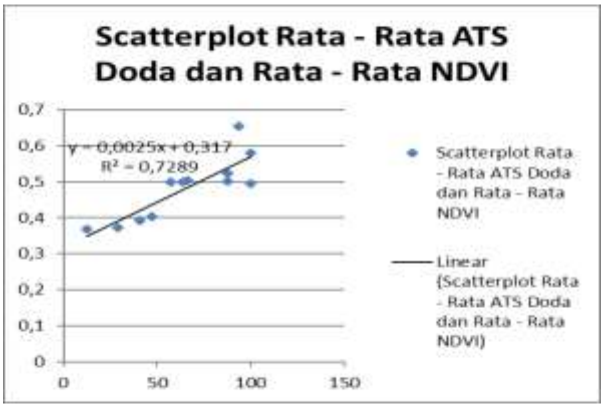
No	Groundwater Availability	Percentage
1	Very Less	< 10 %
2	Less	10 – 40 %
3	Moderate	40 – 60 %
4	Enough	60 – 90 %
5	Very Enough	90 %

Table 2.2 Groundwater Availability Classification According to Thornthwaite-Mather (1957).

3. Results and Discussion

From the results of this study it can be analyzed that the rain gauge post which has the highest correlation value between rainfall and NDVI values is the Doda rain gauge post and the Lore Peore rain gauge post.

The correlation value between rainfall in the Doda rain gauge posts respectively from 2015 to 2017 was 47%, 52%, and 75%, respectively. The biggest correlation value is in 2017 at the Doda rain gauge post. The positive correlation value shows that the increase in NDVI is directly proportional to the increase in rainfall. for an average of 3 years the correlation is 77%.



Graph 3.1 Scatterplot of Average Doda Rainfall and Average of NDVI.

The regression equation of the Doda Rainfall Average and the NDVI Average shows a value of y = 0,000x +0.403 and has an R2 value of 0.59 which can be concluded that there is a 59% variation of the Rainfall that affects changes in NDVI values. A positive regression equation shows that there is a positive relationship between Doda rainfall and NDVI values.

Figure 3.1 Total Monthly Rainfall at the Doda Rain gauge post.

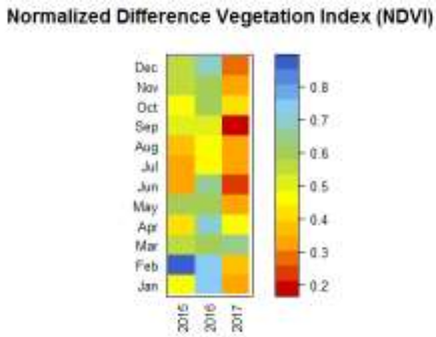
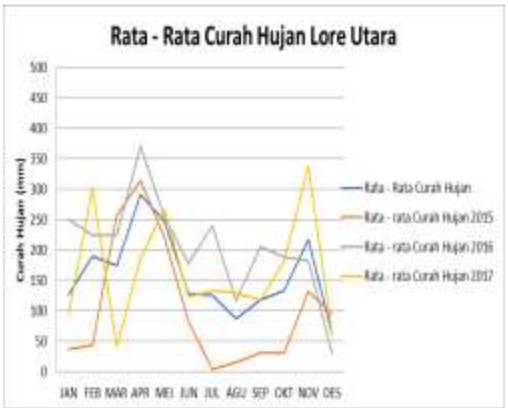


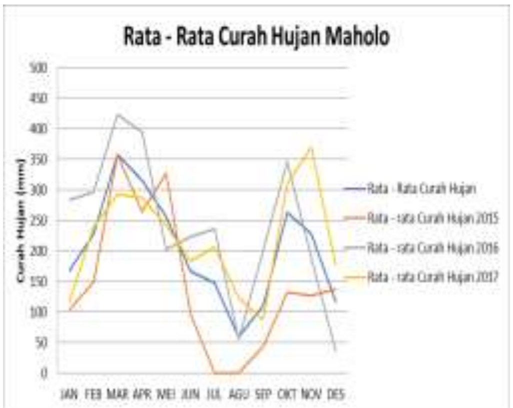
Figure 3.2 Normalized Difference Vegetation Index (NDVI).

The amount of monthly rainfall seen in Figure 3.1 affects the value of NDVI (Figure 3.2). According to the classification of Holben (1986) it can be concluded that vegetation in the study area is at a moderate and dense level. From the picture above it can be seen that the month with the lowest rainfall was in July, August and September this was also followed by a reduction in NDVI values which in July, August and September were at the lowest values. The highest amount of rainfall was in February followed by an increase in NDVI values.

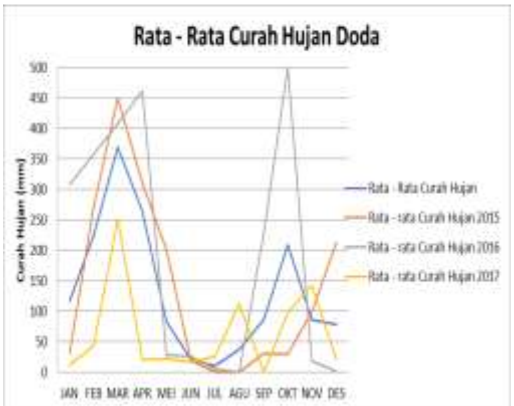
A.



B.



C.



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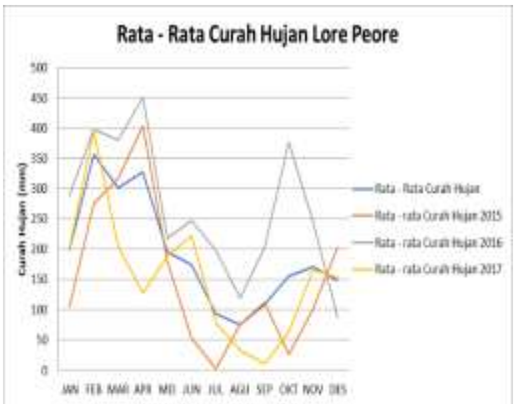
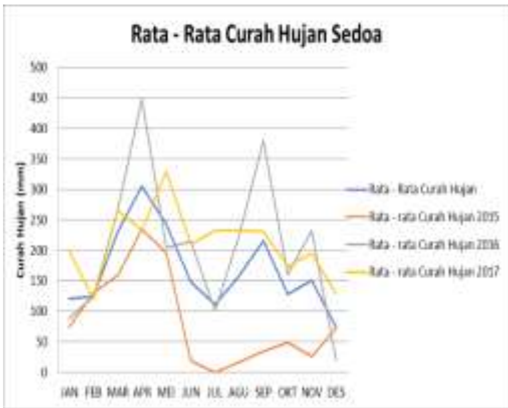
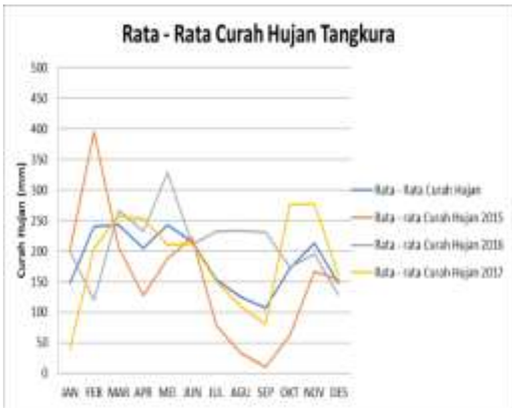


E.



F.



Graph 3.2 A. Average Rainfall of Lore Utara, B. Average Rainfall of Maholo , C. Average Rainfall ofDoda , D. Average Rainfall ofLore Peore, E. Average Rainfall ofSedoa , F. Average Rainfall ofTangkura .

Rain gauge post in Lore Utara as shown in graph 3.2 A has an equatorial rain pattern which has two rain peaks found in April and November, while rain with a minimum value is found in August. Judging from the graph of average rainfall in 2015, 2016, 2017 when compared to its normal conditions, normally the peak of rainfall occurs in April and November, but 2017 has 3 peak peaks, namely February, May and November.

Whereas in Figure 3.2 B it can be concluded that rain gauge post in Maholo has an equatorial rain pattern which has two rain peaks found in March and October, while rain with a minimum value is found in August. Judging from the graph of average rainfall in 2015, 2016, 2017 when compared to normal conditions, there was a shift in the peak of rain which normally occurs in March and October, in 2017 changed to March and November. As for the minimum rainfall that usually occurs in August, that year experienced a shift and occurred in September.

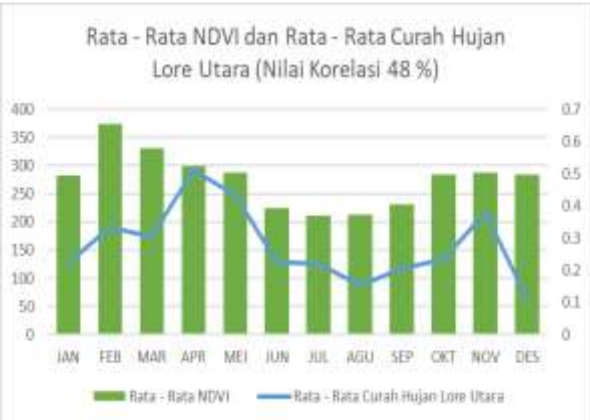
Can be seen from the graph 3.2 C above the rain gauge post in Doda has an equatorial rain pattern which has two rain peaks found in March and October, while rain with a minimum value is in July. Judging from the graph of average rainfall in 2015, 2016, 2017 when compared to normal conditions, in 2015 the October, November and December periods experienced an increase in rainfall trends, whereas in normal conditions the trend experienced a decrease in rainfall.

Rain gauge post in Lore Peore based on data from graph 3.2 D has an equatorial rain pattern which has two rainfall peaks found in April and November, judging from the average rainfall graph for 2015, 2016, 2017 when compared to normal conditions, in 2016 from January to December experiencing an increase in the value of rainfall each month.

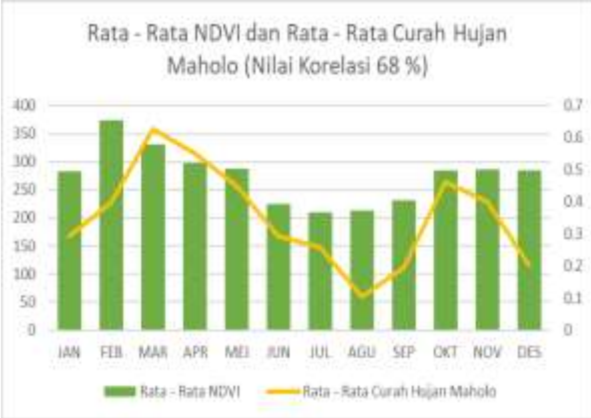
Rain gauge post in Sedoa from graph 3.2 E, it can be seen that there is an equatorial rain with two peak peaks in April and September. Judging from the graph of average rainfall in 2015, 2016, 2017 when compared to normal conditions, 2015 from July to December experienced an increase in rainfall trends for the period.

Meanwhile in Tangkura, rain gauge post has an equatorial rain pattern that is not very clear with two rain peaks. Judging from the 3.2 F graph of average rainfall in 2015, 2016, 2017 compared to normal conditions, in 2016 there was a change in rainfall patterns, which normally equatorial rainfall patterns become anti-monsoonal rainfall patterns.

A.



B.



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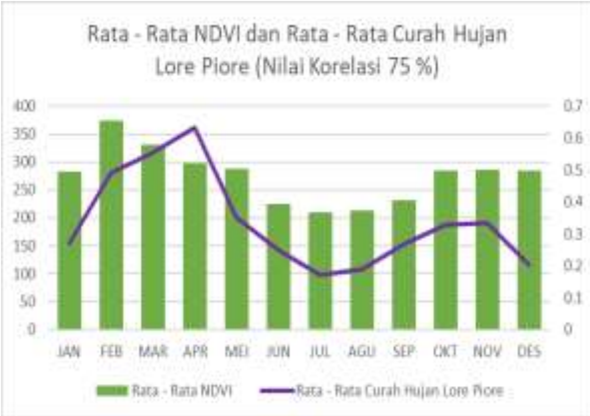
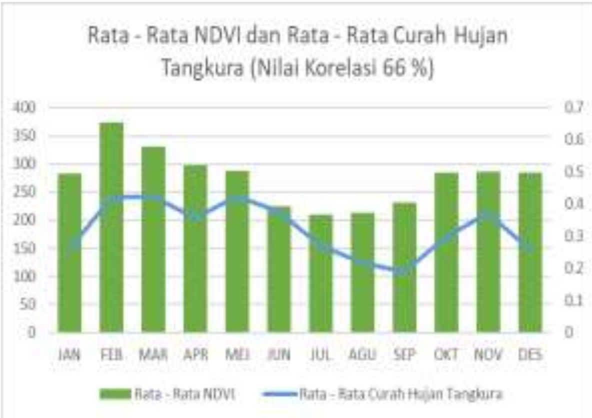


D.



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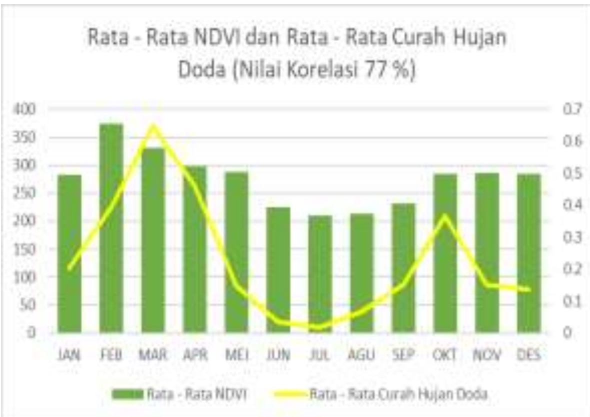

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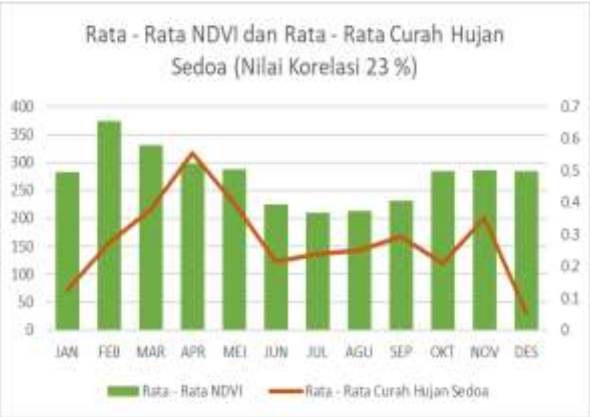
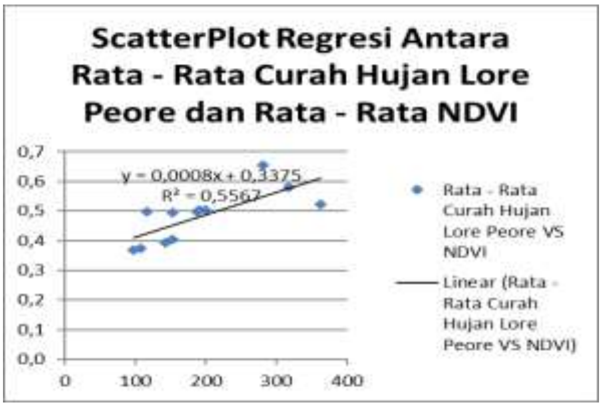


Graph 3.3 A. Average NDVI and Average Rainfall of Lore Utara, B. Average NDVI and Average Rainfall of Maholo, C. Average NDVI and Average Rainfall of Doda, D. Average NDVI and Average Rainfall of Lore Peore, E. Average NDVI and Average Rainfall of Sedoa, F. Average NDVI and Average Rainfall of Tangkura.

Graph 3.3 illustrates the condition of the average trend of NDVI in the study area of the rainfall trend in several rain gauge posts located around the study area during the 2015-2017 period, which included the Lore Utara rain gauge post, Maholo rain gauge post, Doda rain gauge post, Lore Peore rain gauge post, Sedoa rain gauge post, and Tangkura rain gauge post. From some of the rain gauge posts, it can be seen that the rain gauge posts whose rainfall values have a strong correlation are Doda Rain gauge posts, Lore Peore Rain gauge posts, Maholo Rain gauge posts, and Tangkura Rain gauge posts whose values are 77%, 75%, 68%, and 66 respectively. %

From the correlation value it can be seen that the correlation value is positive where the increase in NDVI values in the study area is directly followed by an increase in rainfall variability. The decreasing trend in NDVI values followed by rainfall variability was in the June, July and August periods. While the highest NDVI values that can also be analyzed occur because the increase in the amount of rainfall is the period in March and April.

In the Lore Peore rain gauge post the highest correlation value of rainfall to NDVI respectively from 2015 to 2017 was 44%, 55%, and 67%. The highest correlation value is in 2017. While the average correlation value in the Lore Peore rain gauge post is 75%.



Graph 3.5 Scatterplot of Average Rainfall Lore Peore to Average of NDVI.

The regression equation from the graph above y = 0,000x - 0.337 between the average monthly rainfall over a 3-year period from 2015 to 2017 shows that the R2 value of 0.556 can be concluded that there is about 56% variation of rainfall that affects changes in NDVI values. A positive regression equation shows that there is a positive relationship between Doda rainfall and NDVI values.

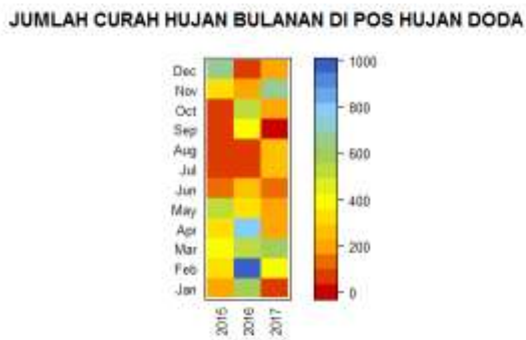


Figure 3.3 Total Monthly Rainfall at theDoda Rain gauge post.

The lowest amount of rainfall in the Doda Peore rain gauge post was in the July, August and September periods. This shows that the decrease in the amount of rainfall also affects the decrease in NDVI values in Figure 3.2. The highest amount of rainfall in April was also seen to affect NDVI values but not too significantly.

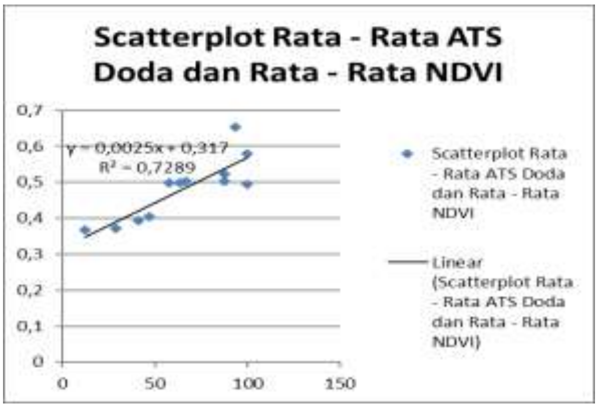
The results of the calculation of groundwater availability in a row from 2015 to 2017 also show that the highest correlation of ATS to NDVI is in the Doda rain gauge post and Lore Peore rain gauge post. From the results of ATS processing in the Doda Rain gauge post, it can be seen that the highest correlation value was in 2016, amounting to 59%, while in 2015 the correlation value was 42% and in 2017 the NDVI correlation value was 43%.

The results of the calculation of groundwater availability in a row from 2015 to 2017 also show that the highest correlation of ATS to NDVI is in the Doda rain gauge post and Lore Peore rain gauge post. From the results of ATS processing in the Doda Rain gauge post, it can be seen that the highest correlation value was in 2016, amounting to 59%, while in 2015 the correlation value was 42% and in 2017 the NDVI correlation value was 43%.

Figure 3.4 Monthly groundwater availability at the Doda Rain gauge post.

Figure 3.4 shows that during the period of 2015, 2016, and 2017 in July the ATS values were respectively in poor, very low, and insufficient conditions. This condition is directly proportional to the NDVI value (Figure 3.2) which is also below the value of 0.6 for the year. On average each year ATS is in sufficient to very sufficient conditions.

The average ATS value in the Doda rain gauge post over a 3 year period if correlated to the NDVI value will result in a correlation of 85%. This shows that there is a very strong relationship and influence between the increase in ATS on NDVI values.



Graph 3.6 Scatterplot ATS Doda and Average - NDVI score.

The regression equation that has a value of y = 0.002x + 0.317 and has an R2 value of 0.728 indicates that there is a 72% variation in rainfall that affects the value of NDVI. Value of 0.317 indicates that if there is no increase in the value of the ATS then NDVI is at the value of 0.317. A value of + 0.002x indicates a regression coefficient that we can conclude that the addition of every 1% NDVI value is influenced by the addition of rainfall by 0.002 mm.

Figure 3.4 Monthly groundwater availability at the Lore Peore rain gauge post.

Groundwater availability at the Lore Peore rain gauge post from Figure 3.4. It can be seen that in 2016 and 2017 in general it is at a very sufficient level. Only in August 2015 were the conditions lacking. The correlation value of ATS to NDVI respectively from 2015 and 2017 is 54% and 17%. The correlation value in 2016 cannot be calculated because it has homogeneous ATS data. If seen from the percentage of groundwater availability in the Lore Peore rain gauge post, it is not too significant in influencing changes in NDVI values.

4. Conclusion

From the results of this study it can be concluded that rainfall and Groundwater availability have a considerable influence on changes in vegetation which are analyzed using remote sensing which produces the NDVI index. Rain patterns that occur in some of these rain gauge posts are equatorial rain patterns which have two peaks of the rainy season. Raindrops that have an influence based on the correlation value between Rainfall and NDVI are quite high is are Doda which have a correlation value of 77% and Peore which have a correlation value of 75%. This is because, the area taken as a sampling that has very good vegetation observed from Google Earth is an area that is close to the two rain gauge posts.

Doda also has a very high correlation with Groundwater availability in the study area which has excellent vegetation based on Google Earth imagery. The average groundwater availability during the period 2015 to 2017 in Doda Rain gauge post has a correlation value of 85% to the average NDVI. Whereas in the Lore Peore rain gauge post the correlation tends to fluctuate.

If seen that the period July, August, and September (JAS) has the lowest value of both rainfall, ATS, and NDVI. Then, it can be concluded that the month is a dry period in the study area. Whereas wet bulldozers with good NDVI values were February, March and April.

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