FUTURE SUITABILITY OF TEA PLANTS - CLIMATE ANALYSIS USING REMOTE ANALYSIS IN JAVA, INDONESIA

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Abstract. Tea production is highly dependent on the geographical and climatic conditions of the environment where the plants are grown and on the crisis of climate change from time to time. Therefore, an analysis is needed to determine the impact of climatic conditions on the tea production industry, especially in Indonesia. Precipitation and temperature are the contributing factors to the productivity of tea. This phenomenon can be understood through analysis and projection of climate. This analysis can be utilized for mitigation and adaptation to applied climate in Indonesia's agriculture sector, especially in the industrial production of tea. By comparing the analysis of climate for tea in the past 1991 – 2020 period and the projection of future climate in the period 2051 – 2070, this study explains climate analysis to the production of tea, especially in Gunung Mas and Java Island, Indonesia. The result shows that climate analysis in the past in the period 1991 – 2020, obtained existence influence and trend change to bulk available rain and temperature for the region Gunung Mas and its surroundings. Projection suitability land industry plant tea based on scenario future climate seen the impact with decrease suitable area as land growth plant tea. Climate scenarios RCP 4.5 and RCP 8.5 for 2070 show the influence of climate impact on the suitability of the tea plantation land industry.

Keywords: *tea, climate, productivity, RCP, geography*

1 INTRODUCTION

Tea (*Camellia sinensis*) is one of the most consumed beverages in the world (FAO, 2016). This plant has quite specific agro-climatic requirements that are only available in tropical and subtropical climates, only a few varieties can be grown in mainland England and parts of Washington, United States. In the process of growth, tea requires a hot and humid climate. Some specific requirements for tea plants are an environment with temperatures ranging from 10 – 30 degrees Celsius, having an annual rainfall of 1250 mm, preferring to grow in soils that have acid levels, growing with a slope of 0.5 – 10 degrees, and being at an altitude of up to 2000 meters. The geographical aspect of the tea plant is limited to several regions around the world and is very sensitive to the growing conditions of the plant (FAO, 2016).

Tea is a plant that has been affected by climate change (Carr, 1972). The production of an industrial plant depends on its environment, in the tropics where the intensity of sunlight is excessive, two main factors play a dominant role in plant growth, namely temperature and rainfall (Wijeratne, 2007). Research on climate change shows how it affects changes in the quantity of tea production growth (Novogrodzki, 2019). These changes affect tea yields in all sectors, namely by changing the level of rainfall, increasing temperatures, shifting the time of the production season, and encouraging an increase in insect pests.

Although tea production is projected to increase significantly over the next decade, there is still a potential danger to the tea industry and associated livelihoods which are already reeling from frequent floods and droughts (Arthur, 2018). Because few geographic areas worldwide can accommodate commercial tea growth, tea production is highly sensitive to changes in temperature and rainfall patterns, the recurrence of extreme events, and more. The possible impacts of climate change already occurring in lost yields and increased management costs for developing planting strategies (FAO, 2016).

Climate change triggered by global warming is one of the major environmental problems facing the world today. There are many countries in Asia and Africa with regional economies based on agriculture. Tea plantations in several countries of these two continents are the main livelihood option for millions of people. Over the last few years, some of these tea-producing countries have witnessed a disturbing trend of decreasing tea yields and productivity, mainly due to biotic factors and abiotic stresses (FAO, 2016).

One of the most common plants found on plantations in Indonesia is the tea plant (PTPN VIII, 2020). Some companies cultivate tea plantations in Indonesia, one of them is PT Perkebunan Nusantara VIII (PTPN VIII). Location PTPN VIII has 41 business units and gardens spread across 13 regencies/cities in the province of West Java (Bogor, Sukabumi, Cianjur, Bandung Regency, West Bandung Regency, Bandung City, Subang, Purwakarta, Garut, Tasikmalaya, Ciamis, and Pangandaran) and 2 districts in Banten Province (Lebak and Pandeglang). The annual report of PTPN VIII in 2020, reported that the productivity of tea in Indonesia below the shade experience fluctuation in the last 5 years. It can be seen in Figure 1. The volume of productivity in 2016 was 1,487 Kg/Ha, increased in 2017 to 1,612 Kg/Ha, then decreased in 2018 to 1,263 Kg/Ha, increased again in 2019 to 1.375 Kg/Ha, and continued in 2020 in the position 1,537 Kg/Ha.

2 MATERIALS AND METHODOLOGY

The tea production industry is influenced by geographical and climatological factors. Rainfall and temperature are factors that play a role in tea productivity. This phenomenon can be understood through analysis and quantitative approach to the tea production estimation on the climatological data that influence it. This analysis can be used as a form of climate mitigation and adaptation applied in Indonesia to the agricultural sector, especially in the tea production industry.

2.1 Location and Data

The research was conducted over the Tea Plantation location Gunung Mas – PTPN VIII which is in the area Village South Tugu, Cisarua, Bogor Regency, West Java, and the region of Java Island in Indonesia (Figure 2-1).

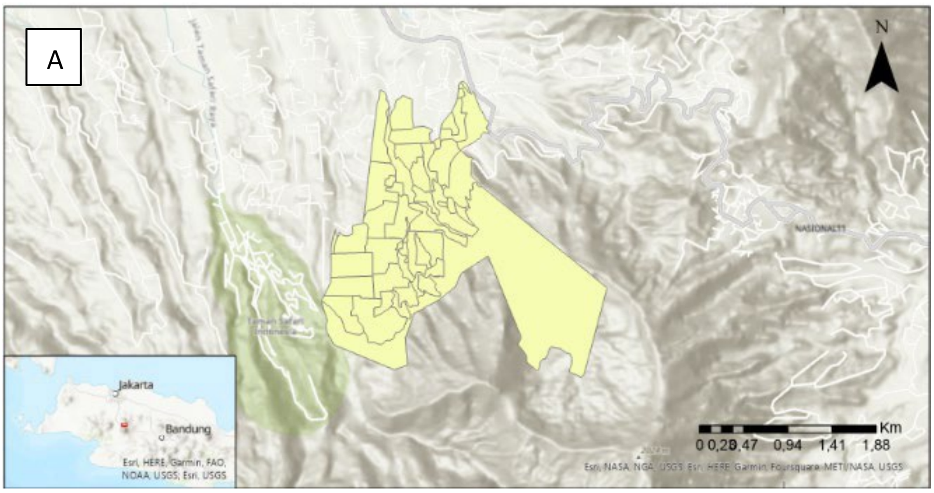


Figure 2-1. a) Location of Tea Plantation Gunung Mas in Bogor Regency marked is at in polygon colored yellow, b) Location of Java Island

2.2 Standardization of data

Analysis of past climates recorded in Tea Plantation; Gunung Mas done as considerations for projection industry production tea in the future. The climate element under this study includes global climate data in the form of the Nino 3.4 index and local data climate in the form of bulk rain and temperature. Analysis was carried out statistically and spatially as well as conducted narration descriptive analysis to explain the influence of climate on tea productivity. The scope of Java Island chosen as consideration analysis for climatology needs scale with a minimum area of 200-2000 km (Manessa, 2022).

The research variables used in this study refer to previous studies and theories that affect the tea production industry. These variables consist of climatological and productivity variables tea that can be seen in Table 2-1.

Table 2-1: Study Variable

Name	Parameter
Rainfall	millimeter (mm)
Temperature	Celsius
Tea Production	kg/ha
Nino 3.4	-

Climatological data taken limited to the data from 1991 – 2020. Rainfall data/precipitation data (CH) and temperature data taken from data belonging to the Meteorological Agency Climatology and Geophysics (BMKG) and PTPN VIII, Nino 3.4 data taken from proprietary data National Oceanic and Atmospheric Administration (NOAA), and productivity data taken from PTPN VIII's Gunung Mas Plantation which is limited from 2001 – 2020.

2.3 Methods

The research model divided Becomes two, namely analysis of past climate and projections of future climate. Analysis coefficient correlation score statistics with state linear relationship between two variables or more. Coefficient correlation range between -1 to +1. A correlation value of positive shows the existence connection unidirectional Among variables, while a correlation of negative shows a connection between variables the opposite. The equation to calculate correlation is shown in Equation 2.1

$$C = \frac{n\sum xy - \sum x \sum y}{\sqrt{n\sum x^2 - (\sum x)^2}\sqrt{n\sum y^2 - (\sum y)^2}} \quad ....(1)$$

C = correlation coefficient, *x* = first variable, *y* = second variable.
The interpretation correlation score is described in Table 2-2.

Table 2-2: Interpretation correlation score (Sugiyono, 2017)

Correlation Value	Interpretation
0.00 - 0.19	Very low
0,20 - 0,39	Low
0,40 - 0,59	Currently
0.60 - 0.79	Strong

Changing of climate elements and their variability that occurs slowly and deeply long time mean a changing climate. Huber and Jay (2011) explain that climate change is focused on changes in rain and air temperature.

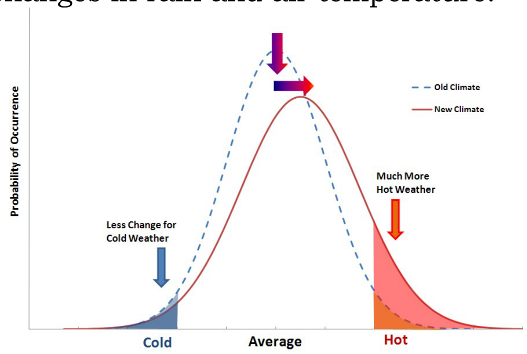


Figure 2-2: Representation shift from temperature distribution consequence of global warming. (IPCC, 2001).

Figure 2-2 is likened to if the curve shift to right, means the air temperature is hotter. If curve size changes, mean that variation temperature increases with existence enhancement frequency incident colder and hotter. However, occur drop frequency average temperature. If there is a combination, it could be interpreted that temperature and variance are increase.

The suitability distribution of the variety of the tea plant species, Camelia Sinensis, which is currently available, was obtained through the Global Biodiversity Information Facility (gbif.org) website, on the island of Java, Indonesia, the distribution of which can be seen in Figure 2-3.

Figure 2-3: Recently distribution species of Tea which marked with yellow hexagonal sign. (GBIF, 2022).

From Figure 2-3, we can see that the spatial distribution of tea is currently generally in parts of West Java and to a lesser extent in Central Java. To determine the suitability of the spatial area of tea plants based on future climatic conditions, the Maximum Entropy method is used.

Phillips et al., (2006) introduced the *Maximum Entropy* (Maxent) method for modeling the distribution of geographical something species only by using attendance data. Maxent is a method from *machine learning* with correct formulation mathematically and has an amount of purposeful aspect making it very suitable for modeling distribution from something species. *Maxent* is a statistical model and to apply it we must realize how the relationship between a component in models, this is what is meant are the data model and the ecological model used (Austin, 2002). An example from the data model of *Maxent* is the tea plant, while the ecological model in question could be in the form of a climate model form.

In determining the accuracy of the Maxent model, the use of ROC (*receiver operating characteristic*) analysis can be applied to find out the calculation of the most suitable algorithm against the model (Phillips et al., 2006). The area below the ROC curve (AUC/*area under the curve*) almost always has more height for *Maxent* (Figure 2-4.), showing more discrimination good among suitable areas and not suitable for the species under this study.

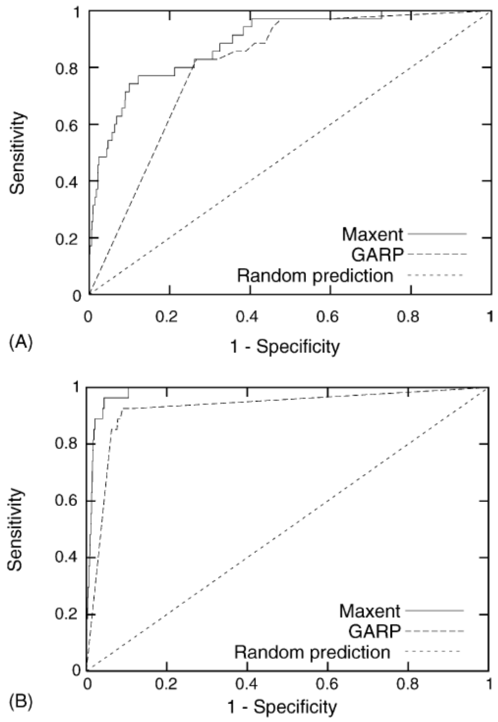


Figure 2-4: ROC and AUC curves to determine the best accuracy
(Phillips et al., 2006)

Algorithm statistics machine *learning* used in this research are *generalized linear model (GLM), support vector machines (SVM), random forest (RF), the boosted regression trees (BRT), Classification and Regression Tree (CART), multivariate adaptive regression splines (MARS), mean decrease in accuracy (MDA),* and *functional data analysis (FDA).*

Recently researchers used the MaxEnt method to determine the spatial suitablitiy of plantation. For instance, Elith et al., (2011) used Maxent's method of modeling distribution plants now and in the future by using distribution data *Banksia prionotes* and scenarios AIFI climate for the predicted 2070 with a combined 23 GCM (Global Climate Models) for the Australian region. The vegetation restoration approach using MaxEnt method is also functional for regional-scale studies to identify and rank hotspot locations for revegetation and restoration planning (Asadalla et al., 2021). The degradation of the suitable area is mainly due to increasing temperature and deforestation in future predictions whitch it shown by the modelling results that illustrate the suitable habitats of Styrax sumatrana are likely to be reduced under future climate change scenarios or lost in 2070 under the RCP8.5 scenario (Saputra, et al., 2021). The data sources for the Maxent model in this study are described in Table 2-3.

Table 2-3: Maxent model data source

Data	Data Type	Data Source
2051 -2070 scenarios	RCP 4.5 RCP 8.5	World Climate
Climate	GCM CMIP 5 – MIROC	World Climate
Distribution Tea	Vector	GBIF
2051 -2070 scenarios	RCP 4.5 RCP 8.5	World Climate

In Table 2-3. one of the climate scenarios is in form of RCPs *(Representative Concentration Pathways*). RCPs are scenarios that include Suite time emission and concentration Suite complete house gas glass and aerosols and chemically active gases, and land use and land cover (Moss et al., 2008). The MIROC climate model was selected in this research because also used by BMKG as a projection model climate in Indonesia.

GBIF (*Global Biodiversity Information Facility)* provides access open data about all types of life on Earth (GBIF, 2022). Recorded data form in GBIF i.e. distribution tea data plantation, including tea spread in Indonesia, the species namely *Camellia sinensis L. Kuntze.*

Research model analysis was processed using Microsoft Excel, R Studio, and ArcGis Pro to generate statistics analysis and spatial later described descriptively analysis. Analysis of past climate and projections for the future climate is focused on in this research. Workflow is described in Figure 2-5.

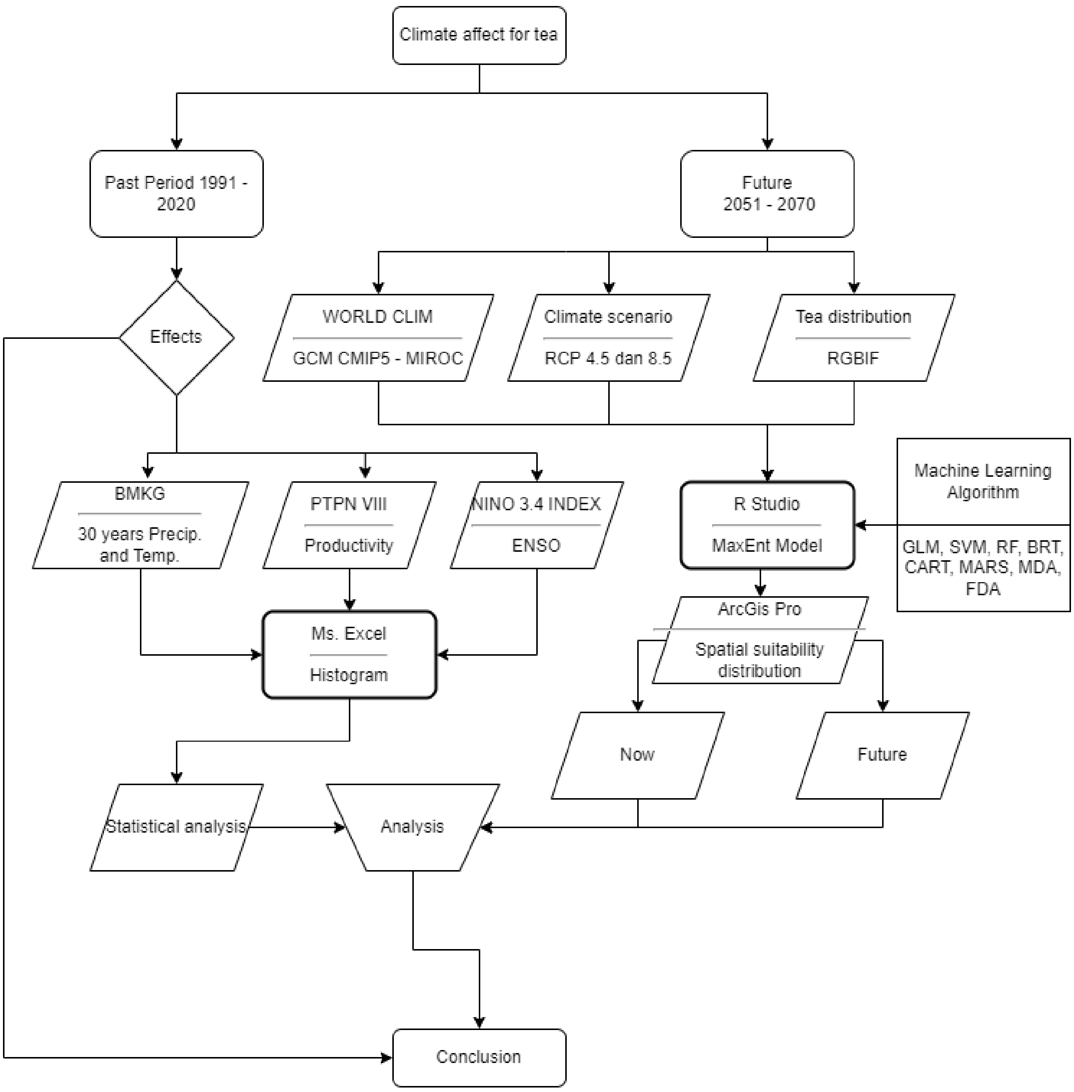


Figure 2-5: ROC Workflow of the research

3 RESULTS AND DISCUSSION

3.1 Influence of Global Climate on Tea Industry Production in 1991 – 2020

The relationship between global climate drivers and annual rainfall intensity and its relationship to tea productivity is discussed in this study.

It can be seen in Figure 6 that the connection between bulk rain and Index Nino 3.4 that occurred in the region Gunung Mas has interrelated relationships. When Nino 3.4 goes negative, shows an existing increase in the annual CH intensity that occurs at Gunung Mas. The opposite also happens

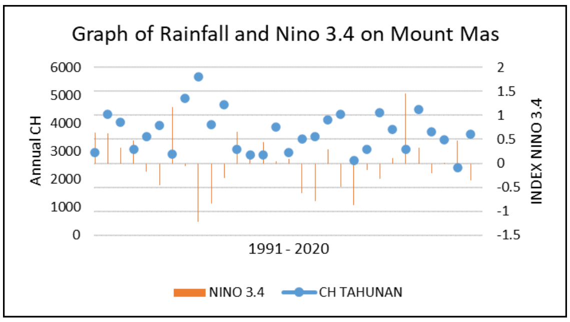


Figure 3-1: Chart of the relationship between CH in Gunung Mas and the Nino 3.4 Index

when Nino 3.4 is positive, the movement of annual CH in Gunung Mas tends to decrease. If seen from number statistics, the correlation connection between variables has a correlation category currently with a score reached -0.43 which indicates between variables have enough opposite relationships one each other.

CH's relationship with the productivity of the Gunung Mas Plantation is described in Figure 7. Shows that productivity in Gunung Mas is lacking could be explained by a good relationship to the intensity of rainfall annually recorded from the period 2001 – 2020. Relationship among variables has a coefficient correlation of -0.17 which indicates a low relationship between both.

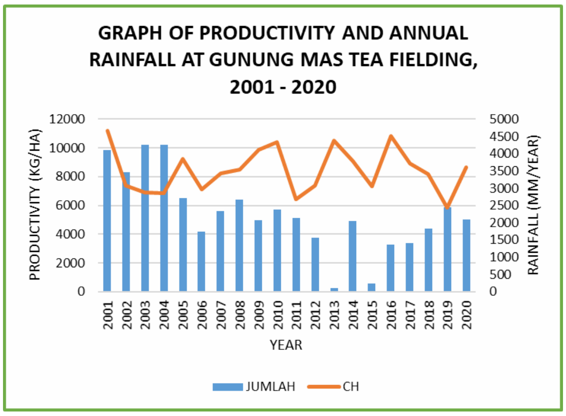
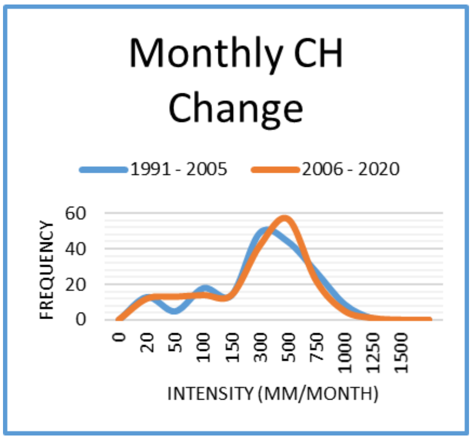


Figure 3-2: Chart of the relationship between CH in Gunung Mas and the Nino 3.4 Index

3.2 Changes in Climate Trends in the Gunung Mas area in the past period 1991 – 2020

Occur existence changes the CH trend that occurred at the Gunung Mas Plantation in the period 1991 – 2020, this is explained in Figure 3-3.



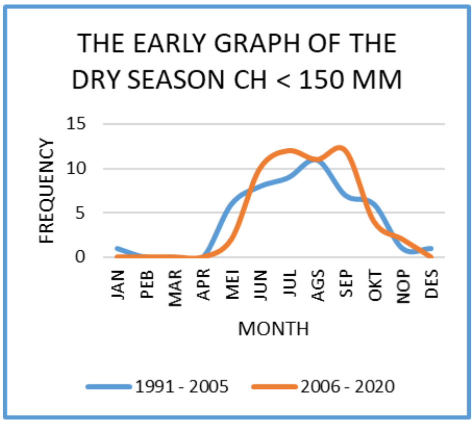
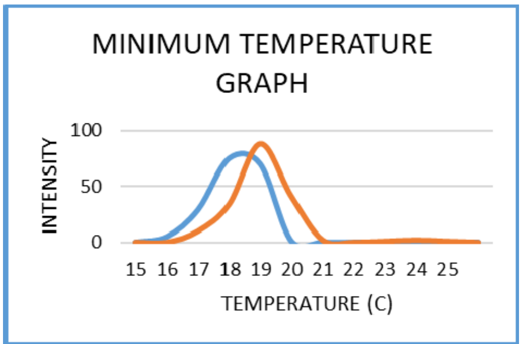
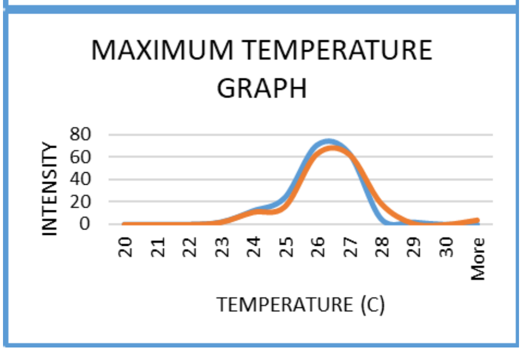


Figure 3-3: Changes in CH in Gunung Mas in the Period 1991 – 2020
(Changes in the monthly intensity and frequency and changes beginning season based on monthly CH criteria <150 mm)

Monthly CH change is seen in Figure 7a) that monthly CH intensity in the period 2006 – 2020 tends to have increased intensity and more frequency compared to the period 1991 – 2005. Beginning season changes marked drought with monthly CH < 150 mm/month in the region Gunung Mas looks to existence shift from the usual period 1991 – 2005 start at the beginning of April, now the 2006 – 2020 period is back at the beginning the month of May, it can be seen in the histogram data Figure 7b).

Trend changes are also found in indicators of climate temperature in the region around the Gunung Mas Plantation described in Figure 3-3.





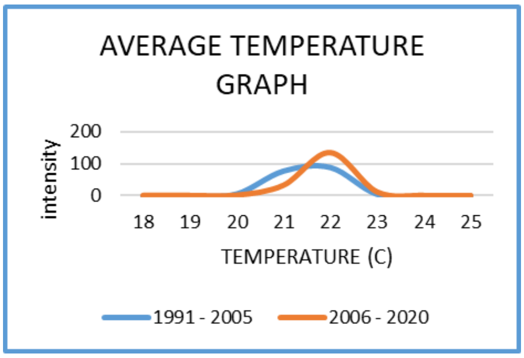


Figure 3-4: Change of temperatures at Gunung Mas in the Period 1991 – 2020
(Changes of minimum temperature, change of maximum temperature, and change of average temperature)

Recorded temperature taken from BMKG data around the area of Gunung Mas shows an existence trend increase from the period 1991 – 2020 towards the period 2006 – 2020, which can be seen in the histogram of Figure 4.4. The minimum temperature is increased with a peak intensity of 1^{0C} from 18^{0C} to 19^{0C} as the intensity minimum temperature of the period 1991 – 2005 to the period 2006 – 2020. There is a temperature maximum shift existence increase more temperature high in the period 2006 – 2020 compared to the period 1991 – 2005. For the average temperature, the shifting temperature seen from the histogram graph shifts to right showing that the temperatures increased in the period 2006 – 2020 is higher compared to the period previously which is the period 1991 – 2005.

3.3 Climate Projection for Industry Production Tea in the Future period 2051 – 2070

The scatters tea plant in Figure 3-5 is shown with a black point. The background with the green color shows the suitable land that can be overgrown by tea plants. Tea locations on Java Island showed in the region part of the big region of West Java to Banten, which is also the location of a tea plantation owned by PTPN VIII. Another part is in the region of Central Java.

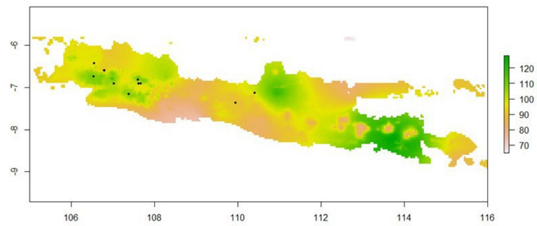


Figure 3-5: Distribution of Current Suitability Land of Tea Plant and The Scatters Location of The Tea Plant

Projection distribution suitability land for tea crops in the future simulated using climate variables based on calculation *machine learning*. The calculation of AUC, COR, and TSS as well as Deviance (Figure 3-6) is seen to see the most appropriate algorithm to use as models.

```
model Mean performance (per species), using test dataset (generated using partitioning):
-------------------------------------------------------------------------------

 ## species   :  species
=========================

methods    :     AUC     |     COR     |     TSS     |     Deviance
---------------------------------------------------------------------------
glm        :     0.86    |     0.43    |     0.69    |     1.1
svm        :     0.87    |     0.67    |     0.72    |     0.43
rf         :     0.95    |     0.76    |     0.92    |     0.28
brt        :     0.83    |     0.41    |     0.67    |     0.53
cart       :     0.77    |     0.56    |     0.56    |     0.57
mars       :     0.85    |     0.6     |     0.68    |     2.86
mda        :     0.68    |     0.55    |     0.58    |     1.16
fda        :     0.87    |     0.4     |     0.69    |     0.51
```

Figure 3-6: Calculation Results Suitability Maxent Algorithm for Tea Plants on the Java Island

Found that the RF method has the highest AUC, COR, and TSS values as well as the lowest Deviance value. It shows that the machine learning method using the RF method for predicting scatter suitability land plantation is the most accurate. Spatially, depicted in Figure 3-7 with color intensity from chocolate to green show the suitability of the right land for tea plants. The more colored green location or going to variable 1.0, shows the suitability location for plants tea the higher or better. Applicable on the contrary if the more colored chocolate or going to variable 0.0, indicating location is not enough suitable for distribution for the tea plant.

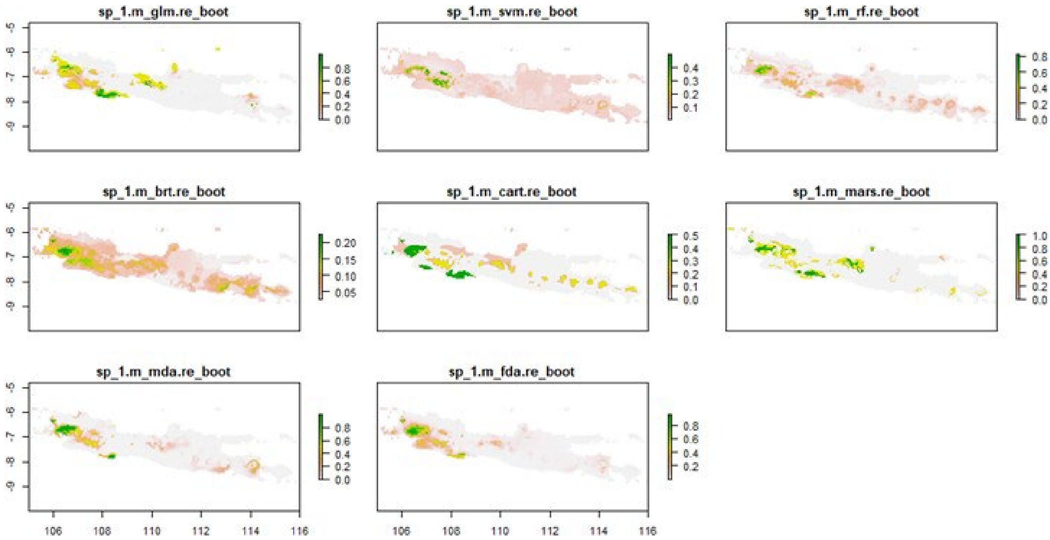


Figure 3-7: Analysis Spatial Model for Fit Location Plant Tea on the Island Java

In Figure 3-7, the RF method is shown on the map (sp_1.m_rf.re_boot) which proves that the suitability RF method can be seen from the prediction scatter tea plant that is in the region Java part adjacent western and like the state that exists at this time.

Use projection climate RCP 4.5 and RCP 8.5 can is known existence change suitability land for location plant tea in the future in 2070 as can be described in Figure 3-8.

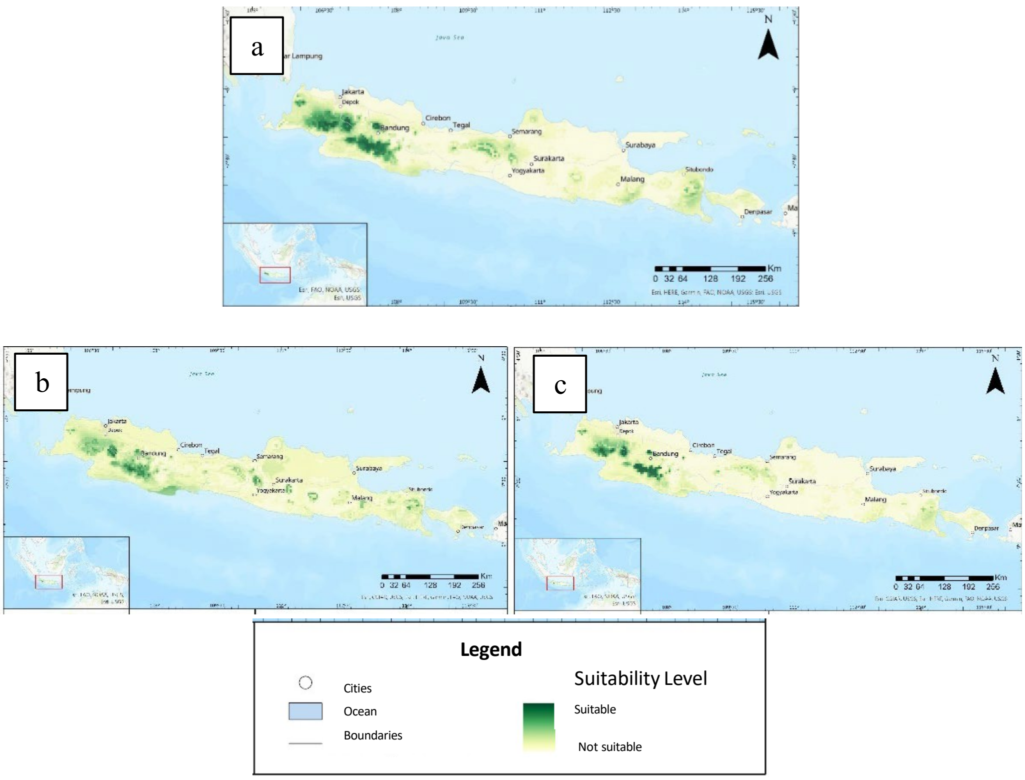


Figure 3-8. Comparison Suitability Land for Plants Tea on the Java Island, a) Present, b) Future with RCP 4.5, and c) Future with RCP 8.5

Changing of suitability land for crops tea based on the scenario of future climate shows the impact of the decreased suitable area as land growth for the tea plant. In Figure 3-8. a), seen in the present scatter area growth plant tea on Java Island located in the western region of Java Island. Future projections are in Figure 3-8. b) and c), the suitability of land for tea crops is reduced shown by the green color. In Figure 3-8. b), climate model scenario RCP 4.5 shows that suitability land tends to decrease with land area reduced from the present. This is at a glance like that shown in Figure 3-8. c), shown that with climate scenario model RCP 8.5, suitability land for tea crops seen reduced compared to the current and RCP 4.5 scenarios, and suitability levels tend to group focused on several locations only.

4 CONCLUSIONS

Analysis of climatic conditions in the past shows the influence of climate on the tea production industrial area in the region Gunung Mas, Cisarua, Bogor Regency. From the results of the field study conducted, information was obtained that the quality of tea production can decrease if it enters the dry season. Estimates for calculating the start of the season are important because events that have occurred several times have disrupted tea productivity, such as a long dry season, or the erratic start of the rainy season that can cause pests to tea plants (Ricky, 2022).

From the results of past climate analysis in the period 1991 - 2020, it was found that there was an influence and trend of changes in rainfall and temperature for the Gunung Mas area and its surroundings. The global climate driving factor, ENSO, shows a interrelated relationship with the annual CH value in Gunung Mas with a correlation of -0.43. Monthly CH intensity in the 2006 – 2020 period tends to have an increased intensity and a higher frequency than the previous period or the 1991 – 2005 period. The change at the beginning of the season in the Gunung Mas area shows a shift from the 1991 – 2005 period which usually starts in April, now in the 2006 – 2020 period, which will become in early May. The average temperature in the Gunung Mas area shows a trend of increasing temperature values that are warming from the period 1991 – 2005 to the period 2006 – 2020.

The projection of land suitability for the tea plantation industry based on future climate scenarios seems to have an impact on the reduction of suitable areas for growing tea plantations. Climate scenarios using RCP 4.5 and RCP 8.5 for 2070 show that climate influences have an impact on the suitability of land for the tea plantation industry. The suitability of land for tea plants which are currently described as being in the western part of Java is decreasing. RCP 4.5 shows that land suitability tends to decrease with a slightly reduced land area from the present. Meanwhile, in RCP 8.5, land suitability for tea plantations seems to be much reduced compared to the current scenario and the RCP 4.5 scenario and the suitability level is more likely to cluster focused in a few locations.

ACKNOWLEDGEMENTS

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