Climatic Suitability for Robusta Coffee in West Lampung Under Climate Change

Y Sarvina 1,5*, T June 2, S H Sutjahjo 3, R Nuralina 4 and E Surmaini 5

1 Natural Resource and Environmental Management Science Graduate School, IPB University, Bogor, Indonesia.
2 Department of Geophysics and Meteorology, Faculty of Mathematics and Natural Sciences, IPB University, Bogor Indonesia
3 Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University, Bogor, Indonesia
4 Department Agribusiness, Faculty of Economics and Management, IPB University, Bogor, Indonesia
5 Indonesian Agency for Agricultural Research and Development, Bogor, Indonesia

E-mail: yeli_1983@apps.ipb.ac.id, taniajune@apps.ipb.ac.id

Abstract. West Lampung has long been recorded as one of the Indonesian major Robusta coffee producers. Coffee is an annual crop sensitive to climatic conditions. Therefore, climate change have been reported to affect yield and area suitable for coffee production. Assessing climate suitability coffee area in West Lampung is crucial for a sustainability of coffee production system. This study aims to identify changes in coffee crop suitability under climate change. Coffee production data from the local agriculture office and climate data from Wordclim were processed using Maximum Entropy (MaxEnt) and ArcGIS to project the impact of climate change on distribution change of coffee suitability. The Result of MaxEnt indicates an important shift in climatic suitability of coffee area in the future. Suitable grown areas decrease. This shift requires an adaptation strategy for sustainable coffee production system in West Lampung.

1. Introduction
Robusta coffee is the main plantation crop in West Lampung Regency. This is designated as a main regional product through the regent's decree of West Lampung No. B/336/KPTS/III.2/2014. In addition, West Lampung Robusta coffee plantation was also designated as one of the national plantation areas by the Minister of Agriculture through the Minister of Agriculture Decree No. 46/KPTS/PD.300/1/2015 dated January 16, 2016, concerning the determination of the national plantation area.

Economically, coffee plays an important role in the economic development of the West Lampung Regency because this sector gives significant contribution to gross domestic product (GDP). The plantation sector contributed around 24.82%. Moreover, coffee farming absorbs almost 70% of the labour force [1]. In 2020 West Lampung coffee production reached 53878.1 tons with an area of 59,859 Ha [2].

Coffee is a perennial crop that is very sensitive to climatic conditions. Most plantation crops such as coffee are cultivated on dry land, which proves to be more susceptible to climate variability [3]. Various studies also reported that climate variability causes dynamics of coffee production [4-7]. Climatic variability also causes changes in coffee penology [8].
Coffee is among the crops under threat from climate change because coffee is a biannual plant sensitive to climatic variation. Various studies have stated that the impact of climate change on the coffee production system includes the impact on the production system and the suitability of the coffee climate. Climate change influences on reduction of coffee production [4,8-11], coffee quality [11], an increase in pest and disease attacks [12,13] and alteration of coffee climatic suitability. Various studies of climatic suitability coffee crop in coffee-producing countries have been carried out, such as Indonesia [14], and globally [15,16]. These studies show that in the future (2050), suitable area for coffee plantations will decrease.

Research on the impact of climate change on production and climate suitability has so far focused more on Arabica coffee because of its higher economic value than Robusta coffee. These impact studies are also mainly studied in coffee-producing countries in Latin America, such as Brazil, Ecuador, and Mexico. Studies for the Southeast Asian region, especially in Indonesia, are still very limited. Especially for Indonesian, almost 70% of the national coffee production takes place by Robusta coffee. Therefore, a study of the impact of climate change on Robusta coffee is very essential.

The study of climatic suitability for coffee is very important for the development of the coffee area. Since coffee is an annual crop with a long-life cycle. The development of the coffee area in the future must consider climatic suitability. The study of the suitability of the coffee climate is also very important for coffee centers that have developed. Identify which areas have suitable climatic characteristics and which are not. For areas that are not suitable, it is very essential to add production inputs or develop other cultivation technologies so that production can be increased.

Currently, almost 70% of coffee plantations in West Lampung are over 20 years old. To maintain the sustainability of coffee production system, coffee rejuvenation is required. Identification of the suitability of the coffee climate is very much needed to support decisions for new coffee development areas. Therefore, identification of the suitability of the climate of Robusta coffee in West Lampung is very essential.

Analysis of climatic suitability or land suitability of a commodity requires good mapping skills and expensive software. Therefore, a straightforward approach is needed so that these studies can be carried out by the local agricultural officers. MaxEnt is an approach widely used in species distribution analysis, especially in cases with limited data. Besides that, MaxEnt has other advantages, namely; it is open-source software and relatively easy to use.

This study aims to identify the suitability of the coffee climate in The West Lampung Regency both for current and its projections using climate modeling. The results of this study are expected to support the local government to determine the coffee area and technology development in the future.

2. Method

2.1. Study Area
This study focusses on West Lampung Regency, Lampung Province, which is divided into 15 Subdistrict and lies on latitude 4°,47′,16″- 5°,56′,42″ S and between longitude 103°,35′,08″ - 104°,33′,51″ E. Lampung Province is located the southernmost Sumatera Island Indonesia. West Lampung Regency has a total area of approximately 2141.57 Km2 with an altitude that varies from 200 to 2000 meters above sea level. Based on Oldeman, this regency has a type B climate with has 7-9 months wet months and annual rainfall ranging from 2500-3000 mm. The research location area is shown in figure 1.
Figure 1. Study Area.

2.2. Data

This study used coffee plantation location data from West Lampung Agriculture and plantation office. WorldClim climate data [17], both current and projected climate data, was used to identify current and projection climatic suitability. For climate projections, this study applied data from the Global Circular Model (GCM) CNRM-CM5-2. The CNRM-CM5-2 model was chosen since this model was reported to have the best performance for climatological research in Southeast Asia [18]. The maxent was simulated with a 2.6 RCP scenario.

Bioclimatic data derived from air temperature and rainfall data was applied. The bioclimatic variables used were 11 variables from 19 variables. The bioclimatic data and bioclimatic data used in this study are presented in Table 1. The species distribution modelling maximum entropy approach was applied to analyse current and future shifts in climate suitable for the cultivation of Robusta coffee. Open Source software Maxent which is downloaded at https://biodiversityinformatics.amnh.org/open_source/maxent/ was used in this study [19].

| No. | Variable bioclimatic | Symbol | Unit          |
|-----|----------------------|--------|---------------|
| 1   | The Average Annual Temperature | BIO1   | Degrees Celsius |
| 2   | Diurnal Temperature   | BIO2   | Degrees Celsius |
| 3   | Isothermally (BIO2/BIO7) (×100) | BIO3   | Dimensionless  |
| 4   | Temperature Seasonality (standard deviation ×100) | BIO4   | Degrees Celsius |
| 5   | Max Temperature of Warmest Month | BIO5   | Degrees Celsius |
2.3. Analysis

The sample location data should be converted to point with latitude and longitude information (X, Y) and data was saved in CSV format. Bioclimate data was clipped by area study and should be converted to CSV format. Location and bioclimate data were the primary input MaxEnt model. The sample location data were selected randomly. The training data were 75% of the sample data, and the test data were the remaining 25% of the sample data.

MaxEnt software was run to identify the entropy maximum of probability distribution and used to estimate the distribution of target species under various conditions [19]. The jackknife test (systematically leaving out each variable) was used to identify the dominant climatic factors determining the potential distribution of the coffee climatic suitability. The performance of Maxent predictive was shown by the area under the curve (AUC). AUC is an index that can evaluate the performance of the model to discriminate presence from absence. The model performance was classified as failing if AUC value 0.5-0.6, poor 0.6-0.7, fair 0.7-0.8, good 0.8-0.9, and excellent 0.9-1.

The output MaxEnt model prediction is in ASCI file format. ArcMap software was applied to map the distribution of model prediction. The coffee climatic suitability was divided into four classes. The suitability class was shown in table 2. The output of this study is the map for current and projection 2050 coffee climatic suitability.

### Table 2. Suitability assessment for coffee cultivation in Sumatera.

| Class of suitability     | Suitability Cut-Off Values | Description                                           |
|--------------------------|----------------------------|-------------------------------------------------------|
| High suitable            | > 0.6                      | Land with an optimal condition suitable for coffee cultivation |
| Suitable                 | 0.4-0.6                    | Land with a minor climatic limitation for optimal coffee cultivation |
| Moderately suitable      | 0.2-0.4                    | Land with the major climatic limitations that may significantly reduce the production of coffee |
| Unsuitable               | < 0.2                      | Land with the severe climatic limitation that are not favorable for the cultivation of coffee |

3. Result and Discussion

The performance of the model was determined by AUC value (figure 2). The AUC value is 0.763. It means the performance of the Maxent to model climatic suitability coffee in this study is fair (adequate). The performance of Maxent can be increased by adding coffee points (occurrence points). Based on this
AUC value, it can be concluded that the MaxEnt model can be applied to climatic suitability analysis in regency level.

![Sensitivity vs. 1 - Specificity for Coffee_lambar](image1)

**Figure 2.** The performance MaxEnt Model.

The Jackknife value for coffee climatic suitability in West Lampung was shown in figure 3. Among the selected environmental variables, the most contributing variable to coffee climatic suitability is Bio 1 (annual temperature), Bio 8 (Mean Temperature of Wettest Quarter) and Bio 9 (Mean Temperature of Driest Quarter) and Bio 14 (Precipitation of Driest Month). This result indicates that the probability climatic suitability of Robusta coffee was determined by temperature.

![Jackknife of AUC for Coffee_lambar](image2)

**Figure 3.** The Jackknife Maxent model for coffee climatic suitability in West Lampung.
Figure 4 revealed the map of climatic suitability for Robusta coffee, while the change of area was shown in table 3. Climatic suitability for Robusta coffee in West Lampung ranges from unsuitable to high suitability. The predicted future potential climatic suitability area distribution for Robusta Coffee under the RCP 2.6 climate change scenario is shown in figures 3b and 3c. The MaxEnt model output shows a significant alteration between the current and future climatic suitability in which unsuitable area increased.

![Map of Robusta coffee climatic suitability for current and projection 2050.](image)

The area highly suitable with the 2.6 RCP scenario was predicted to decrease around 23.28 %. Area suitable and moderately suitable also shifts to unsuitable area. The changing area of climatic suitability
in 2050 need to be considered in planning and coffee development in West Lampung. Adaptation strategy should be applied for coffee sustainability.

| Suitability class | Current (ha) | Projection 2050: RCP 2.6 26 (Ha) | Projection-current (ha) | Percentage Change (%) |
|-------------------|--------------|-----------------------------------|-------------------------|-----------------------|
| Unsuitable        | 704.77       | 1187.65                           | 482.87                  | 68.51                 |
| Moderately Suitable | 328.12      | 218.41                            | -109.72                 | -33.44                |
| Suitable          | 384.07       | 176.37                            | -207.69                 | -54.08                |
| Highly Suitable   | 700.73       | 537.60                            | -163.13                 | -23.28                |

This study identifies the impact of climate change on climatic suitability for Robusta coffee in West Lampung. The result of this study project that the potential climatic suitability of Robusta coffee will be decrease based on GCM climate scenarios. Considering this result, an adaptation strategy is required for the sustainability of Robusta coffee production system. The potential climatic suitability is important for future coffee development to identify future area coffee production. For sustainability coffee production, identification coffee production technologies for unfavored climatic condition are needed.

4. Conclusion

The Maxent model have adequate performance to predict climatic suitability of Robusta coffee in West Lampung. Temperature plays important role on climatic suitable distribution model. The climatic suitability for Robusta coffee was projected to shift. Suitable grown areas decrease. This shift requires adaptation strategy for sustainability coffee production system in West Lampung. This result indicates that climate change have significant impact on Robusta coffee climatic suitability.

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