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MORALITY BEFORE KNOWLEDGE

Climate change impacts on coffee production in Indonesia: A review

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ABSTRACT
Indonesia is ranked in the top 5 coffee production countries in the world with the largest production being Arabica and Robusta coffee beans. Approximately ninety percent of coffee produced in Indonesia is being exported and as the trend in local consumption increases, the demand for coffee is escalating. However, future coffee production is challenged by climate change. **Background**: This paper outlines the impacts of climate change variables including environmental stressors on coffee production quality and quantity of Arabica and Robusta species, discusses the influences on suitable areas for coffee cultivation and the coffee pests related to coffee productivity, as well as suggests mitigation and adaptation approaches in Indonesia. **Methods**: The literature review approach was utilized to complete this paper which involves collecting, analyzing, and correlating the findings of prior studies. The paper only considered literature with the following terms in the title; climate change impact, coffee production, mitigation, adaptation, and Indonesia. **Finding**: Increasing temperature degrades coffee production both in Arabica and Robusta coffee beans. The overall suitable area for cultivating coffee is shifting towards higher altitudes However, Indonesia is projected to lose more than half of the suitable area for cultivating Arabica by the year 2050. Climate change improves coffee pests' thermal tolerance and enables them to grow in warm temperatures. **Conclusion:** Common mitigation approaches include shade plantation and soil moisturization control which both improve coffee productivity. Another strategy is the cultivation calendar modified the coffee life cycle with climate prediction.

KEYWORDS: adaptation; climate change impact; coffee production; Indonesia; mitigation.

1. Introduction

The culture of drinking coffee in Indonesia has existed since the 16th century when Indonesia was still under Dutch colonial authorities. They are the pioneers who provide access to arabica coffee beans, which are now considered one of the best Indonesian coffee beans. When coffee plantations in Indonesia were invaded by pests at the end of the nineteenth century, the Dutch decided to introduce pest-resistant robusta coffee beans to Indonesia. According to research, Robusta coffee represents about 90% of coffee production in Indonesia. Despite this, Indonesia is well-known for its Arabica coffee which has strong and rich flavors, and it is regarded as one of the best coffee beans in the world (Gumulya & Helmi, 2017).

National statistics stated that Indonesia is ranked 4th in the top leading coffee bean production country in the world following Brazil, Vietnam, and Colombia. The top five coffee producers in Indonesia are located in Sumatra Island, precisely in Aceh, North

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Sumatra, Bengkulu, South Sumatra, and Lampung. The coffee beans produced are being exported with a contribution of up to 98%. Let alone local consumption which has been trending in the past decades, the demand for coffee is on the rise. Under these circumstances, Indonesian coffee farmers should have the opportunity to improve their well-being. However, future plantations of coffee are expected to be dealing with climate change events (Directorate General of Plantations, 2021; Muslihah et al., 2020).

Studies and research have been conducted on the influence of climate change on coffee production especially in Indonesia. Most of the literature reported that coffee production is projected to decline in the future, including a decrease in coffee yield, the loss of areas suitable for coffee cultivation, and the expansion of pests and diseases that have an indirect effect on coffee cultivation (Pham et al., 2019).

By evaluating previous studies, this paper aims to evaluate the influence of climate change on coffee production in Indonesia, particularly. Effects on the Robusta and Arabica coffee beans are particularly discussed in this paper as both of them have been classified as vulnerable plant species to climate change (DaMatta et al., 2019). This paper outlines the impacts of climate change variables including rising temperatures, heavy rainfall, and precipitation on coffee production quality and quantity, discusses the influences on potential suitable areas for cultivating Arabica and Robusta coffee in Indonesia and coffee pests related to coffee productivity, and furthermore suggest the mitigation and adaptation approaches that are possible to be applied in Indonesia.

2. Methods

This paper was written with a Literature Review approach. The fundamental idea of a literature review is to serve as a ground understanding for future studies by collecting, analyzing, and correlating the findings of prior studies. This approach presents a comprehensive overview of the interested topic as the studies develop over time (Snyder, 2019). The literature being reviewed in this paper was approached by extensive research and selection of the most relevant to the topic by using the inclusion-exclusion method systematic review. The inclusion criteria was set before searching began. The first criterion is to limit the literature publication year to the last five years, which is 2017-2022, to keep up with the most recent issues and data. The second criterion was to narrow down the topic by only considering literature with the following keywords in its title; climate change impact, coffee production, mitigation, adaptation, and Indonesia. Thus, only literature in English or Indonesian was taken into consideration.

The objective of the search process is to access information resources and databases, i.e. Google Scholar, Science Direct, ResearchGate, Springer, Elsevier, and Open Access Journal services. The literature obtained from the search process were then analyzed thoroughly using keyword correlation to classify the ones that are most relevant to the given topics and are worth further investigation.

3. Results and Discussion

Coffee is vulnerable to climate change because it requires specific environmental conditions to grow optimally. In a study reported in (Gokavi & Kishor, 2020; Merga & Alemayehu, 2019), the authors suggested that the ideal condition required for both Arabica and Robusta to promote optimal production as shown in Table 1.

Table 1. The ideal condition for arabica and robusta for optimal production

Species	Optimum temperature	Annual precipitation	Height elevation (above sea level)
Arabica	15—24℃	1500—2000 mm	1000—2000 m
Robusta	24—30℃	~2000—2500 mm	800 m

(Gokavi & Kishor, 2020; Merga & Alemayehu, 2019)

Robusta showed more tolerance to temperature and is said to be more resistant to climate change, however, it is sensitive to very low or very high temperatures. (Gokavi & Kishor, 2020) This idea is supported by a study conducted by Kath et al. (2020) who demonstrated that Robusta production decreases roughly 14% for every 1°C increase over a minimum temperature of 16.2°C during the growing season. The study also proposed a linear relationship between yield degradation and minimum temperature. In other words, the more the temperature increases above its minimum point, the more yield will decrease consequently. Thus, different locations might result in different optimum temperatures for yield production and demand further investigation to obtain valid data.

The flowering phase, ripening, and the quality of coffee beans produced in rising temperatures and precipitation deficit will experience degradation. Pham et al. (2019) During the rainy season, the first precipitation is stimulating the coffee flowering process. If the precipitation is unstable, it will critically affect the yield produced and its quality fall (Merga & Alemayehu, 2019). Sujatmiko & Ihsaniyati (2018) confirm this statement by claiming that climate change results in heavy rainfall and longer drought which prevent the flowers from blooming thus indicating less yield produced.

Aside from affecting the coffee yield production, Increasing temperature stimulates the suitable area for coffee cultivation to shift towards higher altitudes and affects coffee pests resistance. Quite several current coffee-growing countries are expected to not be suitable for cultivating coffee in the future due to changes in soil composition and weather conditions, e.g. humidity, acidity, and other parameters. According to Gokavi (Gokavi & Kishor, 2020), the lowest altitude suitable for coffee cultivation may increase up to 15 feet per year or is equal to approximately 5 meters. Merga & Alemayehu (2019) stated that climate change will expand the area suitable for Robusta coffee production throughout the world while the area suitable for Arabica cultivation is decreasing. Research by Muslihah et al supports the statement by revealing that 67% of the area in Indonesia will no longer be suitable for growing Arabica, however on the brighter side there will be 28% new suitable area by the year 2050. Thus, new challenges and adaptation approaches will continue to demand development for future sustainability (Muslihah et al., 2020). The potential arabica cultivation area in Indonesia is shown in Figure 1.

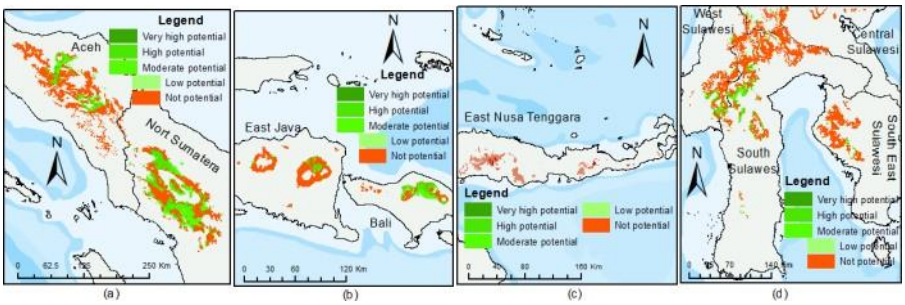

Fig. 1. Potential arabica cultivation areas in Indonesia
(Muslihah et al., 2020)

Climate change may improve the coffee pests' thermal tolerance and initiate their wider distribution around the cultivation area. The most common coffee pests are the

coffee white stem borer and coffee berry borer (Gumulya & Helmi, 2017). The study case observing coffee berry borer behavior discovered that the pests could not live properly before the industrial revolution, thus climate change increased the global temperature and allowed these pests to grow. The estimated minimum temperature for H. Hampel to be able to grow is 15℃ and will eventually stop after 30℃ (Gokavi & Kishor, 2020). The same study case also observed the coffee white stem borer behavior and learned that these pests are common in areas with more shaded trees which allow the CWSB to grow at a greater minimum temperature. The presence of these pests will depreciate the quality of coffee production.

The impacts of climate change on coffee production above can be mitigated by several approaches. The most commonly mentioned approaches in the literature are shade plantation and soil moisturization control. In the study by Achwan et al. (2019), shade plantations function as the temperature control for the coffee plant in the dry season, as a windbreaker to prevent the young coffee plant from being blown away, and as a soil erosion prevention system. Shade trees proposed ecosystem benefits, increasing the shade trees improved coffee productivity. plants that could be used as shade trees for example orange, avocado, banana, and others. However, shade and coffee density should be at optimum levels for the best productivity (Anhar et al., 2020). During the dry season, the soil needs to be moisturized by irrigation for sufficient water supply for the coffee plants. In unpredicted weather conditions under climate change, irrigation serves as insurance in case there is a water shortage (Gokavi & Kishor, 2020).

Another mitigation approach most commonly used in Aceh and presented by study Achwan et al. (2019) is making Rorak or a Dead-end trench. Aside from being practical and affordable, Rorak can be used for water conservation during the dry season. Rorak is usually 50 cm high and 3 m long with a width of up to 1 m. It is placed around the coffee plants. Roark is a water and soil conservation system that captures rainfall to infiltrate the soil. Rorak is shown in Figure 2.

The most important contributor to global warming and climate change is carbon dioxide. The increase in carbon dioxide concentration in the atmosphere results in temperature rise, unexpected droughts, and heavy rains, posing a threat to agricultural production including coffee. DaMatta et al. (2019)conducted a study on coffee performance at an elevated carbon dioxide level and suggested that the coffee crop could tolerate better environmental stresses related to climate change, such as droughts, at high levels of carbon dioxide concentration. Hence, the statement indicates that elevated concentrations of carbon dioxide could counteract the negative effects of rising temperatures on coffee production.

Coffee plants have an annual life cycle which differs according to climate conditions in the cultivation area. Thus, study Sarvina et al. (2020) proposed mitigation strategies that utilized the cycle and climate prediction to create a cultivation calendar. The use of the cultivation calendar is expected to realize productive coffee farming where input cultivation is adapted to phenological conditions and the environment. This can be supported by the availability of data, the accuracy of climate forecasts, and advanced analytic technology.

4. Conclusion

Climate change clearly affects coffee production in Indonesia. Increasing temperature degrades coffee production both in Arabica and Robusta. The flower is unable to bloom during the phase due to unpredictable weather, heavy rainfall, and droughts thus decreasing coffee production. The overall suitable area for cultivating coffee is shifting towards higher altitudes thus increasing the potential area suitable for Robusta. However, Indonesia is projected to lose more than half of the suitable area for cultivating Arabica and at the same time expand its new suitable area by 28% by the year 2050. Climate

change improves coffee pests' thermal tolerance and enables them to grow in warm temperatures. Common mitigation approaches include shade plantation and soil moisturization control which both improve coffee productivity. Coffee performance at elevated carbon dioxide levels could mitigate environmental stress, for example, droughts. The last mitigation strategy suggested in this paper is called the cultivation calendar. This calendar modified the coffee life cycle with climate prediction and has the potential to be applied as a guide for more coffee productivity.

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