Future-Proofing Coffee Cultivation through Terroir-Based Adaptation Framework: Developing Rural Communities in Indonesia

Fitrio ASHARDIONO*

Abstract:
In the tropical region of Southeast Asia, coffee is among the most valuable agricultural crops produced and Indonesia is one of the largest producers of coffee in the world. This region is among the most vulnerable to anthropogenic climatic change, where the temperature variability is projected to increase, with a significant increase in the variability of precipitation patterns, increasing occurrences of severe weather events and temperature increases. Climate change will bring negative impacts on crop production yields, especially coffee, thus directly impacting the livelihoods of smallholder coffee farmers in Indonesia. This inquiry aims to explore how the Terroir-based Adaptation Framework can be utilized as an important tool for the coffee growers in the Solok Region to swiftly adapt to the ongoing climate changes, while enhancing the production and quality characteristics of their Arabica coffee beans. Under the current climatic trend, future production will not be able to satisfy the increasing demand for high-quality coffee, thus coffee prices are projected to increase. Additionally, through this framework the coffee farmers can feel pride of ownership in the coffee beans that they produce and be encouraged to increase Arabica beans' production using their traditional cultivation knowledge, thus ensuring the sustainability of coffee cultivation in their areas.

Keywords: *Terroir, Coffee, Climate Change, Ecosystem, Sustainability, Rural Communities*

1. Introduction

(1) Climate Change and Coffee Cultivation

Ongoing recorded observation and forecasting of global climatic conditions have shown that climate change will have different impacts on each region. Rapid changes in regional climatic conditions will increase climate-related hazards as well as the occurrences of extreme climatic events. Changes in the mean air temperature and the precipitation level will transform the future agricultural

* Assistant Professor, College of Policy Science, Ritsumeikan University
Email: fitrio-a@fc.ritsumei.ac.jp
Received on 2020/1/31, accepted after peer-reviews on 2020/10/5.

Journal of the Asia-Japan Research Institute of Ritsumeikan University, 2020.
PRINT ISSN 2435-0184 ONLINE ISSN 2435-0192, Vol.2, pp.59-76.

landscape, in which established cultivation regions may disappear while new cultivation regions emerge. These changes will also transform the social and economic conditions of agriculture communities in specific areas as the crop suitability gradually changes, directly affecting the crop production yield.

The tropical regions are among the most vulnerable to anthropogenic climatic change, where the temperature variability is projected to increase, with the tendency of increasing local temperatures (Bathiany et al., 2018). The tropical climate of the Southeast Asian region is also the subject of these changes, where climate change is expected to lead to a significant increase in the variability of precipitation patterns, increasing occurrences of severe weather events and temperature increases (ADB, 2010). From the agricultural perspective, climate change in Southeast Asia will have negative impacts on crop production yields, forest harvesting, and biodiversity.

In this region, coffee is among the most valuable agricultural crops produced, and in particular, coffee products from Southeast Asia are gaining more and more popularity due to their perceived high-quality characteristics. In 2018, Indonesia was the fourth largest producers of coffee in the world, with a combined production of both *Arabica*[1] and *Robusta*[2] beans totaling 612,000 tons (ICO, 2019). This quantity has actually been in continuous decline for the past few years, and this has most likely been caused by increasing climatic variability such as sudden changes in precipitation patterns and their volumes (Schroth et al., 2009; Jaramillo et al., 2013). While coffee is not the main agricultural crop in Indonesia, the demand for it has been rising in the past years as the world's coffee consumption is continuously rising.

Coffee production in Indonesia is mainly dominated by smallholder coffee growers, most of whom rely heavily on the surrounding ecosystem and natural environmental conditions for their livelihood, thus making them extremely vulnerable to changes in the climatic conditions. As the author mentioned above, it has been well documented that changes in the climatic conditions alter the natural environmental conditions of an agricultural region, directly affecting the production yield and quality characteristics of its agricultural products, as has been observed in the previous research on winegrape and tea cultivation (Ashardiono & Cassim, 2015).

Changes in the natural environment will directly affect the coffee plants, increase the incidence of coffee pests and diseases, and furthermore, indirectly affect the population dynamics (Jaramillo et al., 2013). Continuous exposure to temperature variability and rising air temperatures will not only degrade the coffee bean quality but can also severely damage coffee plants by inhibiting plant growth and causing yellowing of the leaves. Moreover, sudden changes in the precipitation variability will cause erratic flowering and ripening cycles, thus requiring additional resources in the cultivation process (Rahn et al., 2014).

While historically, these extreme weather events have had significant impacts on coffee cultivation, the coffee farmers were able to recover the coffee production. However, the predicted future impacts of changes in the global environment might bring irreversible changes to coffee production (Tucker et al., 2010). Furthermore, the changing climatic behavior may alter the

1 Coffea Arabica is believed to be the first species of coffee to be cultivated and represents around 60 percent of the total world coffee production. Specialty coffees and gourmet coffees are mostly produced from Coffea Arabica beans.

2 Robusta variety or Coffea Canephora represents around 40 percent of the total world coffee production and is perceived to be of inferior quality to Coffea Arabica, thus it is primarily used for producing instant coffee.

precipitation patterns and increase the temperature to the extent that coffee cultivation will no longer be beneficial (Gay et al., 2006).

(2) Coffee Cultivation in Indonesia

Different coffee regions in Indonesia have shown variations of natural environmental characteristics, thus leading to differences in terms of cultivation processes, production systems, natural environmental conditions, and product quality characteristics. The Robusta coffee variety accounts for approximately 80 percent of the total coffee production in Indonesia. However, in recent years in line with the growing demand for high-quality specialty coffee, the production of Arabica coffee is slowly gaining popularity, as Arabica beans produced in Indonesia possess a distinct characteristic which is a desired trait for high-quality coffee beans.

Some of the most well-known coffee products in Indonesia are produced on the island of Sumatra, where coffee production regions are scattered all over the island from the north to the south. *Aceh Gayo*, *Mandheling*, *Lintong* and *Solok* are the four best-known coffees produced in Sumatra, where these beans are renowned for their unique and rich flavor which is sought after by many foreign buyers.

Domestic demand for these high-quality coffee beans has also been increasing, creating economic opportunities for the local rural communities to be involved in coffee production activities. Despite the growing demand, the increasing unpredictability of the climatic conditions has directly affected coffee cultivation in Sumatra Island. Heavy rainfall and strong winds have been observed to be occurring more frequently in the Gayo Highland, located in the northern part of the island, increasing unpredictability in the timing of the harvest, which has led to a decline in the coffee production yield.

In comparison with the other more internationally well-known coffees from Sumatra, Solok coffee beans which are produced in the Solok Region are more popular in the domestic market. The Arabica beans produced in this region are regarded as high-quality coffee which has a distinct aroma and taste characteristic; furthermore, in the past years, the demand for Solok coffee from the international market has been rising significantly. However, Arabica beans production in this region is comparatively low compared to other regions, as most coffee farmers are still producing Robusta beans. Additionally, the total coffee production yield has been in decline in the past two years.

Similar to the Gayo Highland, it is likely that changes in the climatic variability and patterns have been occurring in the Solok Region, thus reducing the region's coffee cherry harvest yield. It is also important to highlight that the Arabica coffee plants are more susceptible to climatic variations in comparison with the Robusta coffee plants, thus there may be many different factors related to the declining harvest yield. Concerning these changes, it is most likely that the coffee farmers and the agricultural communities in this region have a low awareness of the potential climatic impacts on coffee cultivation.

As the changes in the climatic variability are projected to continue, it is crucial for the smallholder coffee farmers in the Solok Region to have a better understanding of the projected climatic impacts, as well as to develop swift and optimal adaptation methods. Utilizing the terroir concept, the unique quality characteristics of Solok coffee can be further clarified in relation to the natural environmental conditions of the region and the techniques utilized for local production. Utilizing this approach, smallholder coffee farmers will be able to understand the relationship between the climatic factors and the quality characteristics of the harvested coffee beans, thus raising the social awareness of the effects of climate change in their region.

The application of the Terroir-based Adaptation framework will empower the smallholder coffee farmers to adapt to the ongoing environmental changes, while also helping them to cope with the growing socio-economic issues. This inquiry aims to elucidate important social and environmental factors in the coffee production processes unique to the Solok Region, by constructing a swift and optimal adaptation framework based on the terroir concept in Ecosystem-based Adaptation (EbA). As EbA places emphasis on the surrounding ecosystem of a community, the terroir-based approach will strengthen the farmers' attachment to the region, thus allowing the development of a comprehensive and effective adaptation framework, transforming the region into a stronger and more resilient rural community.

2. Theoretical Framework and Research Objectives

(1) Terroir-Based Adaptation Framework

The terroir concept explains the relationship between the natural environmental element and the agriculture practices element, where these elements are directly influencing the characteristics of an agricultural product (Ashardiono, 2019). Through the terroir-based approach, the unique values and the characteristic of the coffees produced in the Solok Region can be further identified by analyzing the region's environment physical traits including the existing ecosystem, and its relationship with the practiced cultivation methods.

In regard to the qualitative differences between Arabica and Robusta varieties, the demand for Arabica beans is higher, which leads to a higher economic valuation because they possess finer flavors which are characterized by their excellent acidity. In comparison, while the Robusta beans are perceived to have a lower quality characteristic with a harsher flavor and a strong astringency, these beans are easier to cultivate, and the higher caffeine content also makes them less sensitive to insects and pests. The perceived high-quality characteristics of Arabica beans can be directly related to the location where they are grown, thus different regions will produce Arabica beans with different quality characteristics.

The elements in the terroir concept explain the unique environment and ecosystem characteristics of a particular cultivation area, and how the factors have shaped and created the natural environmental conditions, which are unique to that area alone. Coffee plants grown under these conditions will have distinguishable quality characteristics when compared to a similar product from another region. Using the terroir-based approach, it can be observed how local cultivation techniques have played a significant role in the coffee cultivation process in the Solok Region.

Through monitoring and measurement of the climatic and soil factors, as well as analysis of the topographical and cultivar condition, the natural environmental element of the Solok Region can be quantified by developing precise bioclimatic indicators. Furthermore, by observing the correlation between these indicators and the cultivation processes practiced by the coffee farmers, the significance of the social and cultural influence on the coffee cultivation can also be understood.

In relation to the ongoing global environmental change, as discussed by Frank et al. (2011), perception of risk toward climatic effects is shaped by the social identity of the agricultural community. Through the identification of important terroir factors, especially those which are related to the socio-cultural aspect of the coffee farmers in the Solok Region, their perception of the potential impact of climatic variability can also be understood.

As in the terroir-based approach, knowledge about the social and cultural values and norms of the

coffee farmers' communities are essential aspects of the coffee cultivation processes, and this knowledge is also important for constructing effective adaptation strategies. The coffee farmer's agricultural knowledge is mostly derived from their personal experience, and when combined with precise bioclimatic information, these farmers will be able to make better decisions on conducting cultivation processes as well increasing their risk perception of climate impacts.

With the identification of important terroir factors and the accompanying bioclimatic indicators, the coffee farmers can utilize this information in conjunction with their agricultural knowledge to construct new cultivation methods to adapt to the ongoing climatic impacts. This terroir-based approach is also useful for conducting cost-effective cultivation processes which can enhance the coffee product quality characteristic as well as adding more value to the products.

Through the Terroir-based Adaptation Framework (Fig. 1), the coffee farmers will be able to strengthen their resilience to ongoing climate change, as their local agricultural knowledge alone will not be sufficient to build their adaptive capacity. The terroir-based approach and the accompanying bioclimatic indicator will provide useful new information to the coffee growers, enhancing their perspectives on the critical factors as well as vulnerabilities in the coffee cultivation processes.

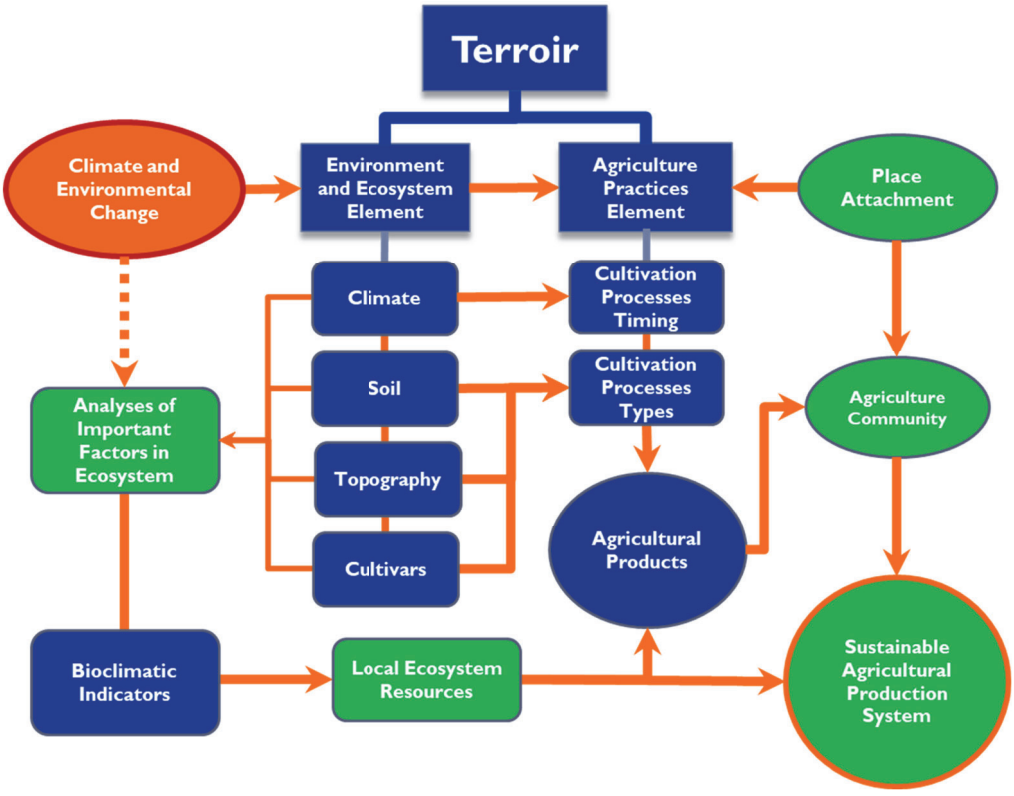

Figure 1. Terroir-based Adaptation Framework

Based on the utilization of the Terroir-based Adaptation Framework, it can also be expected that the coffee farmers will further understand the unique quality characteristics of their coffee products. With increased awareness of the coffee quality, the farmers will be able to develop and conduct a better coffee cultivation process that can improve the coffee cherry quality and harvest yield based on the region's natural environmental condition.

The Terroir-based Adaptation Framework will also provide a new perspective to the coffee farmers on how they recognize the natural environment characteristics in their region. Through this

framework, they will be able to re-utilize the natural resources available in their surrounding environment not only for coffee cultivation but also for other cultivation processes, as some coffee farmers usually cultivate secondary crops to complement their coffee production.

Increased recognition of the coffee product's quality by the coffee farmers themselves will directly affect the region's agricultural communities, sending signs to these communities that through coffee production, improved economic and social conditions can be achieved. The improvements will not only benefit the coffee farmers but will also strengthen the identity of these communities and their place attachment as the original locations of well-known coffee products, furthermore this will also further develop the farmers' and their communities' sense of ownership of the products.

Utilizing the terroir-based approach, the bioclimatic indicator can also be used as a functional indicator to delineate the boundaries of the cultivation area in relation to the quality characteristics of the coffee products. The data obtained through monitoring and measurement will be useful for creating a detailed traceability record of the coffee products with their cultivation processes, thus providing safety and quality assurance to the consumers by including detailed information on the terroir elements contributing to the product's characteristics.

(2) Research Objectives

This paper proposes to apply the Terroir-based Adaptation Framework to the Solok Region, especially in important coffee cultivation areas. Through this framework, important factors in coffee cultivation, especially those which come from the natural environment and ecosystem services can be identified. Additionally, this analysis will be conducted to understand the influences that create Solok Coffee's Arabica beans unique quality characteristics.

Based on the preliminary analysis, it can be observed how the Terroir-based Adaptation Framework is suitable for application in the Solok Region, as it will enable the coffee growers to confidently take ownership of their coffee products, as well as providing a stronger sense of attachment to the Solok Region. In addition, this framework will be a means of improving the coffee cultivation processes, increasing its productivity, and leading to the recognition of coffee products from the Solok Region among the Solok residents.

From the expected outcomes of this inquiry, the Terroir-based Adaptation Framework can be further utilized to formulate effective climate change adaptation which is designed specifically with the local ecosystem in mind, thus emphasizing the social and economic benefits to the coffee farmers. Furthermore, through this framework, the Solok agricultural communities should have increased risk perception toward global environmental changes, especially on the variations and extremes of local climatic conditions. From a broader perspective, it is likely that through the knowledge of the quality characteristics of Solok Region Arabica beans, more people will have a greater understanding of the uniqueness and importance of the quality traits as well as the cultural relationship between the coffee products and their cultivation regions.

Through this framework, it is hoped that the local agricultural communities will develop a stronger attachment to their roots, through the unique quality characteristics of their Arabica beans, which will ultimately increase awareness of the impact of climate change on the Solok Region, and ultimately this approach could then be utilized in other agricultural communities throughout Indonesia.

3. Coffee Production in the Solok Region

(1) Solok Region

Solok Region is located approximately 64 kilometers from Padang City (Fig. 2), the capital city of West Sumatra Province and is accessible by land transportation with a travel time of around 75 minutes. The Solok Region consists of three separate administrative areas, which are Solok Municipality, Solok Regency and South Solok Regency. In general, this region is well-known for its production of rice which has always been the main agricultural commodity. Rice is cultivated in most of the wetlands in the flat areas of the region, while in the drylands corn is the main crop produced by the farmers.

Figure 2. Location of Solok Region

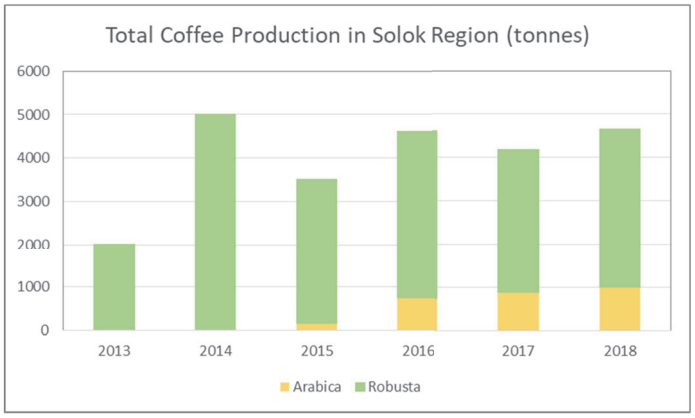

Figure 3. Total Coffee Production in Solok Region (tonnes)
(Compiled from the Statistics of Solok Municipality, Statistics of Solok Regency, and Statistics of South Solok Regency)

Coffee production is more popular among the farmers in the highland areas as the colder climate at higher altitudes is suitable for coffee cultivation. In the region, Robusta variety is cultivated at an altitude between 1,000 - 1,400 meters, while at elevations above 1,500 meters most of the coffee farmers are cultivating the Arabica variety. Based on 2019 statistical data, the total coffee production for the Solok Region in 2018 was 4,656.11 tonnes, where the total coffee production for the Arabica variety was 1,010.47 tonnes, which is 21.7 percent, and the total production for the Robusta variety is 3,645.64 tonnes or 78.3 percent (Fig. 3).

Historically, coffee cultivation in West Sumatra began during the Dutch colonial period in the early eighteenth century. During this period the Dutch East India Company introduced the Arabica variety to the region, although afterward in the late eighteenth century the coffee rust disease wiped out all the Arabica variety in the region. As a replacement, the Robusta variety was introduced to Sumatra around the early nineteenth century because the variety was deemed to be less susceptible to diseases, and ever since, all of the coffee cultivated in the Solok Region consisted mostly of the Robusta variety.

From the statistical data analysis, it can be observed that the cultivation of the Arabica varieties was only reintroduced less than ten years ago in the Solok Region, thus in 2015, the region was finally able to formally produce Arabica beans once again. With higher market value of the Arabica beans, the government as well as coffee retailers are encouraging the coffee farmers to switch from Robusta production to Arabica variety. Based on the total production yield of the Arabica variety, the Solok Regency is currently the largest producer, followed by the South Solok Regency where they have also started to produce the Arabica variety since 2017 (Fig. 4).

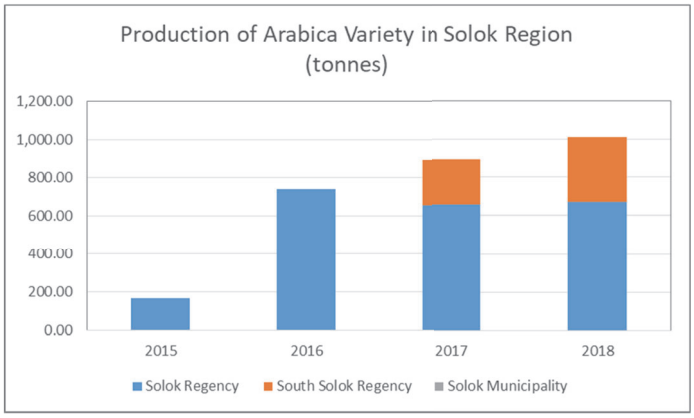

Figure 4. Production of Arabica Variety in Solok Region (tonnes)
(Compiled from the Statistics of Solok Municipality, Statistics of Solok Regency, and Statistics of South Solok Regency)

The most common post-harvest processing method being used in the region is the semi-washed or wet-hulled process, known as *giling basah*, which is widely practiced in Indonesia to process Robusta beans. This method is actually not considered to be a good method as the processed beans tend to have undesirable flavors in the cup. The *semi-washed/wet-hulled*[3] process is more popular because it shortens the amount of time required to dry the coffee beans, thus with lower moisture contents it ensures that rotting will not occur during the storage period prior to shipping. For processing Arabica beans, the commonly practiced method is the *washed*[4] process which utilizes a considerable amount of water to wash the processed beans; moreover, it requires more time during drying period.

As previously mentioned, although the production yield is still low, the Arabica beans from the Solok Regency are gaining popularity among Indonesian coffee connoisseurs; hence this is one of the contributing factors which make Solok Arabica Coffees popular in the Indonesian domestic market. With the current Arabica beans production yield in the Solok Region, especially the Solok Regency, it is a challenge to be able to supply the international market, as most of the products are already absorbed by the large domestic demand.

The most well-known Arabica beans from the Solok Regency are produced by a coffee cooperative named *Solok Radjo*. This cooperative was established by a group of coffee farmers and processors with the goal of increasing the quality of their produced Arabica beans, as well as promoting these beans to coffee roasters and cafes in the domestic market. This cooperative led the pioneering work on Arabica beans processing and marketing in the Solok Region, where their approach has been replicated by other coffee farmers and producers in the neighboring South Solok Regency.

The cooperative currently sells their processed Arabica beans to coffee roasters and cafes under the brand name Solok Radjo, where they mainly offer *natural*[5] and semi-washed coffee beans as their products. The Solok Natural is especially well-known among coffee roasters and connoisseurs in Indonesia, thus a cup of coffee brewed from these beans is sold at a premium price because of its

3 The semi-washed/Wet-hulled process consists of five steps which are: manual sorting, pulping, first drying, hulling and second drying.

4 The washed process consists of six steps which are: sorting (using water tank), pulping, fermentation (using water tank), washing, drying, and hulling.

5 The natural process consists of three steps which are: manual sorting, drying, and hulling.

perceived high-quality characteristics and unique flavors.

With the increasing popularity driving the domestic demand for Arabica beans from the Solok Region, coffee production is projected to increase in the coming years, with more coffee farmers shifting from producing Robusta beans to Arabica beans. Based on this projection, it is important to ensure the coffee production system is conducted in a sustainable manner, taking account of the potential climate change impacts, while also providing direct social and economic benefits to the smallholder coffee farmers in the region.

(2) Research Methodology

In order to achieve the stated research objectives, this research utilizes an empirical research approach, mainly using qualitative analysis through direct observations and interviews with the coffee producer. In this inquiry, coffee producer is defined as all stakeholders involved in the coffee production process, which consist of coffee farmers (coffee cherry cultivation), coffee processors (coffee beans processing), coffee buyers (coffee green beans sales and purchase), coffee roasters and café owners.

Quantitative analysis was also conducted using statistical data obtained from the local governments in the Solok Region, although in this inquiry, the focus was placed more on the actual coffee production in the Solok Regency. Direct observations were conducted on the coffee plantations owned by the smallholder coffee farmers in the Solok Region. These direct observations were important to fully understand the unique characteristics of the natural environmental element in the area and how it is affecting the coffee cultivation processes. Direct observation was also conducted at the coffee processing facilities, such as the facilities operated by the Solok Radjo Cooperative, to learn about the preferred coffee processing methods.

Following the observations, interviews were conducted with the coffee farmers, based on a semi-structured style where the questions were organized to collect information on 1) demographic information; 2) coffee production process; 3) terroir information; 4) perceived climatic impacts; and 5) socio-economic and environmental issues.

In this inquiry, the author conducted the interviews in a focus group discussion where careful attention was given to questions which might be related to information concerning the terroir information on natural environmental element and the agricultural practices element. During the discussion, questions which might be considered sensitive were asked based on the respondents' reactions, thus the author would then decide to probe further if the respondent was comfortable, or to return back with less sensitive questions to restore and maintain a conducive environment in the interviews. In general, the discussion was aimed to be conducted in a relaxed environment which made the interviewing process enjoyable for both parties.

Throughout the discussions, the author was assessing the perceived climate change impacts on coffee cultivation and production, especially to understand the relationship between the existing natural environmental characteristics and the quality characteristics of the produced coffee beans. It is crucial to know how the coffee farmers and coffee processors view the potential danger caused by climatic variability and extreme event. From the coffee roasters and cafes that use the Solok Arabica beans, in-depth information about the quality characteristics of the coffee products was also obtained through observations and interviews.

The information obtained through these analyses will provide an essential foundation to apply the Terroir-based Adaptation framework into the coffee production system. By adopting this framework,

the coffee farmers and producers in the Solok Region can improve the production while also ensuring the sustainability of the coffee cultivation. Furthermore, they should also be able to improve their livelihoods, increase their awareness of climate change impacts, and swiftly adapt to future challenges.

4. Research Results and Discussion

(1) Social Survey Result

In this inquiry, the social survey was conducted inside the Solok Regency where the interview subjects were mainly the coffee farmers who are members of the Solok Radjo Cooperative. As mentioned previously, the cooperative focused its activities as a post-harvest coffee cherry processing center to produce Arabica coffee beans from the Solok Regency. The Solok Radjo Cooperative was established in 2012. Its members are coffee farmers, agricultural field advisors, coffee traders, and coffee enthusiasts. Currently there are around 800 farmers registered as members of this cooperative, of which those who are actively engaged in coffee cultivation and production are only twenty-three farmers.

Although the cooperative mainly processes Arabica beans from the Solok Regency, they also purchase a limited quantity of Arabica beans from other regions while also encouraging the farmers in the Solok Regency to switch from Robusta to Arabica variety cultivation. Facing the current situation, one of the cooperative's administrators lamented about the lack of interest from the farmers in increasing their Arabica beans production. He also mentioned that despite the cooperative's offering a relatively high price to purchase Arabica coffee cherries, the farmers were still reluctant to increase their Arabica production.

The establishment of the cooperative was driven by the passion of its founding members to promote Arabica variety cultivation in the Solok Regency, with the objective of increasing the livelihoods of the local farmers. Prior to 2012, the provincial government of West Sumatra had distributed and to some extent promoted the cultivation of the Arabica variety in the region. Although this proved unsuccessful due to lack of local government commitment to support cultivation and production, Arabica coffee cultivation was adopted by several farmers. It was the surprisingly high-quality characteristic of the Arabica coffee beans produced by these farmers which kick-started the cooperative's effort to promote coffee products from the region to the Indonesian coffee market.

In general, the Solok Radjo cooperative processed the Arabica coffee cherries based on market

Figure 5. Post-Harvest Coffee Cherry Processing Center at the Solok Radjo Cooperative
(a) Natural Process; (b) Honey Process (Source: Author)

demands and their processing capacity. Although the coffee products processed using the natural as well as the honey process[6] (Fig. 5) fetch a higher market price, this requires a longer processing time and is very dependent on the weather conditions. On the other hand, despite its slightly lower selling price, the semi-washed process shortens the processing time, thus allowing for an increase in the production capacity.

Figure 6. Solok Radjo Cooperative's Limau Cirago Coffee Beans (Source: Author)

The cooperative maintains several product lineups that are being offered periodically. Furthermore, based on the available coffee cherries and resources they also offer their premium product labeled as *Limau Cirago* (Fig. 6), perceived to be their highest quality product. In creating these product lineups, the cooperative administrators are taking into account the influences of the natural environment factors of the coffee plantations, such as the elevation and topography of the plot, which can be related directly to the air temperatures; the types of soils; as well as the agriculture practices factors such as the cultivation processes utilized by the farmers. As seen in their premium product, the administrators mentioned that the cherry beans for this product have to be harvested from certain locations with specific elevation ranges (1,500-1,700 meters above sea level), specific soil properties, and processed using their own method (modified honey process). From this observation, it

6 The Honey process is similar to the Natural process, with an additional step prior to drying which is pulping, although a specific amount of fruit flesh is purposely left covering the beans.

can be surmised that the Solok Radjo Cooperative does indeed operate on the basis of the terroir-based approach in developing their product offerings.

As mentioned previously, the cooperative operates as a post-harvest processing center which purchases coffee cherries directly from the farmers, thus they maintain their profit from the margin created between their coffee cherry purchases and coffee bean sales. Although they purchase coffee cherries at relatively higher prices compared to other buyers, any profit increases from their coffee beans sales are not felt directly by the farmers, as the purchase price for the coffee cherries is largely stagnant.

From the twenty-three farmer members of the cooperative who are actively conducting Arabica variety cultivation, the author has managed to conduct interviews with five of the coffee farmers to understand their current situation in relation to their coffee cherry production and their social and economic conditions. Because most of the coffee farmers are living far apart, and furthermore because their coffee plantations are usually situated on a hillside or hilltop far from their house, and without a proper access by road, it required a few hours of hiking for the author to visit only one coffee plantation. For this reason, the five selected farmers' plantations are situated quite close to each other, in the *Nagari Aie Dingin*, *Lembah Gumanti* Sub-District.

From direct observation in the coffee plantations (Fig. 7), it can be seen that most farmers have inherited the plot from their previous generations, where originally the Robusta variety was cultivated. The coffee crop is actually being used to complement the production of other crops, which are the cash crops that generate the farmer's primary income. Most of the farmers focused their daily work on the cash crops such as shallots, tomatoes, and potatoes in the plot adjacent or close by the coffee plantation, while the work on the coffee plantation was usually conducted only a few times in a week. It can also be observed in several coffee plantations how the farmers are intercropping the coffee with other crops such as sweet potatoes, chili peppers, and passion fruits.

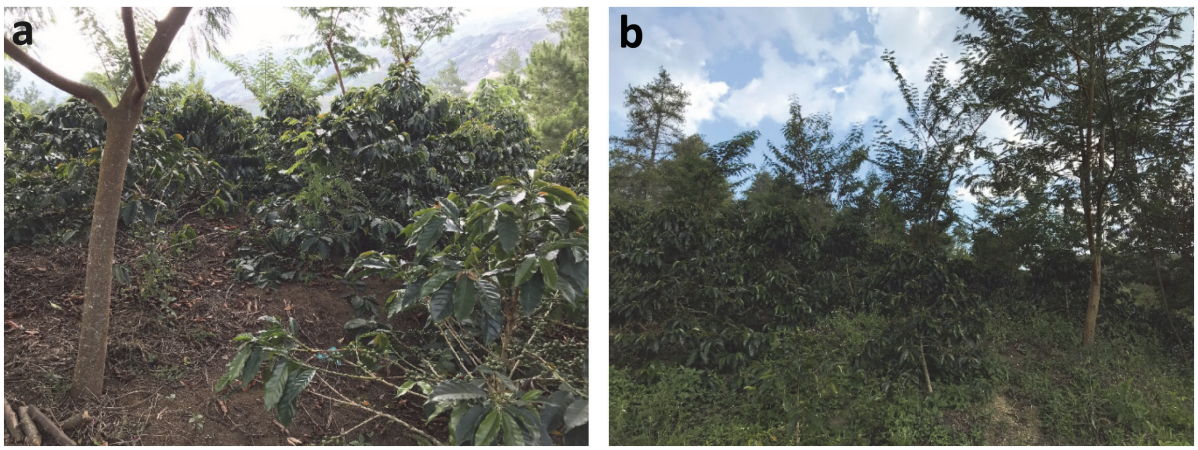

Figure 7. Coffee Plantation in the Solok Regency
(a) Shading Tree inside Coffee Plantation; (b) Intercropped Plantation (Source: Author)

During the interview, on the topic of coffee cultivation especially Arabica variety, the coffee farmers indicated their reluctance to increase the production of Arabica coffee cherries, where the main reasons can be highlighted as:

1. Reluctance to make coffee their primary crop (n=5).
2. Preference to cultivate a variety of other crops (traditional agriculture knowledge and

subsistence agriculture) (n=3).
3. More time, work and resources are needed to cultivate the Arabica variety (n=5).
4. Despite the increased popularity of Solok Coffee, most farmers have not enjoyed any direct benefits from coffee production (n=4).
5. Low sales value of the coffee cherry (n=4).
6. Lack of agriculture and technological assistance from the local government (n=5).

From these interview results it can be concluded that the underlying reason why the farmers are reluctant to increase their Arabica coffee production mostly lies in the perceived insignificant economic gains, against the backdrop of increasing workload and resource usages in comparison to Robusta variety. The coffee farmers also mentioned that the Robusta variety requires less work, where they need to tend the plantation only once a week, in comparison with the Arabica variety which mostly requires daily maintenance. Based on these interviews it can also be concluded that the farmers have yet to receive a significant direct economic benefit from Arabica variety cultivation, which could replace their current cash crop production.

Interestingly, the current approach adopted by these farmers is by conducting intercropping, where the objective is to integrate the coffee cultivation with their cash crop, as a means to reduce the time required to visit their other plots. During the field work, it can be observed that the farmers conduct cultivation in several plots where these plots are located far from each other. Because of this reason, several farmers are planting sweet potato, passion fruit, and shallot alongside the coffee plants, therefore they were able to cultivate different crops in one plot. With this approach, the farmers can also maintain their income from cash crop production, although sacrificing any possible production increase in the coffee cultivation. The types of cash crops are also subject to changes depending on the market price, as most of the cash crops are cultivated only in between four to six months, hence the income from the coffee production also functions as an added livelihood insurance to reduce the effect of market price instabilities.

(2) Perceived Climatic Conditions

As mentioned previously, the five coffee farmers interviewed in this inquiry are working on coffee plantations which are situated inside Nagari Aie Dingin, thus the information obtained from these interviews can represent how the farmers perceived the impacts of climate change on the micro-climatic conditions in the area. The age of these five farmers varies from fifty-seven to seventy years old; they inherited their land from their families and have been working on the plots for most of their lives.

Based on this information it can be concluded that these farmers undoubtedly understand the characteristics of the natural environment and its ecosystem services in their plots. They conduct plot selections for cultivating crops based on their experience and the cultivation knowledge received from their fathers and grandfathers. Although the agriculture field advisors sometimes visit their plots to give some recommendations, they felt they were generally not suitable for their land or required additional resources that would cause them to rely on government support.

Throughout the years, the farmers have learned how to effectively utilize their land to cultivate the cash crops as well as another subsistence crop optimally on their plots, to some extent utilizing the existing environmental characteristics such as slopes and wind direction. Some members of the Solok Radjo Cooperative also believe that the characteristics of the coffee beans might have come from the

influence of the environment and ecosystem services on the coffee plantations.

In relation to the perceived impacts of climate change all the interviewed farmers and members of the Solok Radjo Cooperative stated, in the last five years the perceived climatic impacts are: 1) Extreme wind gusts; 2) Longer drought season; and 3) Changing intensity and period of rainfall. These observations represent the likelihood of future potential dangers that may threaten agricultural production in the area, as the impacts of climate change are predicted to be more intense in the coming years. Although these climatic events have been observed, at the moment the coffee farmers felt there are no significant impacts on the coffee production in the area, and consequently no efforts towards adaptation or mitigation are being conducted.

The farmers are confident that the coffee plants will be able to survive a drought and less worried about gust damages and precipitation changes. This confidence stemmed directly from their experiences in cultivating Robusta variety which is more robust and resistant to pest and climatic variabilities, additionally this statement also shows that the coffee farmers have not fully acquired the knowledge of cultivating the Arabica variety.

In regard to these climatic impacts, the cooperative as coffee processor actually expressed their worries about these extreme climatic events, because along with these extreme events they have found that the increasing climatic variability also causes more incidences of coffee cherries being damaged due to the coffee borer beetle. Based on these statements it can be summarized that although the farmers understand the potential danger of potential climatic impacts, currently they are not prioritizing their coffee production, so as long as the impacts do not directly affect their cash crop production they do not feel the need to make an additional effort to adapt to or mitigate the increasing climatic variability.

(3) Terroir-based Approach

Analysis of the current findings mainly showed, from the farmer's perspective, that the value of their coffee cherries is not reflected by the quality characteristics, and that they lack awareness of the impacts of climate variabilities. These results strengthened the need to adopt the Terroir-based Adaptation Framework to address the current issues faced by both the Solok Radjo Cooperative as well as the coffee farmers. Through the framework, both the farmers and the cooperative can further understand how the local environment, ecosystem services and micro-climate in the coffee plantation influence the quality characteristics of the processed coffee beans. Moreover, using the terroir-based approach, the differences between the traits and characteristics of each plantation's coffee beans can be easily understood, thus allowing for a better information and knowledge sharing among the stakeholders.

The terroir-based approach utilizes data collected by monitoring and recording measurements of the micro-climate, soil, and topographical condition, as well as the cultivated varieties in the coffee plantation. These data can be generated through cooperation between the coffee farmers and Solok Radjo Cooperative as the coffee processors, where the cooperative provides material support and financial incentives to the farmers who provide routine measurement records of their coffee plantation. Using these data, the cooperative and the farmers can further understand the quality characteristics of the harvested coffee cherries, in relation to the environment and ecosystem condition during the cultivation processes.

By correlating these data with the quality characteristic of the coffee beans, the cooperative will be able to develop relevant bioclimatic indicators to assess the level of influence of the local

ecosystem services, as well as to identify the potential impacts of climate variability and other extreme events. From this information the cooperative will be able to provide detailed climatic information to the farmers and assist them in developing optimal adaptation approaches through periodical meetings to facilitate further discussions. This information can also be utilized by the cooperative to select suitable post-harvest processing methods based on the location of the coffee plantation, and the conditions when the coffee cherries were harvested.

The Terroir-based Adaptation Framework will also enable the coffee farmers to take pride in the ownership of the coffee beans that they produced, thus encouraging them to increase Arabica beans production while utilizing their traditional cultivation knowledge to further enhance its quality characteristics. Using the bioclimatic information, the farmers can conduct effective cultivation processes with optimal resource utilization, where these will help them to swiftly adapt to the ongoing climate changes while ensuring the sustainability of coffee cultivation in their areas.

5. Conclusion and Future Research

Through this inquiry, the findings can be summarized in four main points which are: 1) the growing popularity of Solok Coffee can be linked to the special quality characteristic of the coffee products from Arabica beans (the influence of natural environmental conditions and existing ecosystem services in the Solok Regency); 2) The coffee processors are worried about the possibilities of harmful future climate scenarios, where the incidences of coffee borer beetle damages significantly increase to the point where they might decimate the industry; 3) the coffee farmers are more concerned about economic security, which has led to their reluctance to switch to or increase the production of Arabica beans; 4) the cultivation of the Robusta beans requires lower labor inputs and is less affected by climate impacts, thus leading to lack of concern about future climatic impacts.

Based on this summary it is also important to highlight that despite their low awareness, in the cultivation practices, the coffee farmers have been utilizing their traditional knowledge about the local ecosystem to conduct optimal cultivation processes. It is also worth noting that the lack of supporting infrastructure such as better access roads to the coffee plantations has, to a certain extent, hindered the farmers' productivity in conducting efficient cultivation processes as they spend most of their daily time travelling between their plots.

As discussed in the previous chapter, through the application of the proposed Terroir-based Adaptation Framework, both the cooperative and the farmers will be able to have significant benefits both in economic terms as well as in ensuring the sustainability of the coffee industry in the Solok Regency. With a better valuation of the coffee cherries based on their quality characteristics, the farmers will be encouraged to increase their production while also improving the quality of the harvest, where the cooperative can further assist the farmers in developing optimal climate change adaptation methods as well as selecting suitable post-harvesting methods.

Based on this research outcome, future research should be focused on conducting more in-depth analysis to assess the actual benefits of the terroir-based approach to the farmers' livelihoods as well as the development of a local adaptation approach. The recommended analytical tool will be through a series of focus group discussions involving all of the stakeholders, to further understand the complexities which currently exist in the industry. Incorporating another approach such as agroecology into the terroir-based framework can also increase the comprehensiveness of the framework in formulating a local adaptation method. With the ongoing climate changes, it is also necessary to create

a system for the farmers, local stakeholders, local government, and agricultural institutions as well as coffee retailers to easily exchange detailed climate information, as their basis for making optimal and efficient decision-making on the coffee production and cultivation processes.

Through this paper, we can conclude that the Terroir-based Adaptation Framework will benefit the coffee industry, especially for the coffee farmers and coffee processors, by improving the value of coffee beans as well as providing a tool to improve the long-term sustainability of rural communities, especially in developing countries such as Indonesia. Despite the projected climatic impacts, the Terroir-based Adaptation Framework has the potential to ensure the sustainability of agriculture production in the Southeast Asia Region, especially coffee cultivation in Indonesia.

References

(1) Books and Articles

Ashardiono, F. 2019. Application of the Terroir Concept on Traditional Tea Cultivation in Uji Area. In *Sustainable Solutions for Food Security: Combatting Climate Change by Adaptation* (pp. 311-329). Springer, Cham.

Ashardiono, F. 2019. Protecting Japanese Tea Growers from the Devastating Effects of Climate Change: A Terroir-Based Ecosystem Approach for Rural Development. *Journal of the Asia-Japan Research Institute of Ritsumeikan University*, *1*, 29–43.

Ashardiono, F., and Cassim, M. 2014. Climate Change Adaptation for Agro-Forestry Industries: Sustainability Challenges in Uji Tea Cultivation. *Procedia Environmental Sciences, 20*, 823-831.

Ashardiono, F., and Cassim, M. 2015. Adapting to Climate Change: Challenges for Uji Tea Cultivation. *International Journal Sustainable Future for Human Security (J-SustaiN)*, *3*(1), 32–36.

Bathiany, S., Dakos, V., Scheffer, M., and Lenton, T. M. 2018. Climate Models Predict Increasing Temperature Variability in Poor Countries. *Science Advances*, *4*(5), 1–11.

Castellanos, E. J., Tucker, C., Eakin, H., Morales, H., Barrera, J. F., and Diaz, R. 2013. Assessing the Adaptation Strategies of Farmers Facing Multiple Stressors: Lesson from the Coffee and Global Changes Project in Mesoamerica. *Environmental Science & Policy*, *26*, 19-28.

Frank, E., Eakin, H., and López-Carr, D. 2011. Social Identity, Perception and Motivation in Adaptation to Climate Risk in the Coffee Sector of Chiapas, Mexico. *Global Environmental Change*, *21*(1), 66–76.

Gay, C., Estrada, F., Conde, C., Eakin, H., and Villers, L. 2006. Potential Impacts of Climate Change on Agriculture: A Case Study of Coffee Production in Veracruz, Mexico. *Climatic Change*, *79*(3-4), 259-288.

Jaramillo, J., Setamou, M., Muchugu, E., Chabi-Olaye, A., Jaramillo, A., Mukabana, J., Maina, J., Gathara, S., and Borgemeister, C. 2013. Climate Change or Urbanization? Impacts on a Traditional Coffee Production System in East Africa Over the Last 80 Years. *PLoS ONE*, *8*(1), e51815.

Laderach, P., Lundy, M., Jarvis, A., Ramirez, J., Portilla, E. P., Schepp, K., and Eitzinger, A. 2011. Predicted Impact of Climate Change on Coffee Supply Chains. In *The Economic, Social and Political Elements of Climate Change* (pp. 703-723). Springer, Berlin.

Lechthaler, F., and Vinogradova, A. 2017. The Climate Challenge for Agriculture and the Value of Climate Services: Application to Coffee-Farming in Peru. *European Economic Review*, *99*, 5-30.

Rahn, E., Läderach, P., Baca, M., Cressy, C., Schroth, G., Malin, D., Rikxoort, H. V., and Shriver, J. 2014. Climate Change Adaptation, Mitigation and Livelihood Benefits in Coffee Production: Where are the Synergies? *Mitigation and Adaptation Strategies for Global Change*, *19*(8), 1119–1137.

Schroth, G., Laderach, P., Dempewolf, J., Philpott, S., Haggar, J., Eakin, H., Castillejos, T., Moreno, J. G., Pinto, L. S., Hernandez, R., Eitzinger, A., and Ramirez-Villegas, J. 2009. Towards a Climate Change Adaptation Strategy for Coffee Communities and Ecosystems in the Sierra Madre De Chiapas, Mexico. *Mitigation and Adaptation Strategies for Global Change*, *14*(7), 605–625.

Tucker, C. M., Eakin, H., and Castellanos, E. J. 2010. Perceptions of Risk and Adaptation: Coffee Producers, Market Shocks, and Extreme Weather in Central America and Mexico. *Global Environmental Change*, *20*(1), 23–32.

(2) Official Sources

Statistics of Solok Municipality. 2019. *Solok Municipality in Figures*. Solok Municipality, West Sumatra Province, Indonesia.

Statistics of Solok Regency. 2019. *Solok Regency in Figures*. Solok Regency, West Sumatra Province, Indonesia.

Statistics of South Solok Regency. 2019. *South Solok Regency in Figures*. South Solok Regency, West Sumatra Province, Indonesia.