Local-adapted and high-yield varieties for sustainable Robusta coffee farming: Evidence from South Sumatera, Indonesia

A M Hasibuan\textsuperscript{1}, E Randriani\textsuperscript{2}, I N A Wicaksono\textsuperscript{2}, Dani\textsuperscript{2} and T J Santoso\textsuperscript{2}

\textsuperscript{1}Indonesian Center for Estate Crops Research and Development, IAARD, Bogor, West Java, Indonesia
\textsuperscript{2}Indonesian Industrial and Beverage Crops Research Institute, IAARD, Sukabumi, West Java, Indonesia

Corresponding author email: am.hasibuan@pertanian.go.id

Abstract. Climate change causes an adverse impact on the coffee plantation as it directly influences the productivity and quality of coffee products. For the adaptation strategy, using superior variety is often considered an important step because it has potential attributes such as high yield and quality, and is more tolerant to certain environmental shocks. This study aims to analyze the environmental adaptability and financial feasibility of local Robusta coffee varieties. This study used data from field observations, surveys, and interviews of key informants in Ogan Komering Ulu Regency, South Sumatera, Indonesia from 2018-2021. Data were analyzed descriptively. Results showed that three local clones have high adaptability in the study site, even in a high precipitation rate. The varieties are financially feasible to be adopted by farmers, even though on a small scale. Sensitivity analysis with the scenario of decreasing the yield or increasing operational cost as the impact of climate variability about 10 percent showed the lower feasibility indicators (NPV, IRR, and Net B/C), but still higher than the minimum threshold so that still feasible and profitable for farmers. Hence, the three local clones are the potential to be developed for sustainable Robusta coffee plantations.

Keywords: Robusta coffee, local varieties, sustainability, financial feasibility

1. Introduction
Climate change has become a serious threat to the sustainability of agricultural production in the world. Higher temperatures, unpredictable climate patterns, and increasingly extreme weather events have caused a severe impact on farm production directly [1, 2]. While the indirect effect of the changing climate could be resulted from how climate variability affects ecosystem support. For example, increasing temperature and uncertainty in precipitation could accelerate the loss of soil fertility and nutrition [3-5]. The changing climate also could result in the damaging interaction between a plant with pests, diseases, and weeds [6-8], including the pollination services [9] which are essential for plant performance. Hence, the changing climate might contribute to environmental degradation and threaten the stability and sustainability of agricultural production [10].

The impact of climate change on coffee farming has been widely acknowledged. The negative impact of the changing climate on coffee plantations is mostly related to the decreasing productivity and loss of suitable land [11, 12]. For example, in Indonesia, increasing temperature and the changing pattern of
rainfall are projected to reduce the suitable area for coffee farming drastically [1]. This situation is also predicted to occur in Latin America [2, 13, 14], and Africa [14, 15].

Since agricultural production and sustainability have become major concerns, adaptation to climate change should be a priority in agricultural developments. Many studies have proposed some adaptation strategies, such as climate-smart agriculture practices [16, 17], changing farm management, and crop choices [18], and adopting new advanced technology [19]. One of the most popular strategies is the use of superior varieties [2, 20-22]. The varieties should have better performance such as higher yield and quality, better adaptability to the environmental conditions, and also its resistance to pests and disease attacks [23, 24].

However, locally adapted practices may have an important role in climate change adaptation strategies, including local-adapted varieties, as it already has suitability to agro-environmental conditions, including local climate [25-27]. Since coffee productivity and quality are highly affected by local climate conditions (i.e. temperature, precipitation, humidity, and radiation) and agro-environmental factors [see. 15], local-adapted varieties can be a reasonable option for coffee development in a changing climate situation. In addition, coffee farmers often have done self-selection to obtain the best performance of coffee for their multiplication. As a result, there are always the potential local-adapted high-yield coffee plants that are potentially multipliclated and released as new varieties. However, prior to the release, there is some scientific process that needs to be conducted, including the assessment of environmental adaptability and economic feasibility. This study aims to analyze the environmental adaptability and financial feasibility of local Robusta coffee varieties, including the assessment of the impact of environmental shocks on the local coffee farming feasibility.

2. Methodology
2.1. Study sites
This study was conducted in Talang Agung dan Air Rupik Village, Banding Agung Sub-district, South Ogan Komering Ulu (OKU) Regency, South Sumatera Province, Indonesia. These sites are located at the altitude of 600 – 700 above sea levels. Based on the information from local governments, these sites are the Robusta coffee production center and largely have used local-adaptive and high-yield Robusta coffee clones.

2.2. Data collection
This study used primary and secondary data. Primary data was collected by using observation of the selected Robusta coffee plantation in the study sites from 2017 - 2021. This study observed three local-adaptive and high-yield clones i.e. Kobura 1, 2, and 3. To understand the financial feasibility of the clones, we conducted a survey and in-depth interviews with the farmers, local traders, and local government. Data collected was coffee farming systems including input and labor use and price, marketing method, harvest, and post-harvest handling, etc. Secondary data was collected from the Directorate General of Plantation, Statistical Agency, and the Indonesian Agency for Meteorology and Climatology.

2.3. Data analysis
To understand the adaptability of the three local-high-yield Robusta coffee clones, this study used descriptive analysis. The analysis involved the yield of each clone in different precipitation rates and also its adaptability in various shading crops.

Since the local-adaptive and high yield clones have been proposed to be released as local varieties so that it will be legal to be developed, this study conducted financial feasibility to the clones. Hence, data obtained were analyzed by using cash flow projection for 15 years. We have several assumptions for the analysis, as follows: (1) Coffee plantations use a polyclonal pattern that involved Kobura 1, 2, and 3 clones in a proportional share so that the farm productivity is calculated from the mean of the three clones; (2) We assume that there is no rent cost for the land as farmers plant the coffee in their
land; and (3) Data for price used the farm-gate green bean price in August 2020. The price was different for mixed and separated clones which were Rp. 20,000 and 30,000, respectively.

The financial analysis was conducted using discounted cashflows with a 20 percent discount rate. We used common feasibility criteria such as net present value (NPV), internal rate of return (IRR), Net B/C ratio dan payback period.

Cash flow analysis was conducted by calculating estimated inflow or total revenue (TR) and estimated outflow or total cost (TC) which eventually used to calculate the benefit (π), estimated as follows:

$$\pi_t = TR_t - TC_t$$

Where:

- $$\pi_t$$ = benefit of coffee farming year $$t$$
- $$TR_t$$ = total revenue of coffee farming year $$t$$
- $$TC_t$$ = total costs of coffee farming year $$t$$

Based on the projection of $$\pi$$ for coffee farming, we then calculated NPV at 20 percent of the discount rate ($$r$$). This rate was used by considering the credit interest rate at commercial banks for micro and small enterprises in Indonesia in the year 2020. The range of the interest rates was 7 – 20 percent. The formulation of NPV is as follows:

$$NPV = \sum_{t=1}^{15} \frac{\pi_t}{(1 + r)^t}$$

Coffee farming would be financially feasible if NPV is larger than 0. Another criteria used is IRR, formulated as follows:

$$IRR = r_1 + \frac{NPV_1}{NPV_1 - NPV_2} (r_2 - r_1)$$

Where:

- $$IRR$$ = internal rate of return
- $$NPV_1$$ = positive NPV
- $$NPV_2$$ = negative NPV
- $$r_1$$ = discount rate level which causes positive NPV
- $$r_2$$ = discount rate level which causes negative NPV

The IRR value can be interpreted as the highest loan interest rate that can be tolerated if all costs for coffee farming come from loans. This value can also be interpreted as the rate of return of the money spent on coffee farming so that it can be considered feasible and profitable when compared to the rate of return from other businesses/investments, such as deposits. Thus, coffee farming can be said to be feasible and profitable if the IRR value is higher than the loan interest rate or deposit rate.

This study also used the Net B/C ratio as a criterion of coffee farming feasibility, which formulated as follows:

$$Net \ B/C = \frac{PV_{positive}}{PV_{negative}}$$

If Net B/C > 1, the coffee farming will be financially feasible, vice versa.

With the regard to understanding the impact of environmental shocks on the coffee farming feasibility, this study conducted a sensitivity analysis with the following scenarios:

1) Climate variability causes coffee productivity to decrease by 10 percent with no change in operational costs (except harvest and post-harvest costs).
2) Climate variability causes coffee production costs to increase by 10 percent with no change in farm yield.
3) Combination of scenarios 1 and 2.

3. Results and discussion

3.1. Potential yield and agroclimatic adaptability

This study observed the productivity of three local clones of Robusta coffee, namely Kobura 1, Kobura 2, and Kobura 3, in the study sites and a comparison clone from 2018 to 2021. The results show that these three local clones have high productivity (Table 1). Based on the observation in 2019, the productivity for Kobura 1 could reach 3.11 tons/ha, Kobura 2 2.03 tons/ha/year, and Kobura 3 2.05 tons/ha/year. This productivity is much higher than the average yield of Robusta coffee in South OKU Regency (762 kg/ha/yr), South Sumatera (903 kg/ha/yr), and national levels (800 kg/ha/yr) [28]. It implies that Kobura clones are potentially used for Robusta coffee development in South OKU Regency and/or South Sumatera Province, especially for the area with similar agroecosystem conditions.

| Clones  | Yield (ton/ha)* | 2018   | 2019   | 2020   | 2021** | Average |
|---------|----------------|--------|--------|--------|--------|---------|
| Kobura 1|                | 2.76 ± 0.35 | 2.09 ± 0.47 | 2.58 ± 0.38 | 1.47 ± 0.22 | 2.22 ± 0.13 |
| Kobura 2|                | 1.70 ± 0.33 | 1.32 ± 0.35 | 1.83 ± 0.51 | 1.28 ± 0.20 | 1.53 ± 0.25 |
| Kobura 3|                | 1.90 ± 0.15 | 1.54 ± 0.26 | 1.61 ± 0.20 | 1.08 ± 0.13 | 1.53 ± 0.12 |

Note: *) The population of the coffee plantation is 1600 trees per hectare
**) Low production in 2021 due to very high precipitation rates

As shown in Table 1, the average yield in 2021 is much lower than in the previous years due to unfavorable climate conditions (see. Fig. 1). The precipitation rates in 2020 which would influence the coffee production in 2021 was very high. When the highest productivity was reached in 2019, the precipitation rate in 2018 was only one-third of 2020. Compared with the yield in 2019, the productivity declines by 45.66, 27.09, and 40.98 percent for Kobura 1, 2, and 3, respectively. However, the average productivity for the three clones in 2021 is still high which achieve 1.69, 1.48, and 1.21 tons/ha/year, respectively, much higher than the average of Robusta coffee productivity in the South OKU Regency during the favorable climate condition in 2019 which only 762 kgs/ha/year. Our in-depth interview with farmers also revealed that the three local clones have much higher productivity compared with the existing improved variety (i.e. BP 358, BP 354, BP 295, BP 308, and BP 42) as those varieties require decisive dry months for optimal flowering and fruit set process. On the other hand, the local climate seems to be difficult to meet this requirement.

Based on our observations, the clones of Kobura 1, 2, and 3 have good adaptability and suitability for the altitude of 551.1 to 725.6 meters above sea levels. Moreover, these three clones can be intercropped with various shading crops which have high economic values, such as coconut, durians, avocado, forest trees, and many more. Hence, the Kobura clones farming system can be managed in an agroforestry pattern which is important for environmental sustainability [see. 29, 30].
3.2. Economic feasibility evaluation for Kobura clones

3.2.1. Robusta coffee price

World coffee prices have fluctuated quite high in the last decade. After experiencing the highest price in 2011, world coffee prices, both Arabica and Robusta, continuously volatile in a declining trend [31]. However, Robusta coffee price fluctuations tend to be lower than Arabica (Figure 2).

In 2020, the pressure on world coffee prices will be even more severe due to the COVID-19 pandemic. The pandemic has caused major shocks of demand in main coffee-consuming countries such as the European Union and the United States which have been severely affected by the spread of the disease. This condition also contributed to the decline in Robusta coffee prices in the domestic spot market. In June 2020, the price of Robusta coffee had reached Rp. 16,158.- per kg [32]. However, there was a trend of price improvement so that in August 2020 the price of coffee broke the highest record for 2020 of Rp. 21,300.- per kg. This condition is expected to be able to foster optimism for coffee farmers about the recovery of coffee prices in the market.
3.2.2. Cashflow projection and financial feasibility evaluation
Based on the first assumption, we projected the coffee plantation yield for 15 years (Table 2). As the farmers in study sites commonly used the “tak-ent” method, the coffee plantation can be harvested in the second year with a maximum yield is 2.5 tons/ha.

Table 2. The projection of green bean production from 1 ha Kobura coffee plantation.

| Age | Clones | Green bean production (kg/ha) |
|----|--------|-------------------------------|
|    | Kobura 1 | Kobura 2 | Kobura 3 |
| 1  | 0        | 0        | 0        |
| 2  | 0.47     | 0.32     | 0.30     |
| 3  | 1.01     | 0.80     | 0.76     |
| 4  | 2.04     | 1.67     | 1.54     |
| 5  | 2.13     | 1.70     | 1.67     |
| 6  | 2.45     | 1.80     | 1.92     |
| 7  | 2.94     | 1.81     | 2.03     |
| 8  | 2.23     | 1.41     | 1.64     |
| 9  | 2.96     | 2.65     | 1.72     |
| 10 | 2.87     | 2.45     | 2.04     |
| 11 | 2.98     | 2.52     | 2.02     |
| 12 | 2.76     | 2.50     | 1.97     |
| 13 | 2.89     | 2.59     | 2.03     |
| 14 | 2.80     | 2.36     | 2.00     |
| 15 | 2.94     | 2.60     | 1.98     |

Cash flow projection was calculated from the green bean production in Table 2 using different green bean price assumptions as described previously, namely Rp. 30,000,-/kg for separated clones and Rp. 20,000,-/kg for mixed clones. The consequence of separated clones is the harvest and post-harvest costs are more expensive by Rp. 1,500/ kg green bean. Cash flow projections resulting from the calculation of revenue and cost components for coffee farming for 15 years using these two assumptions are presented in Figure 3.

From the calculation of cash flow projections for the production of separated clones, the farmer already gains profits in the 3rd year as the yearly inflows are greater than the outflow. However, if calculated cumulatively, the profit would be obtained in the 4th year with a total cumulative profit for 15 years of Rp. 414,317.052.-. Meanwhile, from the calculation of cash flow projections for the production of mixed clones, farmers can also get profits in the 3rd year. While if calculated cumulatively, the profit would be gained in the 5th year with a total cumulative profit for 15 years of Rp. 189,597.052.-.

Based on the criteria of NPV, IRR, Net B/C, and payback period, the feasibility level of the three local coffee clones is presented in Table 3. The results show that the polyclonal farming of the three local clones is feasible and profitable to be cultivated. However, the level of financial feasibility is much better if farmers carry out harvesting and postharvest activities with separate clones.

Table 3. Financial feasibility of 3 local Robusta coffee clones.

| No. | Feasibility criteria | Separated clone | Mixed clone |
|-----|---------------------|-----------------|-------------|
| 1   | NPV (Rp.)           | 83,113,893.47   | 24,385,026.91 |
| 2   | IRR (%)             | 56.5            | 32.7        |
| 3   | Net B/C Ratio       | 4.21            | 1.86        |
| 4   | Payback Period (year)| 4.29            | 6.76        |
Figure 3. Cash flow projection for 15 years of 1 ha of 3 Robusta clones planted polyclonal (a) separated beans, and (b) mixed beans.

For separated clones, the NPV reached Rp. 83,113,893.47 so that it meets the criteria of being feasible to cultivate. The value of IRR is 56.5 percent, which means that the coffee plantation is feasible as this value is much greater than the loan interest rate on commercial bank loans in the range of 7-21 percent [33]. The IRR value is also much higher when compared to the People's Business Credit (KUR) interest rate which is only 6 percent. Another criterion is the net B/C ratio with the value of 4.21 which also means that the plantation is financially feasible. Meanwhile, the payback period is 4.29 years. For the mixed clones, even it has a lower price, coffee farming is still feasible. The value of NPV, IRR, Net B/C, and payback period are Rp. 24,385,026.91, 32.7 percent, 1.86, and 7.76 years respectively.

3.2.3. Sensitivity analysis for the environmental shocks

Coffee farming is very sensitive to climate variability, on the one hand, and the occurrence of climate variability is more often, on the other hand. Thus, it is important to assess the impact of climate variability on the financial feasibility of the three local clones. We applied three scenarios to examine these issues, (a) climate variability decreases the farm yield by 10%; (2) climate variability increases operational costs by 10 percent; and (3) the combination of scenarios 1 and 2. The financial feasibility of the three scenarios is presented in Table 4.

Table 4. Financial feasibility of 3 local Robusta coffee clones with 3 scenarios.

| No | Feasibility criteria | Scenario 1 | Scenario 2 | Scenario 3 |
|----|----------------------|------------|------------|------------|
|    |                      | Separated  | Mixed      | Separated  | Mixed      | Separated  | Mixed      |
| 1  | NPV (Rp.)            | 61,090,568.51 | 9,702,810.28 | 69,401,957.86 | 12,141,312.97 | 27,557,640.44 | -15,754,898.64 |
| 2  | IRR (%)              | 48.2       | 25.41      | 49.0%      | 26.11      | 33.0       | 10.37      |
| 3  | Net B/C Ratio        | 3.28       | 1.34       | 3.36       | 1.38       | 1.89       | 0.52       |
| 4  | Payback Period (year)| 4.86       | 9.72       | 4.80       | 9.38       | 6.19       | -          |

Based on the four feasibility criteria, Table 4 shows that coffee farming is still feasible for scenarios 1 and 2, both for separated and mixed clones. However, for the third scenario, coffee farming is only feasible for separated clones. To obtain a deeper understanding of to what extent the climate variability causing the reducing of farm yield and increasing operational costs, this study also evaluated switching values to scenarios 1 and 2. The switching values for the decreasing farm yield are 37.73 and 16.7 percent for separated and mixed clones, respectively. It means that coffee farming is still feasible if climate variability causes the decrease of farm yield maximum of 37.73 percent for the separated clones and a maximum of 16.7 percent for the mixed clones. For the second scenario, the switching values of separated and mixed clones are 60.5 and 19.95 percent, respectively. It indicates that the increasing operational costs to adapt to the climate variability can increase a maximum of 60.5 percent for the separated clones where the coffee farming stays financially feasible, while for the mixed clones, the maximum tolerable increasing costs are only 19.95 percent.
4. Conclusion
This study observed 3 local clones of Robusta coffee in South OKU Regency, South Sumatera Province. These clones are locally adapted to the agro-environmental and agro-climatic conditions which have high yields. The yield is even much higher than nationally released varieties that are planted in the same area. Before the three clones are officially released as local-adapted and high-yield varieties and developed widely, it needs to assess the financial feasibility of coffee farming. Our results show that based on feasibility criteria, i.e. NPV, IRR, Net B/C, and payback period, the plantation of the three clones is financially feasible and profitable. Also, these three clones are still feasible under the environmental shocks, based on the sensitivity analysis with three climate variability scenarios. Since the coffee farming with separated clones showed better feasibilities, this study suggests that the Kobura farming systems need to separate the clones in harvest and post-harvest handling. The separated clones method also has better resilience to environmental shocks.

References
[1] Schroth G, Laderach P, Cuero D S B, Neilson J and Bunn C 2015 Winner or loser of climate change? A modeling study of current and future climatic suitability of Arabica coffee in Indonesia Regional Environmental Change 15 1473-82
[2] Läderach P, Ramirez–Villegas J, Navarro-Racines C, Zelaya C, Martinez–Valle A and Jarvis A 2016 Climate change adaptation of coffee production in space and time Climatic Change 141 47-62
[3] Grimm N B, Chapin F S, Bierwagen B, Gonzalez P, Groffman P M, Luo Y Q, Melton F, Nadelhoffer K, Pairis A, Raymond P A, Schimel J and Williamson C E 2013 The impacts of climate change on ecosystem structure and function Front Ecol Environ 11 474-82
[4] Ramos M C and Martinez-Casasnovas J A 2009 Impacts of annual precipitation extremes on soil and nutrient losses in vineyards of NE Spain Hydrol Process 23 224-35
[5] St.Clair S B and Lynch J P 2010 The opening of Pandora’s Box: climate change impacts on soil fertility and crop nutrition in developing countries Plant and Soil 335 101-15
[6] Rosenzweig C, Iglesias A, Yang X B, Epstein P R and Chivian E 2001 Climate change and extreme weather events; Implications for food production, plant diseases, and pests Global Change and Human Health 2 90-104
[7] Nelson W A, Bjornstad O N and Yamanaka T 2013 Recurrent insect outbreaks caused by temperature-driven changes in system stability Science 341 796-9
[8] Delcour I, Spanoghe P and Uyttendaele M 2015 Literature review: Impact of climate change on pesticide use Food Research International 68 7-15
[9] Gomez-Ruiz E P and Lacher T E, Jr. 2019 Climate change, range shifts, and the disruption of a pollinator-plant complex Sci Rep 9 14048
[10] Tilman D, Cassman K G, Matson P A, Naylor R and Polasky S 2002 Agricultural sustainability and intensive production practices Nature 418 671-7
[11] Pham Y, Reardon-Smith K, Mushtaq S and Cockfield G 2019 The impact of climate change and variability on coffee production: a systematic review Climatic Change 156 609-30
[12] Venancio L P, Filgueiras R, Mantovani E C, Do Amaral C H, Da Cunha F F, Dos Santos Silva F C, Althoff D, Dos Santos R A and Cavatte P C 2020 Impact of drought associated with high temperatures on Coffea canephora plantations: a case study in Espírito Santo State, Brazil Scientific Reports 10
[13] Laderach P, Lundy M, Jarvis A, Ramirez J, Portilla E P, Schepp K and Eitzinger A 2011 Climate Change Management: Springer Berlin Heidelberg) pp 703-23
[14] Ovalle-Rivera O, Läderach P, Bunn C, Obersteiner M and Schroth G 2015 Projected Shifts in Coffea arabica Suitability among Major Global Producing Regions Due to Climate Change PLOS ONE 10 e0124155
[15] Chemura A, Mudere B T, Yaweh A W and Gornott C 2021 Climate change and specialty coffee potential in Ethiopia Scientific Reports 11
[16] Mwongera C, Shikuku K M, Twyman J, Laderach P, Ampaire E, Van Asten P, Twomlow S and Winowiecki L A 2017 Climate smart agriculture rapid appraisal (CSA-RA): A tool for prioritizing context-specific climate smart agriculture technologies Agr Syst 151 192-203

[17] Mutenje M J, Farnworth C R, Stirling C, Thierfelder C, Mupangwa W and Nyagumbo I 2019 A cost-benefit analysis of climate-smart agriculture options in Southern Africa: Balancing gender and technology Ecol Econ 163 126-37

[18] Moniruzzaman S 2015 Crop choice as climate change adaptation: Evidence from Bangladesh Ecol Econ 118 90-8

[19] Lybbert T J and Sumner D A 2012 Agricultural technologies for climate change in developing countries: Policy options for innovation and technology diffusion Food Policy 37 114-23

[20] Holden S T and Quiggin J 2016 Climate risk and state-contingent technology adoption: shocks, drought tolerance and preferences Eur Rev Agric Econ

[21] Etwire P M, Fielding D and Kahui V 2019 Climate Change, Crop Selection and Agricultural Revenue in Ghana: A Structural Ricardian Analysis Journal of Agricultural Economics 70 488-506

[22] Hasibuan A M, Gregg D and Stringer R 2021 The role of certification, risk and time preferences in promoting adoption of climate-resilient citrus varieties in Indonesia Climatic Change 164 37

[23] Doss C R and Morris M L 2001 How does gender affect the adoption of agricultural innovations? Agricultural Economics 25 27-39

[24] Ellis R H 1992 Seed and seedling vigor in relation to crop growth and yield Plant Growth Regulation 11 249-55

[25] Aguilera E, Diaz-Gaona C, Garcia-Laureano R, Reyes-Palomo C, Guzmán G I, Ortolani L, Sánchez-Rodriguez M and Rodriguez-Estévez V 2020 Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review Agr Syst 181 102809

[26] Zabel F, Müller C, Elliott J, Minoli S, Jägermeyr J, Schneider J M, Franke J A, Moyer E, Dury M, Francois L, Folberth C, Liu W, Pugh T A M, Olin S, Rabin S S, Mauser W, Hank T, Ruane A C and Asseng S 2021 Large potential for crop production adaptation depends on available future varieties Global Change Biology 27 3870-82

[27] Migliorini P, Gkisakis V, Gonzalvez V, Raigón M and Bárberi P 2018 Agroecology in Mediterranean Europe: Genesis, State and Perspectives Sustainability 10 2724

[28] Ditjenbun 2021 Statistical of national leading estate crops commodity 2019-2021 (Jakarta: Secretariate of Directorate General of Estate Crops, Ministry of Agriculture)

[29] Vaast P, Harmand J-M, Rapidel B, Jagoret P and Deheuvels O 2016 Climate Change and Agriculture Worldwide, ed E Torquebiau (Dordrecht: Springer Netherlands) pp 209-24

[30] Souza H N d, de Goede R G M, Brussaard L, Cardoso I M, Duarte E M G, Fernandes R B A, Gomes L C and Pulleman M M 2012 Protective shade, tree diversity and soil properties in coffee agroforestry systems in the Atlantic Rainforest biome Agriculture, Ecosystems & Environment 146 179-96

[31] World Bank 2020 World Bank Commodity Price Data (The Pink Sheet). the World Bank

[32] Kemendag 2020 Harga Bursa (Forward-Futures-Spot): Kopi Robusta. (Jakarta: Badan Pengawas Perdagangan Berjangka Komoditi, Kementerian Perdagangan)

[33] OJK 2020 Suku Bunga Dasar Kredit (SBDK): Data Posisi Akhir Juni 2020. Otoritas Jasa Keuangan, Republik Indonesia)