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Coffee bean physical quality: The effect of climate change adaptation behavior of shifting up cultivation area to a higher elevation

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Abstract. *Bakri S, Setiawan A, Nurhaida I. 2018. Coffee bean physical quality: The effect of climate change adaptation behavior of shifting up cultivation area to a higher elevation. Biodiversitas 19: 413-420.* The coffee cultivation shifting into a higher elevation can be considered as a farmer's behavioral adaptation to the climate change to find an optimum temperature and more fertile soil for the coffee growth. The behavior is rampant for Robusta coffee (*Coffea canephora*) planters in Lampung Province, the main contributor area that places Indonesia as the second largest coffee bean exporting country for more than two decades. The behavior certainly causes environmental deterioration, while the positive impact has not been well-measured, even for physical bean performance that determine its export competitiveness. This study aimed to determine the effect of the behavior on two coffee bean physical indices, the 1000-dried fruit weight or the index of [W_1000], and the percentage of floated fruit upon water soaking or the index of [FLOAT]. Ordinary Least Square Model was applied at a significance level of 10% with the two indices as the response variables. The predictor variable is the elevation area, accompanied by slope steepness and area position in relation to its exposure against solar radiation. The field survey lasted from June to August 2017. Riped coffee fruit samples were collected from 32 sites, ranging from 300 to 1,170 m asl. The results suggested that the behavior would improve the [W_1000] index but worsening the other.

Keywords: climate change adaptation, coffee bean quality, shifting up to a higher elevation

INTRODUCTION

Climate change has affected almost every aspect of community livelihood, including the coffee farmers' behavior in shifting their cultivation into the upper stream region of the catchment area of Batutegi Dam in Lampung Province, in the Southern tip of Sumatera, Indonesia. On the one hand, the behavior causes deforestation, escalation of land degradation such as rising soil erosion rate and declining water infiltration, while simultaneously increasing drought occurrence in the dry season and flood frequencies in the wet season, destroying germplasm, and worsening water body deterioration. Nowadays, the rate of forest destruction in Lampung Province was so high, leading to more than 60% of the forest not optimally functioned (Wulandari et al. 2016). Meanwhile, Killeen and Harper (2016) predicted that Indonesia as the center of Robusta production would undergo the largest deforestation driven by the shifting of coffee cultivation area to higher elevation as the consequence of farmer's behavior in seeking more suitable temperature and fertile soil to grow coffee crops. On the other hand, the behavior could be considered as local wisdom to adapt to climate change, that is controlled by the steadily rising air temperature as reported by Kpadonou et al. (2012). Until now, Lampung Province is still the major contributor to Indonesia's Robusta coffee export. The agroforestry system is the most prominent culture technique and locally adaptive in coffee crop cultivation (Nurhaida et al. 2007 and 2008). An agroforestry system using shading trees with multi-strata canopy has been known as one of the local wisdom in the Robusta coffee crop cultivation system in Lampung (Nurhaida et al. 2008). Agroforestry is a land use management system which combines the production of agricultural crops and woody perennials for a double purpose of production and conservation (Baliton et al. 2017).

According to Killeen and Harper (2016) both the productivity and quality of Arabica and Robusta coffee largely depend on the climate suitability, especially the precipitation and air temperature. In the tropical rainforest in Lampung, the precipitation but not the air temperature is suitable for growing coffee trees. The air temperature could be tough to manipulate to improve its suitability for growing coffee crop. There are merely two opportunities to achieve more suitable temperature for coffee crop cultivation. The first choice is to manage the shading trees (see Jaramillo et al. 2011) and the second is to move the cultivation into the upper region of the landscape. The first choice is typically applied by farmers in coffee crop cultivation using an agroforestry system by planting shading trees with multi-strata canopy architecture (Nurhaida et al. 2008). Bongase (2017) suggested that growing heat-and drought-resistant varieties of coffee can be done to deal with the high local air temperature at the cropping area, complementing the first choice. Jaramillo et al. (2013) also reported that coffee plants grown along with shading plants are far more resilient and productive, as well as significantly less threatened by its insect pest than coffee grown in monoculture. Unfortunately, this choice usually is in trading off with the threshold of sunlight intensity to meet the coffee crop photosynthesis requirement. The second option, therefore, becomes the only opportunity left in the effort to compensate the air temperature of cropping areas. This second option was in line with the suggestion of some experts such as Jaramillo et al. (2011), and Davis et al. (2012) that coffee crop cultivation area should be moved up to a higher elevation to adapt to the rising temperature caused by the global warming phenomenon.

Having more suitable temperature at the higher elevation, the farmers would have to face the challenges of steep sloping areas, and the lack of area exposed efficiently to solar radiation due to the shifting up onto the upper of protected forest. In cultivating coffee in a steep slope, farmers manage shading plants and litter basalt of the cropping area to retain the soil fertility lost as a result of accelerated soil erosion. Ferreira et al. (2016) stated that besides the coffee cultivation and shading plants, the environmental variables especially the elevation of cultivation area and its exposure to solar radiation have major effect on the temperature for growing and producing coffee fruit. Finally, these variables would affect both coffee beans and beverages quality through a complex formation of photochemical compounds including protein, fat, sucrose, caffeine, chlorogenic acid, cafestol, etc. (Bae et al. 2014, and Patay, et al. 2016). Exposure of coffee cultivation area to solar radiation which is determined by the angle of the solar beam and the length of day affects the quality of the coffee bean and beverages (Righi et al. 2008). The length of day (photoperiodism) directly affect plant photosynthesis while the incidence angle of solar beam radiation determines the amount of photon readily absorbed by plant chlorophylls, which eventually also affect the photosynthesis rate and coffee bean quality. The air temperature controlled by the cascading density of atmospheric gasses is inversely proportional to the elevation, i.e., the higher the elevation, the lighter the gas density and the lower the air temperature (González and Garreaud 2017). The decreasing air temperature, in turn, would affect the efficiency of cell metabolism of a coffee plant.

The background mentioned earlier might justify the reason why the farmers encroach into the protected forest to seek a suitable temperature or a more fertile land for growing coffee. However, the insight on the farmers' experience on the effect of the shifting of the coffee cultivation to the protected forest that has a higher elevation, different slope steepness, and different sunlight exposure is still elusive. We, therefore, are interested in conducting the study to pursue the knowledge.

MATERIALS AND METHODS

Study area

This study was conducted on the catchment area of Batutegi Dam, Lampung, the Southern tip of Sumatera, Indonesia from June to August 2017 by using survey and modeling approach. More than 60% of the land is used as coffee agroforestry cultivation area. The land tenure of the study area is under the authority of the Management Unit of Protected Forest (KPHL) of Batutegi, Service Office of Forestry Affair, the Local Government of Lampung Province, Indonesia. Analyses of coffee bean quality indices were conducted at the Laboratory of Agronomy, University of Lampung, Indonesia.

Procedure

Samples of the ripe coffee cherry fruits were collected from 32 sites of people coffee agroforestry in an elevation range of 300 to 1,170 m asl. The research location is pointed out in Figure 1. We started from the lowest elevation and went up to the summit. We made a plot sites observation for every 25 m to 30 m elevation range. We chose 3-5 coffee crops and took 2-3 kg ripe cherry fruits in each plot. We also measure the site plot elevation, slope steepness, direction of cropping area plot, air temperature, and air humidity by using an altimeter, clinometer, compass, thermometer, and hygrometer, respectively.

We proposed two indicators to express the physical quality indices of coffee bean. The first one was the weight of 1.000 dried fruit, from now on referred to as the index of [W_1000], and the second one was the percentage of coffee fruit that floated in the water, hereinafter referred to as the index of [FLOAT]. The higher the index of [W_1000], the better the coffee quality. Conversely, the higher the index of [FLOAT], the worse the bean quality**.** To prepare the index of [W_1000] variable, we dried 1 kg coffee fruit sample in an oven at 70ºC for 6 days, then continued at 105ºC for 2 days more, and finally measured the weight of 1000 beans from that dried sample. Whereas, the index of [FLOAT] data was obtained by soaking 1 kg of coffee fruit in water, separating the floated fruits from the sunken ones by using nest, then weighing each the floated fruits and the submerged fruits, and expressing the result in percentage. We assumed that there was no significant variation of fruit density among the floated coffee fruits in each sample.

The ordinary least square regression (OLS) model at significance level 10% was applied on to predict bean qualities, i.e., the quality index of [W_1000] and [FLOAT] which we determined as dependent variables. Whereas, the independent variables comprised the elevation, slope steepness, and position of each plot areas concerning its exposure to the sunbeam. The elevation [ELV] was expressed in a unit of 100 m. The slope steepness [STEEP] was expressed in %. Meanwhile, the area location was expressed in 3 dummy variables with the eastward direction used as the reference. The plot facing southward, northward, and westward were referred to as [D_SHT], [D_NRT], and [D_WST], respectively, and each will be scored 1 or otherwise 0. Table 1 shows the dependent and independent variables, and their units, scores, and method of acquisition.

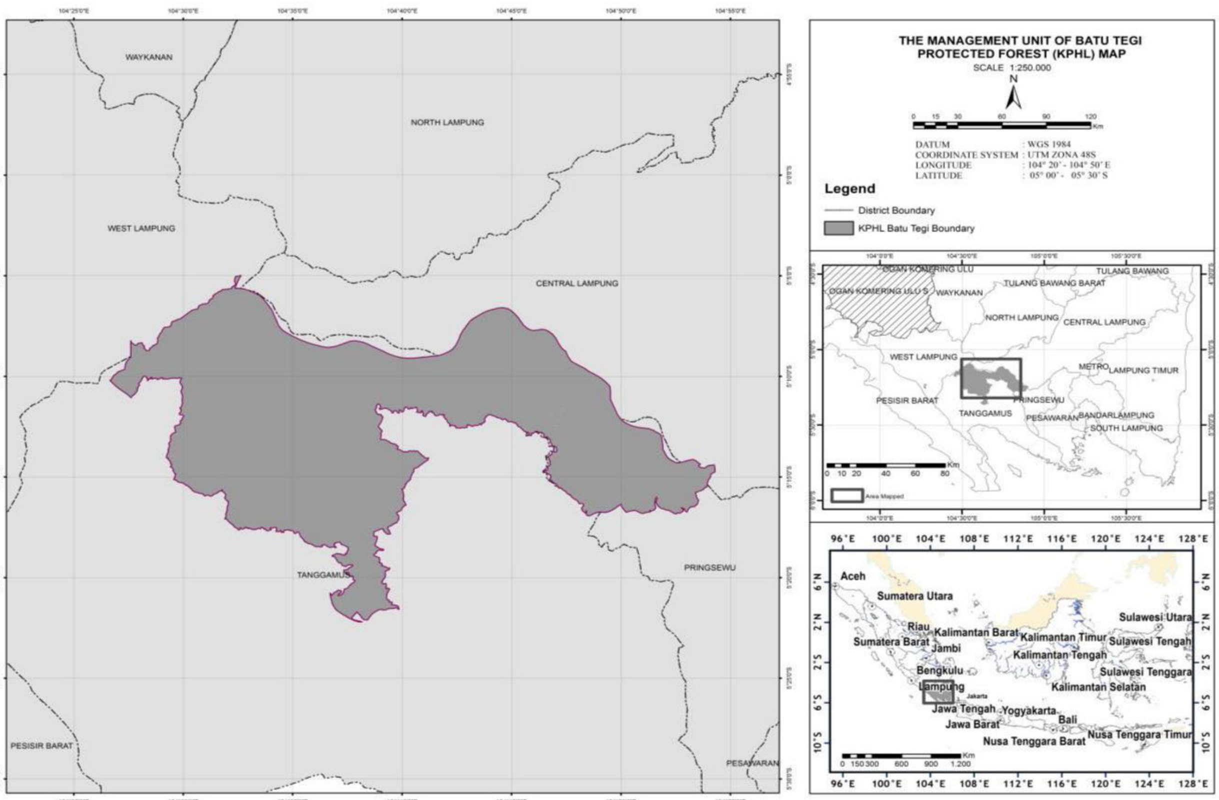

Figure 1. Study area maps in Batutegi, Lampung, Indonesia (reproduced from KPHL Batutegi 2014)

Table 1. The variables, symbol in model, unit, scale of measurement, and the acquisition methods for modeling preparation

Variable	Symbol	Unit	Measurement scale	Data acquisition and the variables preparation in modeling
Dependent variables				
Coffee bean quality index 1	[W_1000]	gram	Ratio	Field sampling at each plot site from 3-5 tree coffee crops, taking 1kg ripe coffee fruit for around 1 kg, dried in chamber of 70ºC for 6 days, continued for 2 days more at 105ºC, then weighted for 1.000 beans.
Coffee bean quality index 2	[FLOAT]	%	ratio	About 1 kg coffee bean was soaked in water, netted the floated beans, weighed, and then calculated it in %. (We assumed that there was no variation in bulk density among the floated coffee fruits).
Independent variables				
Elevation	[ELV]	x100 m asl.	Ratio	Recording each plot site elevation by an altimeter in the field survey then divided by 100 m.
Slope steepness	[STEEP]	%	Ratio	Measuring the slope steepness for each plot by clinometer in the field survey
Area exposition against solar beam radiation*:				Observing the dominant direction of each plot area site then:
Northward	[D_NRT]	-	Dummy	- scored *1* if in the northward direction, by *0* if others
Southward	[D_SHT]	-	Dummy	- scored *1* if in the southward direction, by *0* if others
Westward	[D_WST]	-	Dummy	- scored *1* if in the westward direction, by *0* if others

Note: * Eastward direction treated as the reference

Our air temperature data were merely a temporary because it was only recorded at one-time point during the survey. This data could not represent the actual condition affecting coffee crop growth and fruiting for a long period. Therefore, we prefer using elevation [ELV] to air temperature [TEMP] data as the independent variable to predict the quality of coffee bean. Based on this argument, we then hold an assumption that there was a differential fall or rise in air temperature in accordance with the land elevation.

To test the validity of the above-mentioned assumption, we employed an OLS regression model with air temperature [TEMP] as a dependent variable, and elevation [ELV] and air humidity [HUMD] as independent variables. The regression model used a significance level of 1 to 10%. This verification step was important to show that farmer's behavior in shifting up their coffee cultivation area to the upper region could be regarded as an adaptation behavior in response to climate change to find a more suitable air temperature and more fertile soil for coffee growth

RESULTS AND DISCUSSION

The generic description of study area

The study area lied in the southern hemisphere with specific geographic coordinate at 05º05'50''S-05º16'33''S latitude and 104º30'34" E-104º49'14" E longitude. The site has an area of around 58,162 ha and is under the supervision of Protected Forest Management Unit (KPHL) Batutegi, The Service Office of Forestry Affairs, Lampung Province. Almost 70% of the acreage is cultivated as coffee agroforestry by farmers under the concession of Social Forestry Agreement (*HKm: Hutan Kemsyarakatan*) for 35 years with the landholding for each farmer around 1-5 ha. Under this concession, the farmers are obligated to apply multi-strata cropping technique (agroforestry system). Furthermore, the concession allows them to harvest the non-timber products such as rubber sap, rattan, honey bee, coffee bean, etc.; but prohibits them from taking the timber. The study location is also the catchment area of a dam constructed in 1995 for water reservoir (around 9 million m^3 annually) and hydropower plant (around 125.2 GWh annually) (http://pustaka.pu.go.id). According to the Document of Land Resource Evaluation Planning Project I (CSR, 1989), the topography of the area is hilly to mountainous. The geologic parent material of clastic sedimentary rocks beneath the tropical rainforest had undergone advanced weathering process, forming various silty loam, loam, and clayey soils with the common characteristic of low pH and poor fertility.

The descriptive statistic of the field survey observation on variables including air temperature, air humidity, elevation, bean qualities indices, area elevation, slope area steepness and average monthly rainfall is depicted in Table 2. Whereas the number of the plot area facing south, west, north, and east directions were 4, 8, 5, and 17 respectively.

As depicted in Table 2, both the physical bean indices were varied enough as expressed by their wide range of standard error (*SE*). This variation is seemingly controlled by the variation of air temperature as a result of different cultivation altitudes. The *SE* of air temperature across the landscape of the study area was 1.9ºC that equal to its variance $(1.9)^2$ =3.6ºC. To assess if this variance of the air temperature could be considered as the same effect of the global warming phenomenon, we refer the work reported by Nicolaj et al. (2015) who showed that the air temperature in the Arctic zone in the Holocene geological era was 2-4ºC warmer than that of the present era and had significantly affected the glacier melting which further made the sea level 0.16 m higher. This report suggested that the 2ºC increase in air temperature is indicative enough of global warming. We found that the range of air temperature recorded in the plot sites ranged from 22 to 32ºC with SE=1.9ºC or approximately 2.0ºC. Using Nicolaj et al. (2015) standard, we considered the temperature difference experienced in the highest and lowest sites of the study location is similar to the effect of the global warming. Therefore, the shifting of the coffee cultivation to the higher elevation could be regarded as an adaptive behavior of farmers in response to the rising air temperature.

We further need to know the average value of the [TEM] when farmers shifting up their coffee cultivation area of every 100 m upper. Until recently, almost all scholars hold an assumption known as the Braak's Law (Arsyad, 2000) that the temperature lapse rate is 0.56ºC every 100 m rise in the elevation of atmosphere and vice versa. Interestingly, Bandyopadhyay et al. (2014) reported that the lapse rate at the piedmont zone of Himalaya, India was 0.32-0.54ºC. Therefore, we employed the OLS regression model to test the assumption by analyzing the relationship between air temperature [TEM] as the function of the elevation [ELV] accompanied by the air humidity [HUMD]. The result is provided in Table 3 and Table 4.

Table 2. Descriptive statistic of variables observed in the study area

Variable	Unit	Minimum	Mean	Maximum	SE
Bean quality index of [W_1000]	g/1000 dried bean	1,001.4	1,074.6	1,180.3	70.6
Bean quality index of [FLOAT]	% in water floating fruit test	0.03	0.09	0.27	0.07
Air temperature [TEMP]	ºC	22.0	26.1	31.8	1.9
Air humidity [HUMD]	%	50.0	71.4	84.0	7.3
Area elevation [ELV]	m asl	349	788	1,173	237
Slope steepness [STEEP]	%	2.7	11.5	23.8	5.5
Monthly rainfall*# (in the month of)	mm	107 (August)	244 (-)	374 (May)	124 (-)

Note: * Climate Station of Pesawaran District, Lampung Province (BMKG 2017); - =not relevant, # average data 2012-2016

Table 3. Analysis of variance of the air temperature as function of the elevation (per 100 m upward) and their air humidity recorded during field survey

Source	DF	SS	MS	F	P
Regression	2	29.080	14.540	4.90	0.015**
Residual error	29	86.006	2.966		
Total	31	115.086			

Note: DF=degree of freedom, SS=sum square, MS=mean square, F= the Fisher statistic test, P=the probabilty to fail. *** p<0.01; **p<0.05; *p<0.10

Table 4. The *t-test* of the air temperature [TEM] (ºC) as function of the elevation [ELV] for each a-100 m move upward and their air humidity [HUMD] recorded during the field survey

Predictor	Coef	SE Coef	T	P
Constant	35.888	3.455	10.39	0.00
Elevation [ELV]	-0.3321	0.1328	-2.50	0.018**
Air humidity [HUMD]	-0.09986	0.04336	-2.30	0.029**

Note: *** p<0.01; **p<0.05; *p<0.10

Table 5. Analysis of variance of the impact of elevation, slop steepness and the plot area position on the floated coffee fruits

Source	DF	SS	MS	F	P
Regression	5	10708	21416	7.61	0.000***
Residual error	24	67533	2814		
Total	29	174612			

Note: Note: DF=degree of freedom, SS=sum square, MS=mean square, F= the Fisher statistic test, P=the probabilty to fail. *** p<0.01; **p<0.05; *p<0.10

Table 3 shows the variation of [TEM] obtained from this study was well explained by the variation of the [ELV] accompanied by the [HUMD]. As depicted in Table 4, for every 100 m rise in elevation, the air temperature will decrease around 0.332±0.1328ºC and vice versa, regardless of the air humidity variation. This result showed us that the temperature drops 0.332ºC for every 100 m rise in the people's coffee agroforestry areas. This result is lower than that of the classical Braak's Law which postulates that for every 100 m rise in the atmosphere, there will be a decrease in air temperature by 0.56ºC (see Arsyad 2000). This finding is in between the values range reported by other researchers, for example, Bandyopadhyay et al. (2014) reported that the lapse rate in the piedmont zone of Himalaya, India was 0.32-0.54ºC, and so did Tang and Fang (2006) that report that the lapse rate in Mountain of Taibai-China was around 0.34-0.50 for each 100 m rise. But this finding was different from González and Garreaud (2017) who reported that at coastal mountain in Chile wherein the temperature lapse rate was at 0.65-0.98ºC for every 100 m rise up.

Based on the statistical analysis depicted above, the regression model could be expressed in Eq.[1] as follows:

$$[TEM] = 35.9-0.332\ [ELV]-0.0999\ [HUMD] \quad \text{R-Sq (adj)} = 20.1\% \qquad \text{Eq. [1]}$$

The impact of the shifting up the coffee cultivation elevation on the coffee bean qualities

As it has been mentioned above, we use two terms to express the coffee bean quality indices, the index of dry weight [W_1000] and the percentage of floated coffee fruit [FLOAT]. We need to discuss the two separately in the following sections.

The dried coffee bean quality index of weight

The impacts of elevation, slope steepness, and cultivation area position (with regards to its exposure to the sun) on the ripe coffee fruit are simultaneously depicted in Table 5. By examining the *R_Sq (adj)*, the variance of the three independent variables could only explain 53.3% of the variance of the coffee fruit quality, in particular the [W_1000], whereas the remaining 46.7% must be explained by other variables that we were not counted on in this study, presumably soil fertility, shade tree variety, tree canopy density, etc. The three independent variables, nevertheless, were robust enough to explain the variance of [W_1000] as indicated by the P-value=0.000 which approximately could be written as P=0,0004. In other words, based on the three data, i.e., data of elevation, slope steepness, and cultivation area position, the model could predict the quality index of [W_1000] in very high precision. The P=0.0004 meant that if we use the three independent variables, for every 10,000 times predicting the [W_1000], there would be only 4 time misses.

By using *t-test* analysis, we could further examine the effect of each of the independent variables on the dried bean quality index [W_1000]. As depicted in Table 6, the elevation [ELV] variable significantly affect the dried bean quality (P=0.000). The optimum parameter of this variable was 24.187. If the two other variables, the slope steepness and the cultivation area position were remained constant, the average quality index of [W_1000] would increase by 24.187 gram for every 100 m shift upward of the cultivation area and vice versa. It also could be considered that the farmer's behavior in moving up their area of coffee cultivation is a form of adaptation to achieve a more suitable temperature for coffee growth; thus, an attempt to obtain better coffee bean quality. Additionally, decreasing temperature by 0.332 (*SE*=0.1328)ºC for every 100 m shift upward (Table 4) was a significant effort to adapt to global warming as indicated by the improvement of the coffee bean quality index of [W_1000] of around 24.187g with *SE*=5.228 (see Tabel 6, row 2). This finding supports the idea of replacing Arabica coffee with Robusta varieties because of the vulnerability of Arabica coffee to global warming (see Iscaro, 2014).

In contrast to the elevation, the slope steepness variable [STEEP] resulted in the optimum parameter of negative 0.170. This result indicates that if the two other independent variables were constant, there would be a decrease of 0.17g in the dried bean weight [W_1000] for each 1% change in the slope steepness and vice versa. The decrease of 0.17g is a merely small decrease in dried fruit quality (compared to its SE Coefficient), hence did not give a significant effect to the [W_1000] as indicated by P=0.929. So we could equate the value of 0.17g was equal to 0.00 g reduction of the [W_1000]. This result further suggests that the slope steepness in the whole study area was similar enough in term of its soil erosion potential, and therefore, do not have a significantly different in affecting soil fertility. Another possibility is that the soil surface of the ground in the whole study areas was covered by good litter basalt that protected the soil fertility well enough, but this assertion needs to be studied.

Cultivation areas facing northward [D_NRT] yield the worst bean quality index [W_1000] among all area. A similar finding was reported by Ferreira et al. (2016) that the quality of coffees which are cultivated on the areas facing back the solar beam radiation was normally lower than those on the areas facing directly toward the sun beam radiation. Indicating the impact of the environment on the characteristics of the coffee beans and the quality of the coffee beverage. It was closely related to the characteristics of the grains. For our study, the northward-facing cultivation areas [D_NRT] produced a significantly inferior bean quality (P=0.002) with an average weight 95.87g lower than that of the eastward-facing areas. The inferior quality is presumably due to the less solar radiation received by the areas, affecting coffee plant's photosynthesis during the period of bean filling, which in the region normally take place 6 months before. As shown in Figure 1, the whole study area lied in the Southern Hemisphere at $05^0$05'50'' S-$05^0$16'33'' S latitude. This period of bean filling and fruit ripening during the time of this present study coincided with the intense solar beam exposure toward the Southern Hemisphere. The solar beam exposure is an environmental factor that affects bean filling and maturing alongside the genotype of the coffee plant (Cheng et al. 2016). The northward-facing areas, have their backs toward the solar beam radiation, and therefore, experienced suboptimal illumination for photosynthesis required especially during the period of coffee bean filling and maturing.

Based on the statistical analysis above (Table 6), we formulate the model of regression equation Eq. [2] as follows:

$$[W\_1000]=280+24.2[ELV]-0.17[STEEP]+28.3[D\_SHT]+9.3[D\_WST]-95.9[D\_NRT] \quad \text{R-Sq (adj)} = 53.3\% \qquad \text{Eq.[2]}$$

The percentage of floated coffee fruit in water

Similar to the quality index of [W_1000], the three independent variables applied for predicting the percentage of floated ripe cherry fruit in water or the index of [FLOAT] have been robust predictors as well, as indicated by P=0.002 from the analysis of variance displayed in Table 7. This result suggests that if we predict the quality index of [FLOAT] 1000 times based on the three independent variables, it will fail 2 times. However, it is important to note that this result was obtained after we omitted 6 outliers data from the regression analysis.

Table 6. The *t-test* to examine the magnitude effect of variables of elevation, slope steepness and cultivation area exposition on the dried weight of coffee bean [W_1000]

Predictor	**Coef**	**SE Coef**	**T**	**P**
Constant□	279.81	48.49	5.77	0.000***
Elevation [ELV]	24.187	5.228	4.63	0.000***
Slope steepness [STEEP]	-0.170	1.879	-0.09	0.929
Plot area expotision (*Eastward=0*):				
Southward [D_SHT]	28.26	35.79	0.79	0.437
Westward [D_WST]	9.30	25.79	0.36	0.722
Northward [D_NRT]	-95.87	28.02	-3.42	0.002***

Note: ***p<0.01; **p<0.05; *p<0.10

Table 7. Analysis of variance of quality index of a-1000 gram dried beans of the [W-1000]

Source	**DF**	**SS**	**MS**	**F**	**P**
Regression	5	772.25	154.45	5.56	0.002***
Residual error	21	573.16	27.29		
Total	26	1,345.41			

Note: DF=degree of freedom, SS=sum square, MS=mean square, F= the Fisher statistic test, P=the probabilty to fail. ***p<0.01; **p<0.05; *p<0.10

In contrast to the index of quality [W_1000], the shifting of cultivation area to a higher elevation negatively affect the quality index [FLOAT]. As depicted in Table 8, there was a rise in the index of [FLOAT] of around 1.3454% for each 100-meter rise toward higher elevation [ELV] and vice versa. This increase is statistically significant as indicated by P=0.023. This result is presumably due to the activity of rampant cherry coffee borer insects following the shifting toward higher elevation. The higher the elevation, the more humid the air which further accompanied by the decrease in air temperature. This argument is supported by Eq. [1] expressed above. Jaramillo et al. (2009) showed that *Hypothenemus hampei,* an insect borer of the family *Scolytidae*, live optimally at a temperature between 15 to 35ºC. The female insect activity in boring coffee fruit drop drastically when the air temperature reaches 35ºC, and beyond 35ºC the insect will fail to spawn, suppressing their propagation.

As depicted in Table 3, the air temperature recorded during the study was between 22-32ºC. In line with our discussion, Hindorf and Omondi (2016) who researched in Kenya also suggested that the higher the elevation of a cultivation area, the higher the abundance of the pest attacking coffee fruit. This record seems concurrent and supports the above-mentioned argument. Moreover, our climate data in Table 2 (row 8) indicated that in May that year, the month before we conducted the field survey, the study area experienced the wet season. In relation to this condition, Hindorf and Omodi (2016) have also reported that the activity of the coffee borer was rampant during the wet season that normally occurs between January to March in Kenya.

Table 8. The *t-test* to examine the independent variables that affect the percentage of the floated ripe coffee fruit in soaked water test as index of [FLOAT]

Predictor	Coef	SE Coef	T	P
Cosntant	-1.3930	4.8240	-0.29	0.776
Elevation [ELV]	1.3454	0.5497	2.45	0.023**
Slope Steepness [STEEP]	-0.0880	0.1885	0.47	0.645
Plot Area Expotision (*Eastward=0*):				
Southward [D_SHT]	-0.2810	3.5300	-0.08	0.937
Westward [D_WST]	7.3920	2.7380	2.70	0.013**
Northward [D_NRT]	-8.021	35450	1.55	0.137

Note: ***p<0.01;**p<0.05; *p<0.10

Jaramillo et al. (2011) estimated that climate change would worsen the pest prevalence including that of the berry borer, contributing to the decrease of coffee fruit and bean quality. According to Patay et al. (2016), in warm and humid climate, coffee plants are susceptible to various fungal infections, which can cause a devastated large-scale infection in the large area. The most common fungal disease of coffee species is caused by *Hemileia vastatrix* Berk. & Broome, a Basidiomycota, which causes decoloration on the lower surface of the leaves. In addition, Agegnehu et al. (2015) recorded that the variation of precipitation and air temperature are the most conducive situation for coffee pest disease. Major diseases occurring because of the variation of the two climate variables will increase pest and disease prevalence, expanding the altitudinal range in which the fungal coffee rust disease and coffee berry borer insect can survive (Laderach et al. 2010). For example, the rising temperatures will increase the infestation of coffee berry borer *Hypothenemus hampeii*, particularly in areas where coffee crops were grown unshaded, and continuous cropping practiced throughout the year.

Even though the slope steepness [STEEP] in the study area was relatively heterogeneous, ranging from 2.7% to 23.8% with *SE* =5.5% (Tabel 1), it did not significantly impact the index of [FLOAT]. This result is not entirely understood yet, but it is presumably due to the presence of litter basalts applied in the study areas that protect the land from erosion, thereby maintaining the soil fertility. This favorable condition allows efficient nutrient uptake by coffee plants and renders the crops endure against the pest. Nevertheless, further studies on the effect of slope steepness on soil fertility, crop's endurance to the pest, and coffee fruit quality are necessary.

In term of the impact of the area position with regards to its solar exposure, only the westward-facing cultivation area [D_WST] exhibited a significant difference in the index of [FLOAT] compared with the area facing eastward as indicated by P=0.013. Whereas both the southward- [D_SHT] and the northward-facing [D_NRT] areas did not affect the [FLOAT] in comparison to the eastward-facing ones as indicated by their P=0.937 and P=0.137 respectively. Based on the P value, the parameter or the coefficients of the [D_SHT] and [D_NRT], i.e., -0.2810 and -8.021, can be statistically equated to 0 meaning that both directions give null addition or subtraction to their reference value that is the [FLOAT] of eastward-facing area. In other words, there is no significant difference in the percentage floated coffee fruits of both area direction compared to the east direction. The coefficient of the [D_WST] of +7.392 cannot be statistically equated to 0, suggesting the addition the floated coffee fruits of around 7.392% could not be ignored but robustly different from the eastward-facing direction. This finding also means that the quality index [FLOAT] of the [D_WST] area is the lowest among all the area directions Whereas the [FLOAT] index of the other three area directions area do not statistically differ from that of the eastward-facing area.

The regression model of the index of [FLOAT] as the function of the elevation, slope steepness, and the area position in relation to its exposure to solar radiation is expressed in the following Eq [3]:

$$[FLOAT] =-1.393 + 1.3454\ [ELV] + 0.088\ [STEEP]- 0.47\ [D\_SHT] + 7.392\ [D\_WST]-4.427\ [D\_NRT]$$
$$R\text{-}Sq\ (adj) = 47.3\%$$

Eq. [3]

To discuss the effect of cultivation area direction in relation to the sunbeam exposure on two indices, we compare Table 6 and Table 8. The two tables are very convincing in showing that the eastward direction gives the best effect on both [W_1000] and [FLOAT] indices. The greater the [W_1000], the better the coffee bean quality and the higher the [FLOAT], the worse the fruit quality. Based on the index of [W_1000], [D_NRT] yield the worst bean quality (Table 6). Interestingly, based on the index of [FLOAT], Meanwhile, [D_WST] yield the worst coffee fruit (Table 8). These results suggest that there is no parallel character of either of these indicators. It further suggests that there is an antagonistic relationship between these two indices but not directly related. Therefore, these two indices cannot be used to evaluate the negative effects of the direction of cultivation but can be used to assess the positive effects.

Our research result can at least be utilized by extension planners to control the coffee farmers' behavior in expanding to a protected forest area. Equations 2 and 3, for example, can be used to calculate the optimal quality of coffee beans when farmers expand into areas with higher elevations and different position with regards to the solar beam exposure at once. This practical knowledge needs to be introduced to the farmers in some extension programs. For the sake of communication effectiveness in the extension programs, the knowledge should be presented in the form of special message to break through the literacy barrier of the coffee farmers in Lampung that are commonly very low, i.e., of around 27-88 words per minute (Nurhaida et al. 2001, 2007, 2011). So it is quite rational to expect the knowledgeable farmers to act rationally in making decisions including in adaptation behavior of shifting up their coffee cultivation area to a higher elevation as the response to the climate change.

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REFERENCES

Agegnehu E, Thakur A, Mulualem T. 2015. Potential impact of climate change on dynamics of coffee berry borer (*Hypothenemus hampi* Ferrari) in Ethiopia. Open Access Lib J 2 (01): 1-11. Article ID: 68012, 11 pages, DOI: 10.4236/oalib.1101127.

Arsyad, S. 2000. Konservasi Tanah dan Air. 2nd ed. IPB Press, Bogor. [Indonesian]

Bae JH, Park JH, Im SS, Song DK. 2014. Coffee and helath. Integrat Med Res 3: 189-191.

Baliton RS, Wulandari C, Landicho L, Cabahug RED, Paelmo RF, Comia RA Visco RG , Budiono P, Herwanti S, Rusita, Castillo AKSA. 2017. Ecological service and agroforestry landscape in selected watershed in Philippines and Indonesia. Biotropika 24 (1): 71-84.

Bandyopadhyay A, Bhadra A, Maa M, Shelina RK. 2014. Monthly variation of air temperature lapse rate in Arunachal Himalaya. J Indian Water Resour Soc 34 (3): 15-25.

Bongase ED. 2017. Impacts of climate change on global coffee production industry: Review. African J Agric Res 12 (19): 1607-1611.

BMKG. 2017. Laporan Pengumpulan Data Curah Hujan 2012-2016 Se-Provinsi Lampung. Board of Meteorological and Climatological and Geophysical Affairs, RI. [Indonesian]

Cheng B, Furtado A, Smyth H E, Henry R J. 2016. Influence of genotype and environment on coffee quality. Trends Food Sci Technol 57: 20-30.

CSR [Center for Soil Research Institute RI]. 1989. Land Resource Evaluation Planning Project I. Board of Research Development, Department of Agriculture RI, Jakarta.

Davis, AP, Gole TW, Baena S, Moat J. 2012. The impact of climate change on indigenous Arabica coffee (*Coffea arabica*): Predicting future trends and identifying priorities. PLoS ONE 7 (11): e47981. DOI: 10.1371/journal.pone.0047981.

Ferreira WPM, Queiroz DM, Silvac SA, Tomaz SR, Corrêa PC. 2016. Effects of the orientation of the mountainside, altitude, and varieties on the quality of the coffee beverage from the "Matas de Minas" Region, Brazilian Southeast. Amer J Plant Sci 7: 1291-1303.

González S, Garreaud R. 2017. Spatial variability of near-surface temperature over the coastal mountains in southern Chile (38°S). Meteorol Atmosph Phys 129:1-16. DOI: 10.1007/s00703-017-0555-4.

Hindorf H, Omondi CO. 2016. A review of three major fungal diseases of *Coffea arabica* L. in the rainforests of Ethiopia and progress in breeding for resistance in Kenya. J Adv Res 2: 109-120.

Iscaro J. 2014. The impact of climate change on coffee production in Colombia and Ethiopia. Global Majority E-Journal 5 (1): 33-43.

Jaramillo J, Setamou M, Muchugu E, Chabi-Olaye A, Jaramillo A, Mukabana J, Maina J, Gathara S, 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. DOI: 10.1371/journal.pone.0051815

Jaramillo J, Eric M, Fernando EV, Aaron D, Christian B, Adenirin CO. 2011. Some like it hot: The influence and implications of climate change on coffee berry borer (*Hypothenemus hampei*) and coffee production in East Africa. PLoS ONE 6 (9): e24528. DOI: 10.1371/journal.pone.0024528.

Jaramillo J, Olaye AC, Kamonjo C, Jaramillo A, Vega FE, Poehling M, Borgemeister C. 2009. Thermal tolerance of the coffee berry borer *Hypothenemus hampei*: Predictions of climate change impact on a tropical insect. PLoS ONE 4 (8): e6487. DOI: 10.1371/journal.pone.0006487.

Killeen JT, Harper G. 2016. Coffee in the 21st century, Will Climate Change and Increased Demand Lead to New Deforestation? Research Paper. Conservation International, New York.

Kpadonou RAB, Adégbola PY, Tovignan SD. 2012. Local knowledge and adaptation to climate change in Ouémé Valley, Benin African. African Crop Sci J 20 (Suppl.): 181-192.

KPHL Batutegi. 2014. Rencana Pembangunan Jangka Panjang Kesatuan Pengelolaan Hutan Lindung Batutegi. Service Office of Forestry Affair, The Local Government of Lampung Province, Bandar Lampung. [Indonesian]

Laderach P, Haggar J, Lau C, Eitzinger A, Ovalle O, Baca M, Jarvis A , Lundy M. 2010. Mesoamerican coffee: Building a climate change adaptation strategy. CIAT Policy Brief No. 2. Centro International de Agricultura Tropical (CIAT), Cali, Colombia.

Nicolaj KL, Kjær KH, Lecavalier B, et al. 2015. The response of the southern Greenland ice sheet to the Holocene thermal maximum. Geology 43 (4): 291-294.

Nurhaida I, Hariyanto SP, Bakri S, Junaidi A, Syah P. 2008. Upaya menanamkan ideologi lingkungan pada masyarakat di wilayah resapan melalui desimenasi kultur teknbis wanatani kopi menggunakan media hiburan buku cergam. Masyarakat, Kebudayaan dan Politik 21: 25-35. [Indonesian]

Nurhaida I, Hariyanto SP, Junaidi A, Syah P. 2007. Meracang media hiburan buku cergam menjadi media belajar untuk alat bantu komunikai. Mediator Jurnal Komunikasi 8 (1): 51-63. [Indonesian]

Nurhaida I, Setiawan A, Bakri S, Wiramnata GAB, Syah P. 2011. Pengembangan komik fabel untuk media komunikasi dan suplemen pendidikan lingkungan. Bumi Lestari Jurnal Lingkungan Hidup 11 (2): 331-346. [Indonesian]

Patay EB, Bencsik T, Papp N. 2016. Phytochemical overview and medicinal importance of coffea species from the past until now. Asian Pac J Trop Med 9 (12): 1127-1135.

Righi CA, Lunz AMP, Bernardes MSB, Pereira CR, Teramoto ER, Favarin JL. 2008. Coffee water use in agroforestry system with rubber trees. Revista Árvore 32 (5): 781-792.

Tang Z, Fang J. 2006. Temperature variation along the northern and southern slopes of Mt. Taibai, China. Agric For Meteorol 139 (3-4): 200-207.

Wulandari C, Yuwono SB, Budiono P, Herwanti S. 2016. Status and development of payment watershed services program in Taman Hutan Raya Register 19, Lampung Province. Intl J Agric Environ Res 2 (2): 267-279.

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