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Paper Contribution External Inbox

SAMSUL BAKRI <samsul.bakri@fp.unila.ac.id> 9 Oct 2017, 19:07
to unsjournals, wiryonogood, solichatun_s, oktia

Dear Editor in chief.

I am enclosing herewith our manuscript that may possible for publishing in the Biodiversitas journal.

Your sincerely.

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wiryono wiryono 9 Oct 2017, 19:21
Assalamu 'alaikum pak Samsul. Apa kabar? Saya editor bhs Inggris pak. Paper pak Samsul nanti akan diproses oleh managing editor. Wassal...

2

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Managing Editor <unsjournals@gmail.com> 11 Oct 2017, 14:24
to Wiryono, Solichatun, Rita, me

Dear Pak Samsul,

Thanks for the mss submission. It will be evaluated soon.

Thank you,
Regards,

Ahmad Dwi Setyawan

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Managing Editor <unsjournals@gmail.com> — 19 Oct 2017, 16:58
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Samsul Bakri et al...

SAMSUL BAKRI <samsul.bakri@fp.unila.ac.id> — 22 Oct 2017, 15:43
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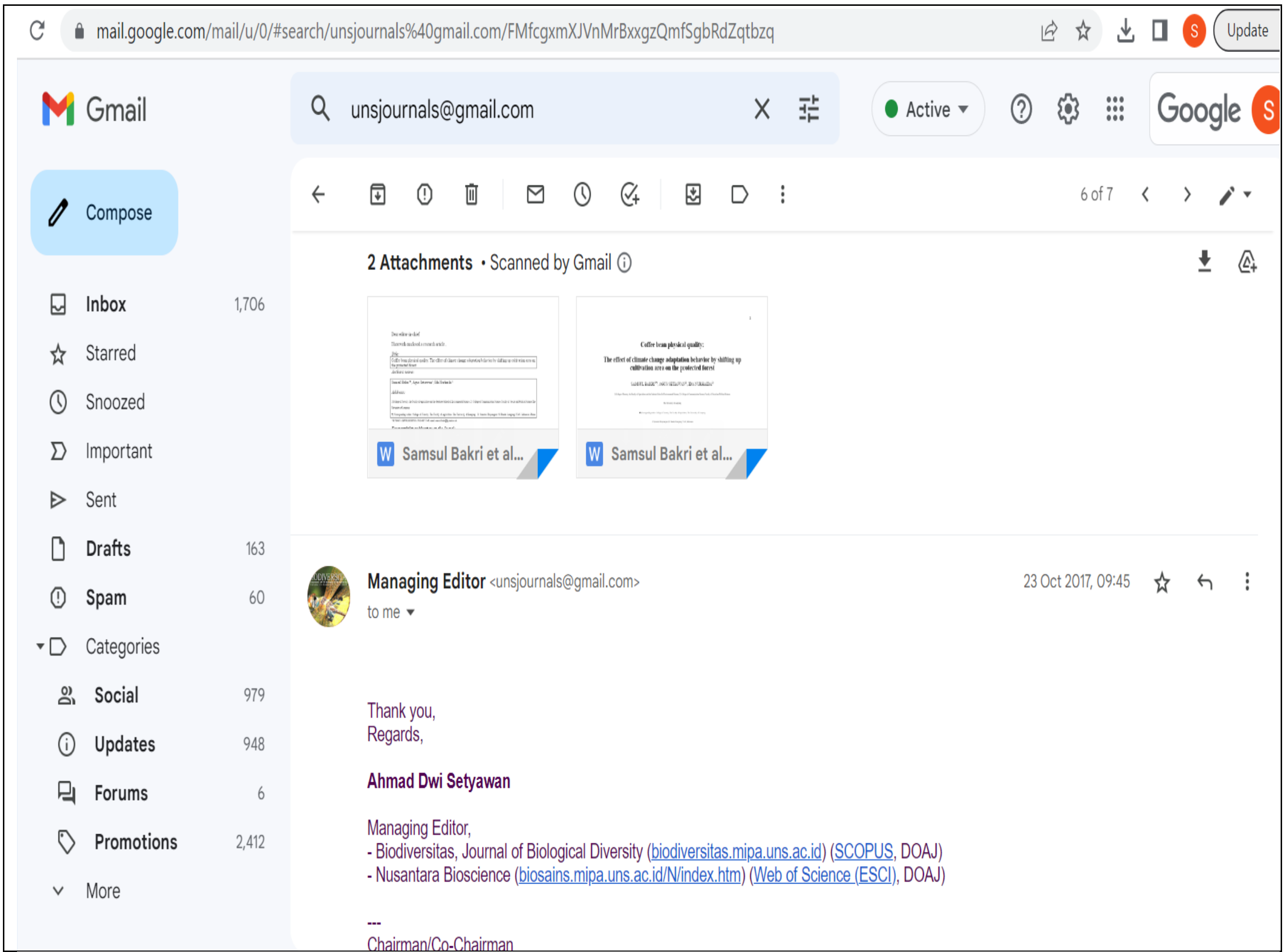
Thanks for your request. We are happy to fulfill it.

Your sincerely.



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23 Oct 2017, 09:45
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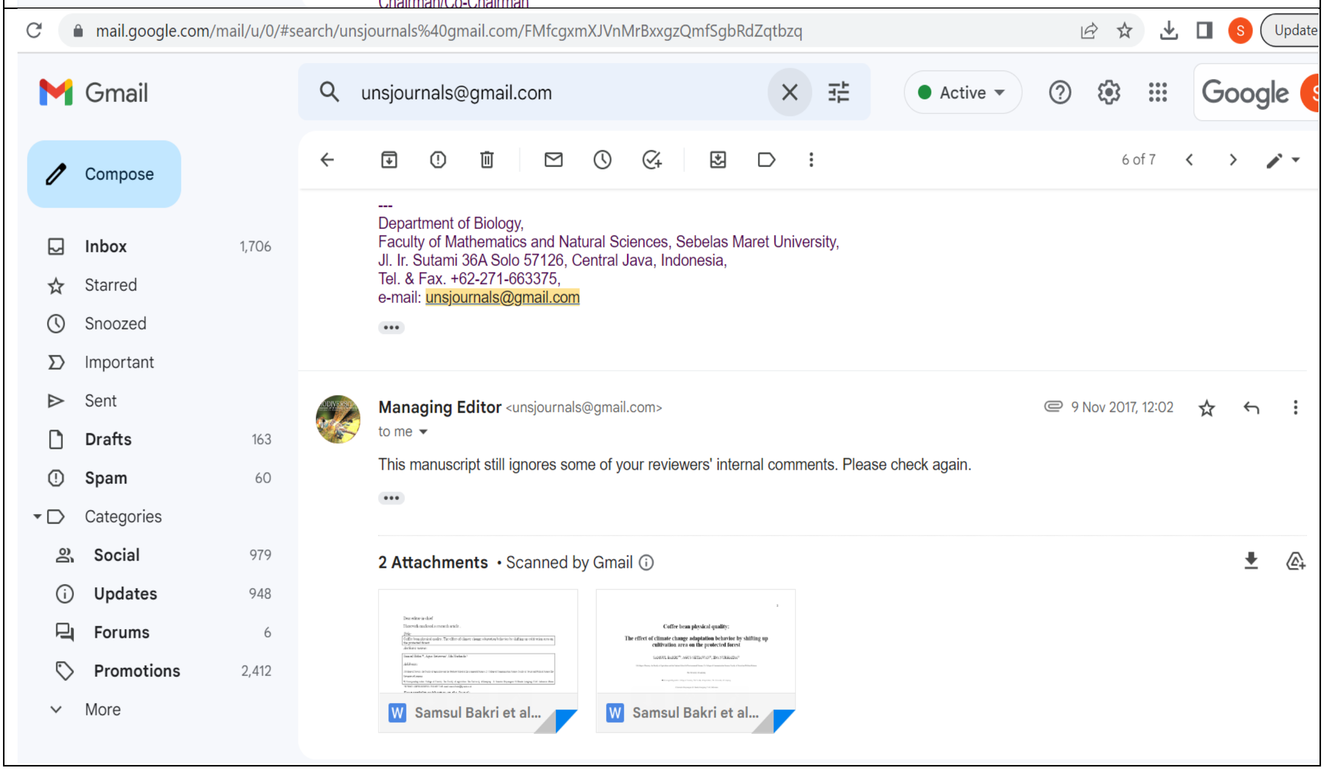

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9 Nov 2017, 12:02
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SAMSUL BAKRI <samsul.bakri@fp.unila.ac.id> — 14 Dec 2017, 22:00
to Managing

Dear editor in chief.

I am enclosing here with the paper we have improved base upon your suggestion.

Your sincerely.

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Managing Editor <unsjournals@gmail.com> — 15 Dec 2017, 06:50
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Thank you,
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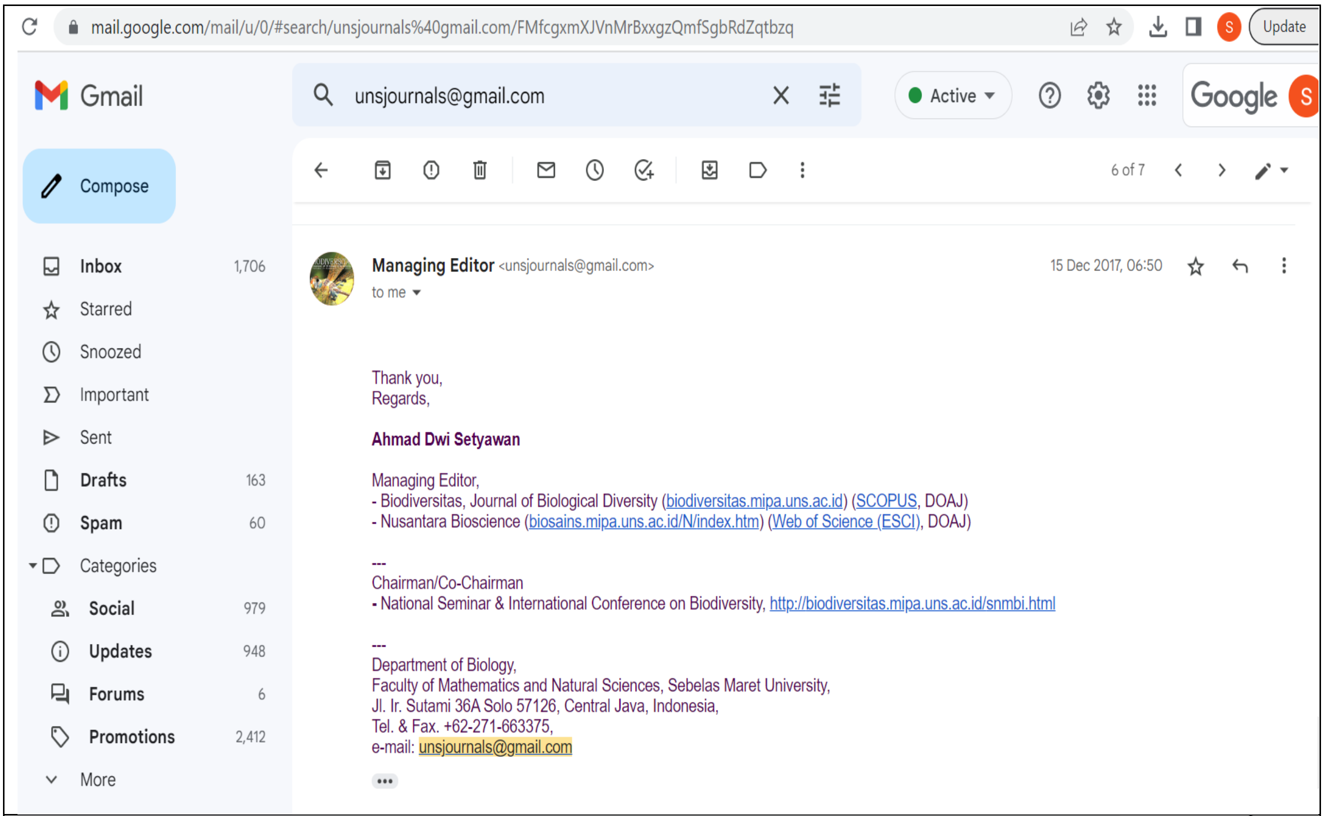

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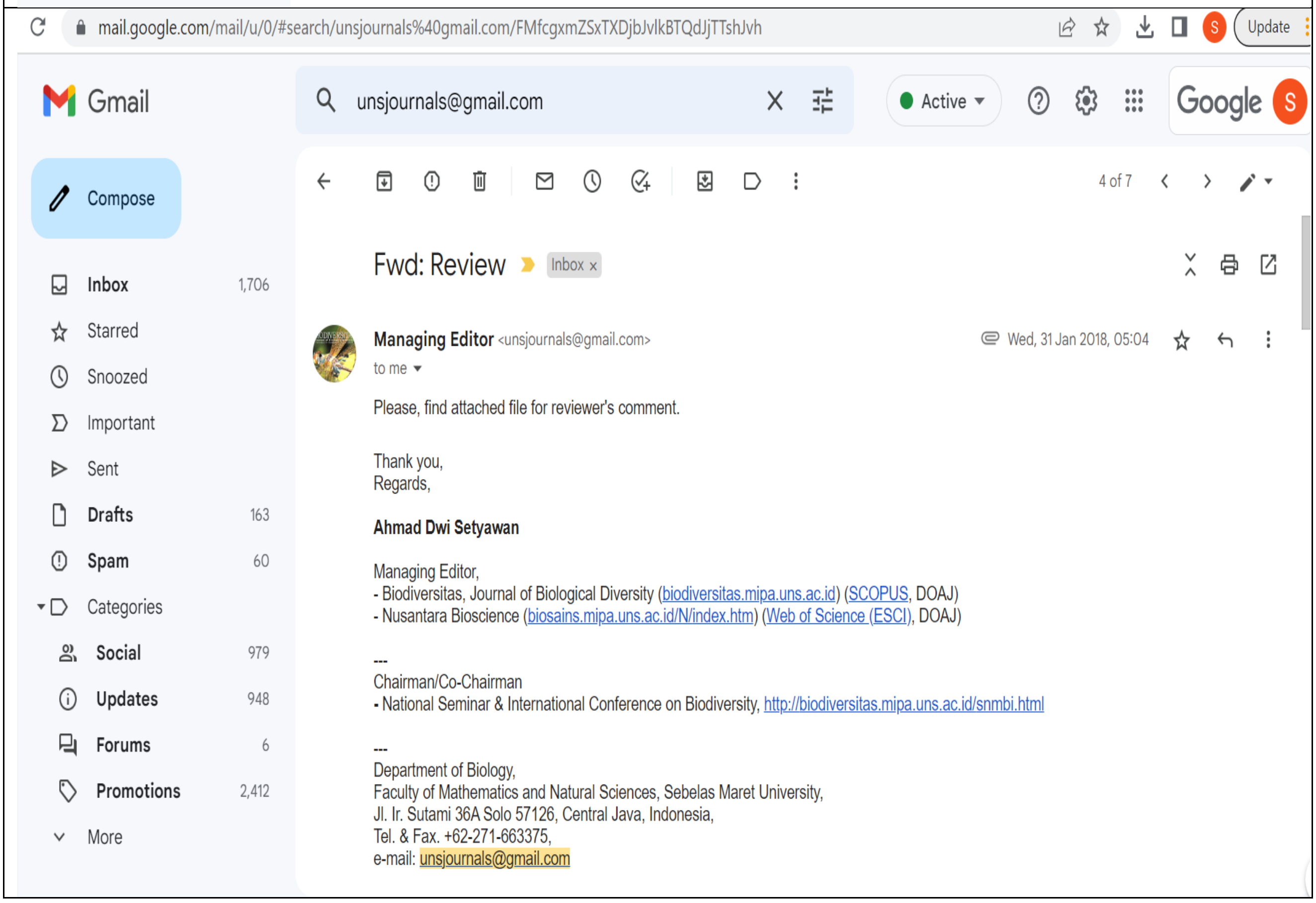

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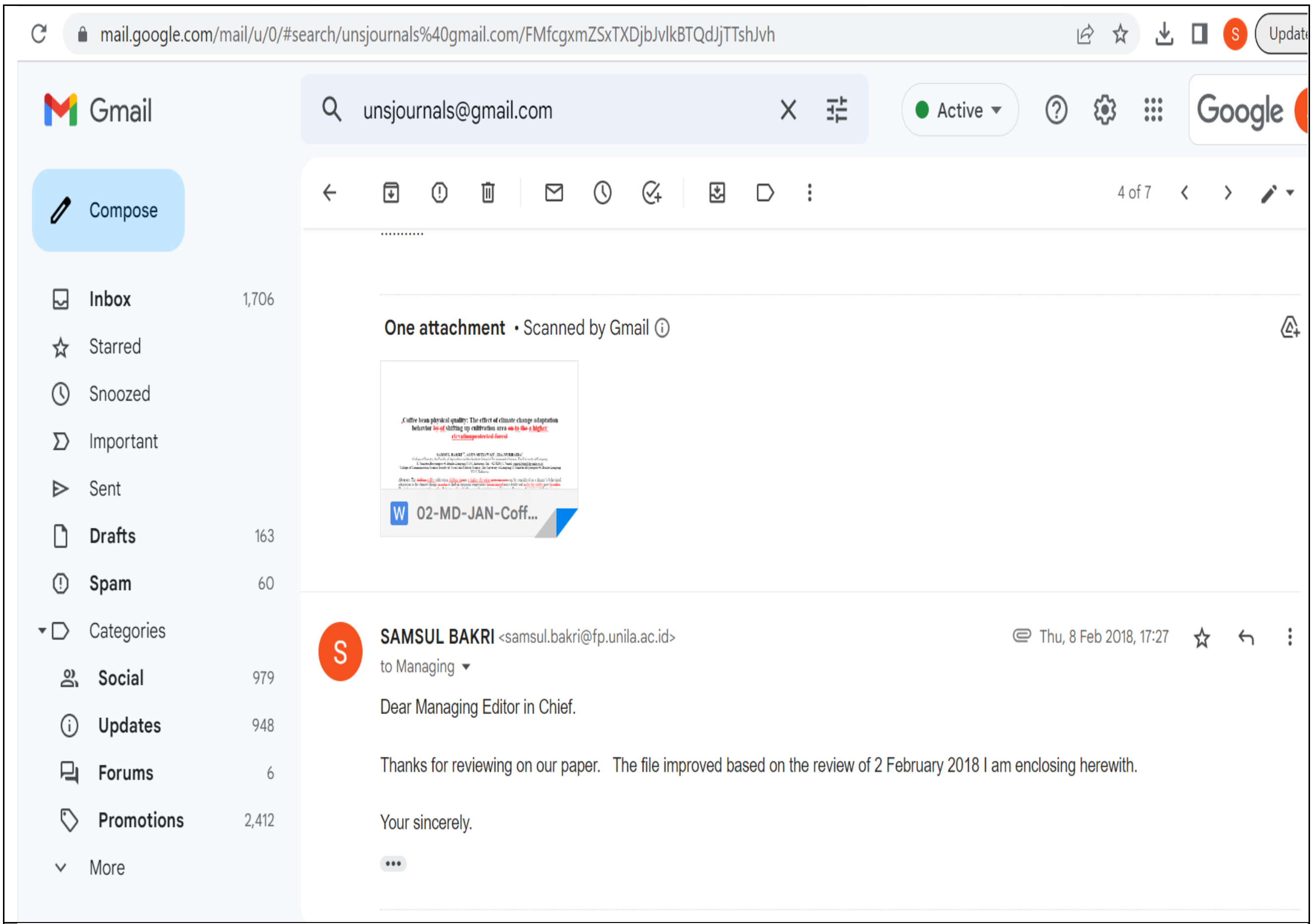
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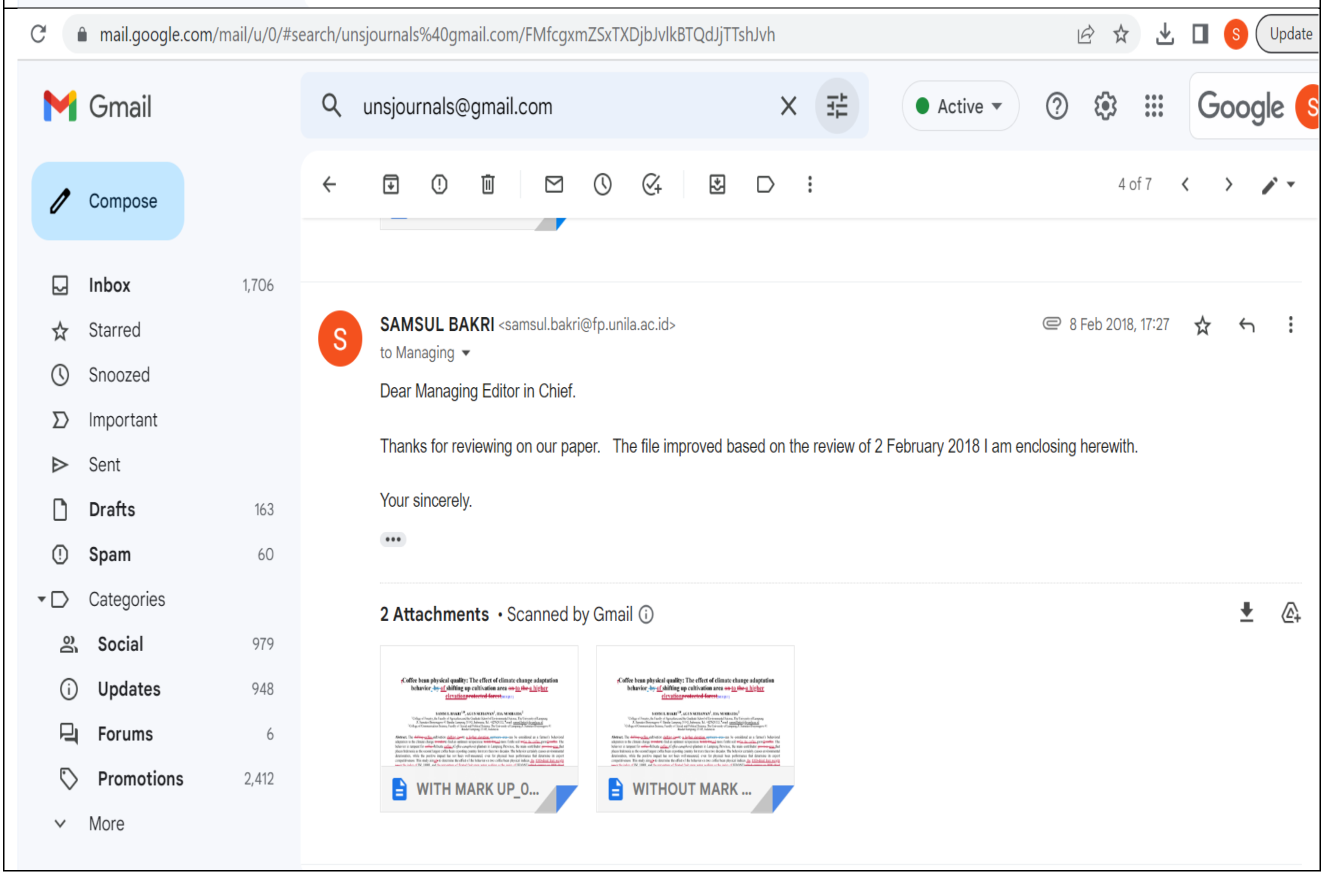
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Many thanks.

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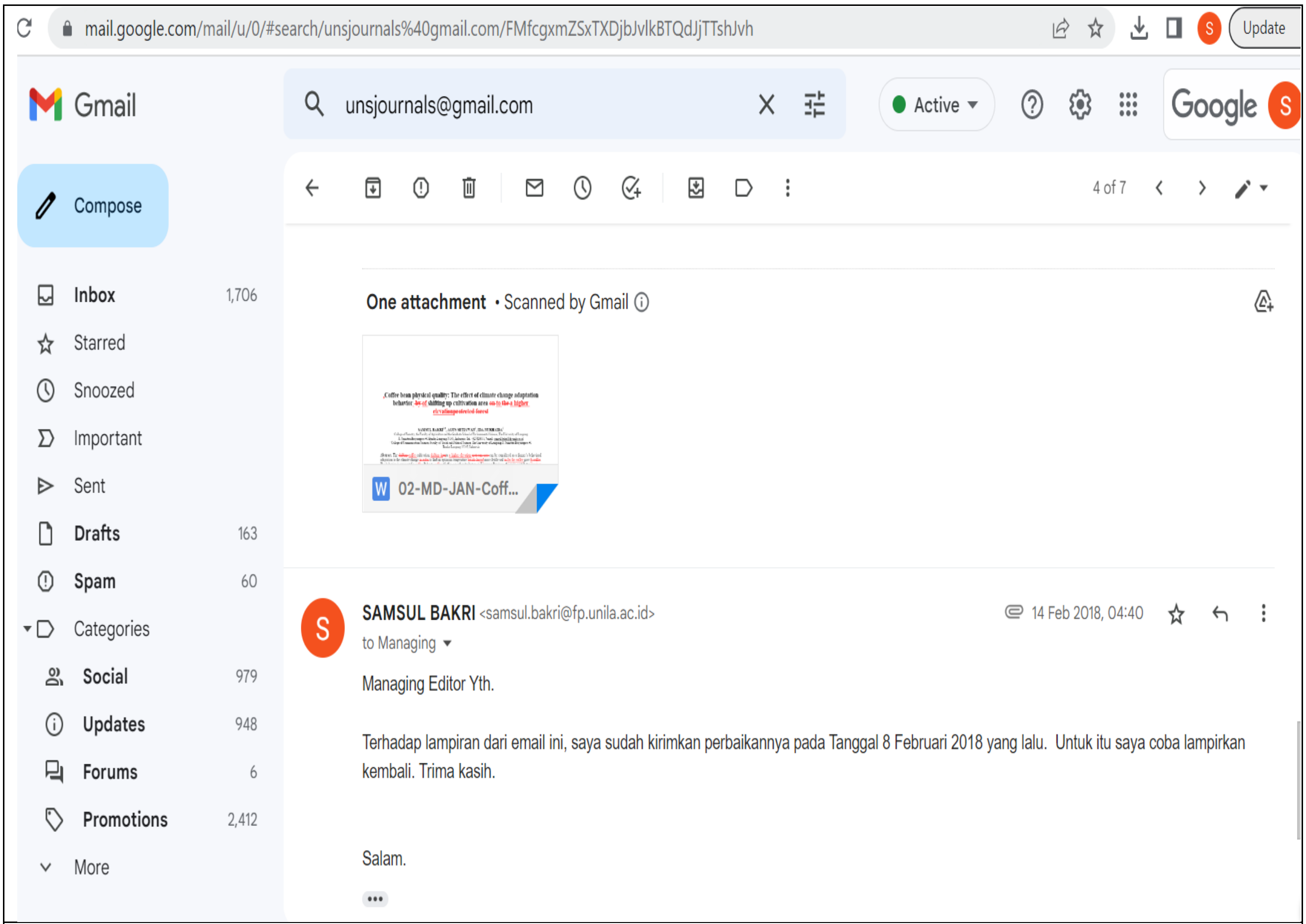
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SAMSUL BAKRI <samsul.bakri@fp.unila.ac.id>
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Managing Editor Yth.
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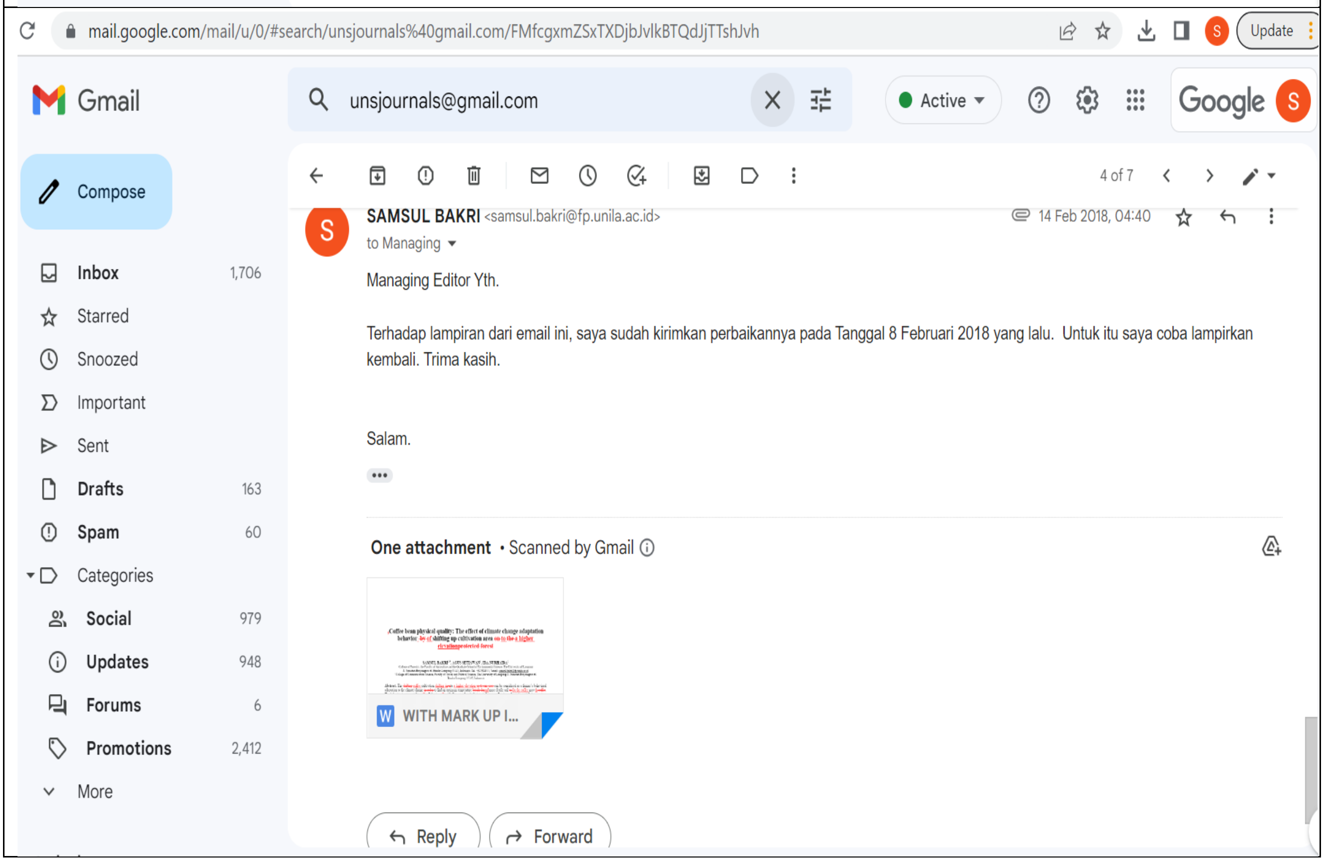
Salam.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Managing Editor Yth.
Terhadap lampiran dari email ini, saya sudah kirimkan perbaikannya pada Tanggal 8 Februari 2018 yang lalu. Untuk itu saya coba lampirkan kembali. Trima kasih.
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SAMSUL BAKRI <samsul.bakri@fp.unila.ac.id> — 16 Feb 2018, 08:18
to Managing

Asrwrb.

Terima kasih atas setting up tipografis terhadap paper kami. Bersama ini kami lampirkan paper yang telah kami proof read kembali.

Semoga Biodiversitas makin jaya. Aamiin YRA.

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Managing Editor <unsjournals@gmail.com> 16 Feb 2018, 11:42
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SAMSUL BAKRI <samsul.bakri@fp.unila.ac.id> 16 Feb 2018, 12:05
to Managing

Masih ada kesalahan dalam catatan kaki yang kami tambahkan: tertulis **have been presented** ..... serharusnya **has been presented**...

Salam,

Terima kasih.

Managing Editor <unsjournals@gmail.com> 16 Feb 2018, 12:56
to me

Tolong kirim kembali naskah lengkap

Thank you,
Regards,

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SAMSUL BAKRI <samsul.bakri@fp.unila.ac.id> 21 Feb 2018, 23:41
to Managing

Managing Editor Yth.

Saya hanya konfirmasi (keep on alert) terhadap perkembangan manuskrip saya. Pada kesempatn ini saya kukuhkan pula bahwa manu
yang saya lampirkan sekarang ini adalah yang sudah paling up date bagi saya.

Terima kasih,
Salam

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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. 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.

Key words: climate change adaptation, coffee bean quality, shifting up to protected forest

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. that coffee crop cultivation

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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 areas 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, the University of Lampung.

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 these two indices, the higher the quality of the coffee beans or please explain…………………..?*** To prepare the index of [W_1000] variable, we dry 1 kg coffee fruit sample in an oven at 70^0C for 6 days, then continued at 105^0C 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 100m. 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.

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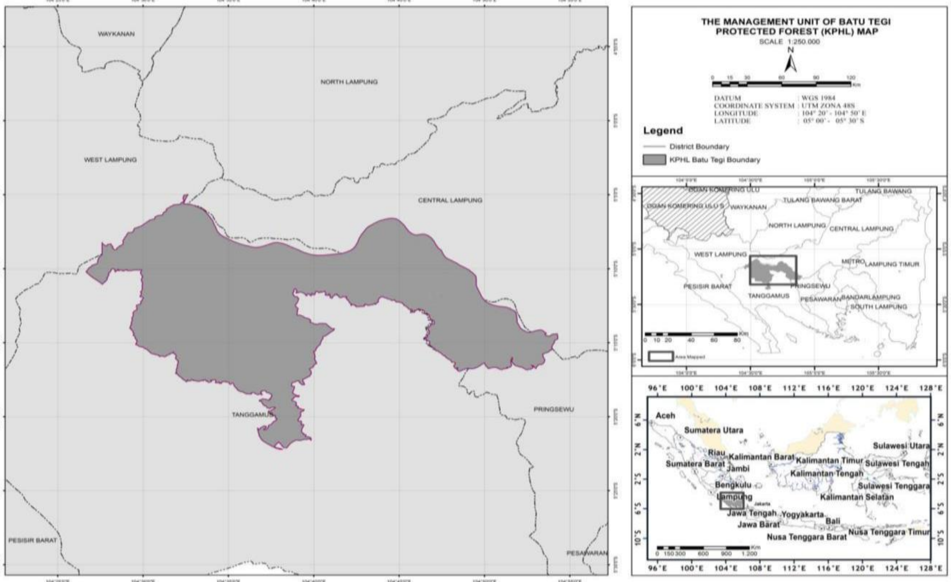

Figure 1. Study area maps (reproduced from Management Unit of Protected Forest of (KPHL) Batutegi, 2014)

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.

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 70^{0}C for 6 days, continued for 2 days more at 105^{0}C, 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 100m.
-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

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.

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RESULTS AND DISCUSSION

The generic description of study area

The study area lied in the Southern Hemisphere with specific geographic coordinate at *05^{0}05'50''S – 05^{0}16'33''S* latitude and *104^{0}30'34'' E – 104^{0}49'14" E* longitude. The site has an area of around 58,162 ha and is under the supervision of Protected Forest Management Unit (KPHL) Batutegi, Department of Forestry, 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 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. The number of the plot area exposition for the directions to the south, west, north, and east were 4, 8, 5, and 17 respectively.

Table 2. Descriptive statistic of variables observed at 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]	^{0}C	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(Augt)	244(---)	374(May)	124(---)

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

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 1.9^{0}C that equal to its variance (1.9)^2=3.6^{0}C. 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 2-4^{0}C 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 2^{0}C 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 32^{0}C with *SE*=1.9^{0}C or approximately 2.0 ^{0}C. 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 in response to the rising air temperature.

Until recently, almost all scholars hold an assumption known as the Braak's Law that the temperature lapse rate is 0.56 ^{0}C each 100m 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 0.32–0.54^{0}C. 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 3. Analysis of variance of the air temperature as function of the elevation (per 100m 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			

Source: Research result (2017) Beri penjelasan apa itu DF, SS, MS, F, dan P

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 each 100m rise in elevation, the air temperature will decrease

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Table 4. The T-test of the air temperature [TEM] (^{0}C) as function of the elevation [ELV] for each a-100m move upward and their air humidity [HUMD] recorded during the field survey

Predictor	Coef	SE Coef	T	P
Constant	35.888	3.455	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

Based upon the statistical analysis depicted above, the regression model could be expressed in Eq.{1} as follows:

$$[TEM] = 35.9 - 0.332\ [ELV] - 0.0999\ [HUMD]$$

$$R\text{-}Sq(adj) = 20.1\% \qquad \text{Eq. \{1\}}$$

The Impact of……………………..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 fruit 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, 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=0.0004. 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. 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.

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

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 each 100m 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)^{0}C for each 100-meter 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 *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

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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

Predictor	Coef	SE Coef	T	P
1. Cosntant	279.81	48.49	5.77	0.000***
2. Elevation [ELV]	24.187	5.228	4.63	0.000***
3. Slope Steepness [STEEP]	-0.170	1.879	-0.09	0.929000
4. Plot Area Expotision(*Eastward=0*):	------	------	------	-----------
-*Southward* [D_SHT]	28.26	35.79	0.79	0.437000
-*Westward* [D_WST]	9.30	25.79	0.36	0.722000
-*Northward* [D_NRT]	-95.87	28.02	-3.42	0.002***

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

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) ……………….*mohon jelaskan keadaan spesifik pada penelitian Ferreira et al. (2016)*. 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 and ripening, which in the region normally take place for 6 months. 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 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]

R-Sq(adj) = 53.3%

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=0.005 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 5 times. However, it is important to note that this result was obtained after we omitted 3 outliers data from the regression analysis.

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	1020.48	204.10	4.46	0.005***
Residual Error	24	1098.67	45.78		
Total	29	2119.15			

S = 6.76592 R-Sq = 48.2% R-Sq(adj) = 37.4% Note: *** 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 the quality index [FLOAT]. As depicted in Table 8, there was a rise in the index of [FLOAT] of around 1.993% for each 100-meter rise toward higher elevation [ELV] and vice versa. This increase is statistically as indicated by P=0.007. 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 35 ^{0}C. The female insect activity in boring coffee fruit drop drastically when the air temperature reaches 35^{0}C, and beyond 35 ^{0}C the insect will fail to spawn, suppressing their propagation.

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As depicted in Table 3, the air temperature recorded during the study was between 22-32^{0}C. 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. 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.

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
1.Constant	-1.243	6.085	-0.20	0.840000
2.Elevation [ELV]	1.9929	0.6743	2.96	0.007***
3.Slope Steepness [STEEP]	-0.0845	0.2349	0.2349	0.722000
4.Area Expotision (*Eastward scored=0*):	------	------	------	-----------
-*Soutward* [D_SHT]	-1.475	4.534	4.534	0.748000
-*Westward* [D_WST]	3.446	3.346	3.346	0.313000
-*Northward* [D_NRT]	-8.021	3.545	3.545	0.033**0

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

Even tough the slope steepness [STEEP] in the study area was relatively heterogenous, 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.

The impact of the area position with regards to its solar exposure to the index of [FLOAT] also shows a similar characteristic, *i.e.*, only the northward-facing cultivation areas [D_NRT] exhibited a significantly different effect compared to the areas facing eastward. Cultivation areas facing northward negatively affect [FLOAT] variable, yielding around 8.02% lower floated cherry fruit than that of the areas facing eastward direction in a significant manner (P=0.033). We argue that the explanation to this result was similar to the how the area position relative to the sun exposure affect the coffee bean's quality index of [W_1000] that the coffee crop which against the solar beam radiation would be more effective but opposite in value. In this case, the solar beam had given the positive impact on the quality cherry coffee fruit. However, we do not completely understand the relationship between the solar radiation, the endurance to the pest, and the abundance of the coffee fruit floated in the water test.

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

[FLOAT] = - 1.24 + 1.99 [ELV] - 0.084 [STEEP] - 1.47 [D_SHT] + 3.45 [D_WST] - 8.02 [D_NRT]

R-Sq(adj) = 37.4%   Eq. {3}.

It is important to note that the deterioration of the coffee bean quality index of [FLOAT] following the shifting up of coffee cultivation area to the upper region should be taken carefully into consideration by the farmers whose encroaching into the upper protected forest especially in the study sites and the surrounding areas. This finding is valuable knowledge in developing some persuasion messages in extension programs (see Nurhaida et al., 2007, 2011) as a counterbalance to the [W_1000] improvement in line with shift upward behavior in planting coffee crops. As suggested by Kpadonou et al. (2012), the extension program should assist the local people to avoid maladaptation in coping with the strategy to combat the global warming. We, therefore, can utilize Eq {2} and Eq. {3} to find an optimal range of elevation that will provide optimum physical coffee bean qualities. This trivial technique would also be very valuable knowledge for the extension workers in persuading farmers to further lessen the encroachment into the protected forest area.

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