Climate change adaptation through a shift in cropping area onto the upper stream region: Measuring coffee beans response in quality#

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The extensification onto upstream region can be regarded as a farmer's behavioral adaptation to the climate change to look for the optimum temperature in growing coffee. This behavior is rampant for Robusta-dominant people agroforestry coffee (*Coffea canephora*) in Lampung Province, Indonesia. The negative impact certainly causes land degradation, while the positive impact on its quality has not been well-measured. This study aims to determine the effect on the upward shift on cropping area altitude to the coffee frruit quality using Ordinary Least Square (OLS) Regression Model. The field survey was conducted from June to August 2017. Samples of ripe cherry coffee collected from 32 sites in the approximate elevation of 300 to 1,170m ASL. The independent variables observed consists of sites elevation, slope steepness, and the exposition area of cultivation. Two indices of bean quality were used as the independent variables. First one was the index of [WD_1000]: the weight of 1000 dried coffee fruit. The other one was [FLOAT], the percentage of ripe coffee fruit floated in the water. Conclusion: For each a-100 m of upward elevation, the [WD_1000] was increased by 24.18g/1000 dried beans accompanied with the [FLOAT] by 1.99% of floating watered bean. It is recommended to conduct further research on revealing the effect on the coffee cup taste.

***Key words**: climate change adaptation behavior, coffee bean quality, shifting cultivation to upper region.*

INTRODUCTION

Climate change had affected almost every aspect of community and livelihood, including the coffee farmers' behavior in shifting cultivation onto the upper stream region of the catchment area of Batutegi Dam in Lampung Province, Southern tip of Sumatera- Indonesia. On one side the behavior, indeed, causes the 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 occurrence in the wet season), destroying germplasm, and worsening water body deterioration. Yet, on the other side, the behavior could be regarded as the local wisdom to climate change adaptation that is controlled by the steadily rising air temperature.

According to Killeen and Harper, (2016) both the productivity and quality of Arabica and Robusta coffee are largely dependent on the climate suitability, especially the precipitation and air temperature. In contrast to the precipitation variable that is very difficult to manipulate, there are two simple opportunities to achieve suitable temperature condition for coffee crop cultivation. The first choice is to manage the shade trees (Jaramillo *et al*., 2011) and the second is to move up onto the upper region across the landscape. The first one, indeed, is normally applied by farmers in coffee crop cultivation agroforestry system. But this choice is in trading off with the threshold of sunlight intensity to meet the coffee crop photosynthesis requirement. The second choice, therefore, becomes the only opportunity left in the effort to combat the global warning by decreasing the air temperature. It is well known in the scientific community as the Braak's Law that the temperature will decrease by 0.56^0C for each 100m elevation in the atmospheric region (Arsyad, 2000). The behavior of the farmer in shifting cultivation onto the upper region could compensate the rising air temperature (as the effect of the global warming) so the air temperature suitability for growing coffee crop could be retained, as well as its productivity and quality. So far we have not found a published paper that assess the effect of the upward shift in cultivation area altitude on the coffee fruit and bean qualities. For the sake of revealing the effects of the farmers' behavior, we were interested in conducting this study.

MATERIAL AND METHOD

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.

Procedure

Samples of the ripe cherry fruit of coffee were collected from 32 sites of people coffee agroforestry at the approximate elevation of 300 to 1,170 m ASL. The research location is pointed out by the Figure 1. We started from lowest elevation and went up to the summit. We made the plot sites observation for each 25m to 30m elevation ranges. We chose 3-5 coffee crops and took ripe cherry bean for around 3kg for each plot. We also took some observation for each site plot elevation including the slope steepness, the exposition or direction of cropping area, the air temperature, and the air humidity by using the altimeter, clinometer, compass, thermometer, and hygrometer, respectively.

We used two indicators to express the coffee fruit quality indices. First one was symbolized as the quality index of [WD_1000] that to express the weight of 1000 dried fruit and the other was the percentage of cherry coffee fruit that floated in water as symbolized by the quality index of [FLOAT]. To prepare the quality index of [WD_1000] variable, we took around 1kg of cherry bean, placed it in the oven chamber that set at 70^0C for 6 days, weighed it, and then counted it. Whereas for preparing the quality index of [FLOAT], we took around 1kg coffee cherry fruit, soaked it in water, separated the floated beans by nest then weighed, and then expressed by the percentage of the fresh fruit coffee.

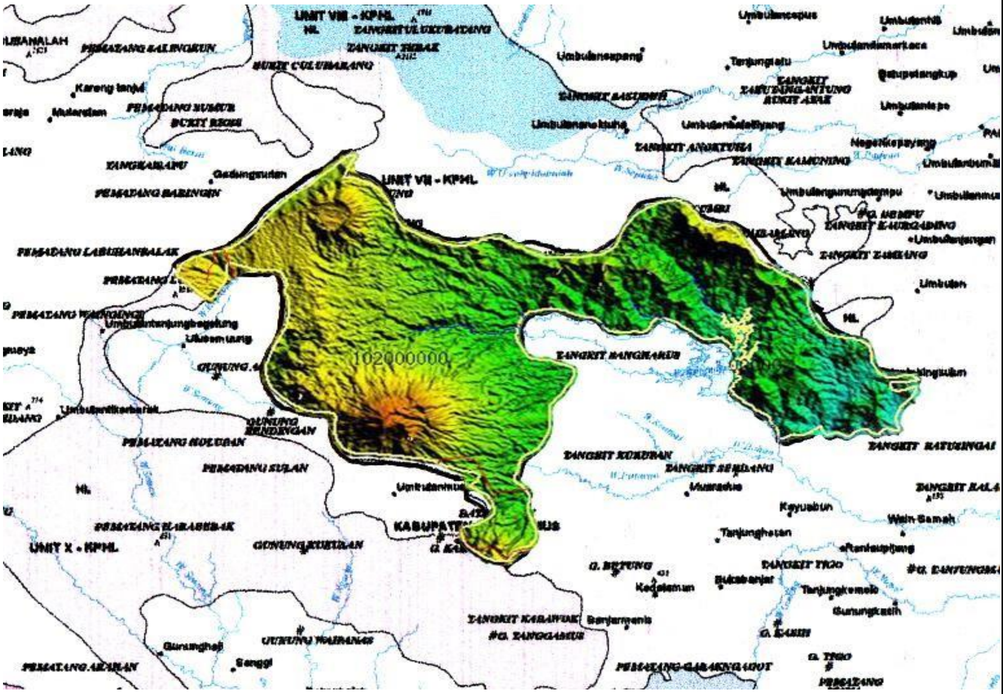

Figure 1. The Study area (Source: KPHL=Unity of Management for the Protected Forest of Batutegi, Service Office of Forestry Affair, Local Government Lampung Province 2014)

The ordinary least square regression (OLS) model at 1% and 5% of significance level was applied on the predicting bean qualities, *i.e.* quality index of [WD_1000] and the quality index of [FLOAT], which we treated as the dependent variables. Whereas for the independent variables were applied 3 tree attributes of each cropping areas that includes the elevation, the slop steepness, and the exposition. The elevation [ELV] was expressed in a 100m range of different heights. The slope steepness [STEEP] expressed in percentage. Meanwhile, the area expositions were expressed in 3 dummy variables with the eastward direction used as the reference and scored as follows: if the dominant exposition was in the direction of southward it is symbolized as [D_SHT], northward as [D_NRT], and westward as [WST] and we scored by *1*, and otherwise was *0*. In Table 1 we provide the dependent and the independent variables, their units, their scores, and their method of acquisition. We applied statistic software to optimize the parameter.

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

No	Variabel	Symbol	Unit	Scale of measurement	Data acquisition and preparation for variables in modeling
I.	***Dependent variables***				
	1. Coffee fruit quality index 1	[WD_1000]	gram	ratio	Field sampling at each plot site from 3-5 tree coffee crops, took bean for around 1 kg, dried in oven for 6 days then weighted for 1.000 beans.
	2. Coffee fruit quality index 2	[FLOAT]	%	ratio	About 1 kg coffee bean was soaked in water, netted that float, weighed, and then calculated it in %
II.	***Independent variables***				
	1. Elevation	[ELV]	*100m m ASL	Ratio	Recording each plot site elevation by altimeter then divided by 100m
	2. Slope Steepness	[STEEP]	%	Ratio	Recording the slope steepness for each plot by clinometer.
	3. Cultivation Area Exposition:				Observing the dominant direction of each plot site then:
	-Northward	[D_NRT]	-	Dummy	-Scored by *1* if in the northward direction, by *0* if others
	-Southward	[D_SHT]	-	Dummy	-Scored by *1* if in the southward direction, by *0* if others
	-Westward	[D_WST]	-	Dummy	-Scored by *1* if in the westward direction, by *0* if others

We realized that our air temperature data were merely the temporary data that only recorded once in our survey. This kind of data were certainly could not represent for the long period of, that certainly control coffee crop growth, so we prefer to use the elevation [ELV] variable as the independent variable to predict the quality of coffee fruit than using air temperature [TEMP]. Based on this argument we then built the research with an assumption that there was a differential fall of air temperature in accordance with the elevation or topographic sequent across the landscape. For the sake of testing the validity of this assumption, we also employed an OLS regression model with the air temperature, which expressed in symbol of [TEMP] as the dependent variable, and the [ELV] accompanied by air humidity, which expressed by symbol of [HUMD] as the independent variables. For this purpose we also used the significance level of 1 and 5%. This verification step was an important thing as the way to prove that the people's behavior in shifting up their coffee cultivation area onto the upper region could be regarded as an adaptation behavior from the climate change in order to find out a more suitable air temperature to grow the coffee crop.

RESULT AND DISCUSSION

The generic description of study area

The area study is lied in the south hemisphere which specific geographic coordinate references is in between latitude *05^{0}05'50''S – 05^{0}16'33''S* and longitude in between 104^{0}30'34" *E* – 104^{0}49'14" *E*. The acreage of around 58,162 ha is under control by Unit of Management Protected Forest (KPHL) Batutegi, Service Office for Forestry Affair of Lampung Province Local Government. Almost 70% of the acreage are cultivated by the farmer as coffee agroforestry under concessionary as Social Forestry Agreement (*HKm*) for 35 year with land holding around 1-5ha per farmer. Under the concession, farmers are obligated to apply agroforestry system which prohibit them to take timber instead of non-timber products, such as rubber sap, rattan, honey bee, coffee bean etc. The area is also the catchment area of Batutegi Dam that built in 1995 for water reservoir of around 9 million m^3 annually and to generate hydropower of around 125.2 GWH annually (www.pu.go.id, 2017). As could be examined in the Document of Land Resource Evaluation Planning Project I (CSR: Center for Soil Research Institute of RI, 1989) the topographic is a hilly complex to mountainous. Under the tropical rainforest the geologic parent material of clastic sedimentary rock have formed various silty loam, loam, and clayed soils with common characteristic of low pH and poor fertility.

The descriptive statistic of the field survey observation in Table 2 that consisted of the minimum, the mean, the maximum, and the standard deviations (SE) of the variables of air temperature, air humidity, elevation, bean qualities indices, area elevation, and slope area steepness. Besides, number of the area exposition for the four direction we enlisted in this table as well.

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

No.	Variable	Unit	Minimum	Mean	Maximum	SE
1.	Bean quality index of [WD_1000]	g/1000 dried beans	1,001.4	1,074.6	1,180.3	70.6
2.	Bean quality index of [FLOAT]	% watered floating fruit	0.03	0.09	0.27	0.07
3.	Air temperature	^{0}C	22.0	26.1	31.8	1.9
4.	Air humidity	%	50.0	71.4	84.0	7.3
5.	Area elevation	m ASL	349	788	1,173	237
6.	Slope steepness	%	2.7	11.5	23.8	5.5
7.	Number of cultivation area's exposition	Plot number:	South: 4	West:8	North:5	East:17

As depicted in the Table 2, both the coffee fruit quality indices were varied enough as expressed by their wide range of standard error (SE). This variation seemingly controlled by the variation of temperature as the shed of the differences of their elevation. Nikolaj *et al*. (2015) proved that the air temperature in the Artic zone in the Holocene geological era was warmer of around 2-4^{0}C than the present era and had significantly affect the melting glacier which further makes the sea level 0.16 m higher. This suggests that the increase of air temperature of around 2^{0}C was enough impact to global warming. Based upon the proof provided by Nikolaj *et al*., (2015), the range of air temperature recorded from this study was 22-32^{0}C with SE=1.9^{0}C or approximately to 2.0 ^{0}C. This finding also could be regarded as identical with the effect of global warming if we move down from the summit along the slope of the study area and vice versa. The opposite direction, therefore, was the reverse of the step up moving onto the summit and could be regarded as a seeking of compensation behavior against the raising air temperature. This behavior also could be considered as an adaptation of the global warming. We had also tested the assumption of the decreasing air temperature as the function of the area of elevation. For this purpose we employed the OLS regression between air temperature [TEM] as the function of the elevation [ELV] accompanied by the air humidity [HUMD] as provided in Table 3 and Table 4.

Tabel 3. Analysis of Variance of the air temperature [TEM]^{0}C as the function of increase of elevation [ELV] per 100m upward and their air humidity [HUMD] 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)

Table 3 depicts that the variation of [TEM] we obtained from this study was explained well enough by the variation of the [ELV] accompanied by [HUMD]. As depicted from Table 4, for each 100m increase of elevation, the air temperature would decline around 0.332±0.1328 ^{0}C and vice versa, regardless the air humidity. This fact told us that temperature decreases 0.465^{0}C for each 100m moving up across the landscape of the people's coffee agroforestry areas. This fact suggests that approximately in accordance with the classical Braak's Law, which postulates that for each increase of 100m altitude in the atmospheric zone, there is a decrease in air temperature by 0.50^{0}C (see Arsyad, 2000). In the model, we also have separated the effect of air humidity [HUMD], so we could claim that the effect of [ELV] to the declining air temperature is free from the effect of the air humidity variance.

Tabel 4. The T-test of the air temperature [TEM]^{0}C as the function of increase of elevation [ELV] for 100m move upward and their air humidity recorded

Predictor	Coef	SE Coef	T	P
Constant	35.888	3.455	10.39	0.000
[ELV]	-0.3321	0.1328	-2.50	0.018
[HUMD]	-0.09986	0.04336	-2.30	0.029

The regression equation could be expressed in Eq.{1} as the following:

[TEM] = 35.9 - 0.332 [ELV] - 0.0999 [HUMD]
R-Sq(adj) = 20.1%

Eq. {1}

[2] The Impact on the coffee fruit qualities
As mention above, we use two terms to express the coffee fruit quality indices, the dried bean quality index of weight and the percentage floating coffee fruit in water.

The dried coffee fruit quality index of weight
The impact of elevation, slope steepness, and exposition area of cultivation on the coffee ripe cherry are simultaneously depicted in Table 5. By examining the *R_Sq(adj)*, the variance of the three independent variables could only explain as many as 53.3% to the variance of the coffee fruit quality, especially for the dried weight of 1000 beans quality [WD_1000], whereas the remaining 46.7% must be explained by other variable besides of the three from the model. The three variables, nevertheless, was robust enough for explaining the variance of the quality index of [WD_1000]. This claim was proved by the P-value=0.000. This value told us that based on the three kinds of data (*i.e.*: data of elevation, slope steepness and cultivation area exposition), the model could predict the quality index of [WD_1000] in very high precision. We could write P=0.0004 that approximately for P=0.000. It meant that if we use the three variables, for every 10,000 times of prediction, there would be only 4 time misses.

Table 5. Analysis of variance of the impact of elevation, slop steepness and exposition area of cultivation on the coffee ripe fruit cherry

Source	DF	SS	MS	F	P
Regression	5	107080	21416	7.61	0.000
Residual Error	24	67533	2814		
Total	29	174612			

Among the three variables, we could further examine on how much was the effect on the dried bean quality index of [WD_1000] by examining the result of the *T-tes*t. As depicted in Table 6, the elevation [ELV] variable could affect the dried bean quality index of [WD_1000] very significantly (P=0.000). The optimum parameter of this variable was 24.187. The fact connoted that if the two other variables were remained constant, the average quality index of [WD_1000] would increase by 24.187 gram for each 100m shift upward of cultivation area and vice versa. It also could be considered that farmer's behavior in moving up their area of cropping were the behavior in the climate change adaption. This fact, therefore, could be equalized as the term for measuring the effect of adaption behavior to the global warming especially in pursuing better coffee bean quality.

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
Constant	279.81	48.49	5.77	0.000
[ELV]	24.187	5.228	4.63	0.000
[STEEP]	-0.170	1.879	-0.09	0.929
[D_SHT]	28.26	35.79	0.79	0.437
[D_WST]	9.30	25.79	0.36	0.722
[D_NRT]	-95.87	28.02	-3.42	0.002

In contrast to the elevation impact, the influence of slope steepness variable that symbolized by [STEEP] that resulted the optimum parameter was -0.170. It meant that in case the two variables were retain to constant, there would be make decrease as much as 0.17g in dried weight fruit bean quality index of [WD_1000] for each change up slope steepness 1% and vice versa. This was a merely little decreasing in dried fruit bean quality so that did not give a significant effect as connoted by the P=0.929. The fact also told us that the slope steepness range of the whole areas of study was similar enough (see Table 1 row 6) to induce soil erosion process that could not make significantly difference effect to the lowering soil fertility. Another reason perhaps the soil surface of the ground in the whole study areas was covered by good litter basalt that protected the soil fertility well.

This was an interesting fact that cultivation areas which exposition is at northward [D_NRT] depicts the worst bean quality index of the [W_1000] among 3 other directions. The northward direction of cultivation areas [D_NRT] produced the lower quality at average of 95.87g than those of the eastward direction. This difference is very significant with P=0.002. Perhaps the most probable explanation to the fact was the least solar beam radiation that could suppress photosynthesis process, especially in the period of bean filling and repening, which in the region normally take place since 6 month before. As could be examined in Figure 1, the whole area of study lies at the south hemisphere in between *$05^0$05'50'' S – $05^0$16'33'' S.* This period was coincided with solar position in the south hemisphere and so did the period of bean filing and repening stage for almost of coffee agroforestry at the area of study. The cultivation areas with northward expositions, therefore, is always face back to solar beam radiation, so that much more suffers from lack of the ultraviolet ray during the period of bean filling.

Based on the analysis above, we could write the regression equation as in Eq. {2}

[WD_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 floating coffee fruit in water

Similar to the quality index of [WD_1000], the three independent variables that were applied for predicting percentage of floated ripe cherry bean in water, symbolized as quality index of [FLOAT], had performed as robust predictors as well. This claim was proved by the analysis of variance that produced P=0.005 as displayed in Table 7. This meant that if we predict the quality index of [FLOAT] based on the three independent variables as many as 1000 times, it would be fail only 5 times. It was important to note, anyhow, that the achievement occur after we omitted the 3 data outliers.

Tabel 7. Analysis of Variance of quality index of a-1000dried bean

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%

In contrast to the index of quality [WD_1000], the effect of shifting cultivation upward would decrease the ripe coffee cherry bean quality index quality [FLOAT]. As depicted in Table 8, there is a rise of float cherry bean at average of 1.993% for each 100m shifting elevation area of cultivation [ELV] upward, and vice versa. The increase was significantly difference as connoted by P=0.007. The fact perhaps was caused by the activity of rampant borer insects for cherry coffee beans, followed by the shifting up of the elevation of the cultivation areas. The higher the elevation, the more humid the air which further accompanied by the decreasing air temperature. This argument also supported by the Eq. {1} expressed above. There are some possible explanation to the fact especially in its connection with the borer pests that are controlled by air temperature or humidity. For example, Jaramillo *et al.*, (2009) proved that the activity of *Hypothenemus hampei*, insect borer of family of *Scolytidae*, is optimum in between air temperature around 15-35^{0}C. The female activity in boring coffee fruit will drops drastically when air temperature is reaching 35^{0}C. The insect also normally fail to spawn, and then leads to suppression of the propagation of their offspring and lessen the boring of cherry bean. Otherwise, the offspring will abundant and the intensity of boring the coffee cherry fruit will rampant then worsen the quality that collected from the higher elevation of the study areas that air temperature decline from 35 to 15 ^{0}C.

As depicted in Table 3, the air temperature record during the study was between 22-32^{0}C. This record seems very concurrent with this argument. Jaramillo *et al.* (2011) estimated that climate change would worsen pest prevalence as the berry borer that could coffee fruit and bean quality. According to Patay *et al.*, (2016) in warm and humid climate, Coffea species are susceptible to various fungal infections, which can kill them in large areas. The most common fungal disease of coffee species is caused by *Hemileia vastatrix* Berk. & Broome, a basidiomycota, which causes a ecoloration on the lower surface of the leaves.

Tabel 8. The *T-test* to examine the independent variables that affect the percentage of the floated ripe coffee fruit

Predictor	Coef	SE Coef	T	P
Constant	-1.243	6.085	-0.20	0.840
[ELV]	1.9929	0.6743	2.96	0.007
[STEEP]	-0.0845	0.2349	-0.36	0.722
[D_SHT]	-1.475	4.534	-0.33	0.748
[D_WST]	3.446	3.346	1.03	0.313
[D_NRT]	-8.021	3.545	-2.26	0.033

In addition the above explanation, Agegnehu *et al.*, (2015) record that the variation of precipitation and air temperature variables are the most favorable to increase of coffee pest disease. Major disease that occurred because of the two climate variables' variation during coffee growing will increase pest and disease prevalence, expanding the altitudinal range in which the fungal disease coffee rust and the coffee berry borer can survive (Laderach *et al*., 2010). For example, rising temperatures will increase infestation by the coffee berry borer that is *Hypothenemus hampeii*, particularly where coffee grows unshaded and the cropping is continuous throughout the year.

As those to the cherry bean quality index of [WD_1000], the slope steepness [STEEP] are not significantly impacting the coffee fruit quality in term of quality index of [FLOAT]. The fact was not completely understood. Perhaps the range of slope steepness in whole area of study was relatively homogenous so does the susceptibility cherry fruit of coffee the pest. It was because the rate of soil erosion was too low that the soil fertility were homogenous too and made nutrient uptake by the crop was indifferent in term of the stance against pest and disease of the coffee crop. But further studies on the effect of slope steepness on the soil fertility, the crop's endurance to the pest, and the percentage of floating coffee fruit are necessary.

As for the impact of the area exposition to the cherry fruit quality index of [FLOAT] also shown a similar characteristic: only the northward direction of cultivated area exposition [D_NRT] which significantly different effect from the eastward one. But in this matter, it was a reverse compared to the effect on the quality index of [FLOAT] variable. The variable of [D_NRT] variable could produce the floated cherry fruit around 8.02% lower than that of the eastward direction. This discrepancy was significant as connoted by P=0.033. We thought that the explanation to this fact was certainly similar with the effect of area exposition to the coffee bean's quality index of [WD_1000] that the coffee crop which against the solar beam would much more influent but opposite in value. In this matter of fact the solar beam had given the positive impact on the quality cherry coffee fruit. This fact was not also completely understood; how the relationship among the solar beam, the endurance to the pest, and the abundance of the coffee fruit floated in water.

The regression equation of the percetage of floated coffee fruit as the function of the elevation, slop steepness, and the expotion of the cropping area is expressed in the Eq {3}, as follows:

[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}.

CONCLUSION

For each 100m shift in cropping area onto the upper stream region there would be an antagonistic indices between the two. The index of [WD_1000] will increase by 24.18g/1000 dried beans while the [FLOAT] will increase by 1.99% of floating. It is recommended to conduct further research on revealing the effect on the coffee cup taste.

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