Coffee Farming Vulnerability: Environmental Dimension Approach in Way Besai Sub-Watersheds

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ABSTRACT
The purpose of this research was to identify the attribute determinants of environmental dimensions that support sustainable production in coffee farming, especially surrounding the watershed area. The research location was a coffee production center surrounding protection forest upstream of Way Besai sub-watersheds, West Lampung. The primary data was collected from the coffee farmers' household during April–May 2021, involved 165 respondents and was conducted by survey method. The data were analyzed using binary logistic regression with the stepwise forward (Wald) method. The result performed that drought, climate, and landscape changes caused the vulnerability of coffee farmer's communities. Changes in the landscape were the cause of the most severe vulnerability of coffee farmers in upstream watersheds. The odd value of the drought ratio of 2.8 indicated that coffee farmers faced 2.8 times the risk of being vulnerable if there was a drought in their farming process.

Keywords: *Coffee farming vulnerability, Environmental dimension, Vulnerability.*

1. INTRODUCTION

Sustainable production in watersheds (DAS) is a severe challenge for farmers. There is a trade-off between economic benefits (productivity) and the sustainability of environmental carrying capacity, including climate change, which poses a risk of farming failure. Resilience and the ability to mitigate climate change risks in upstream watershed areas will determine sustainable agricultural production. The main strategic watersheds (DAS) in Lampung Province are the Sekampung and Way Seputih watersheds. The degradation in the upstream watershed in Lampung occurs due to changes in land use and vegetation cover. Damage in the upstream watershed includes erosion, sedimentation, fluctuations in river discharge, and decreased land productivity. The linkage between global climate change, land use, and food production is very strategic in national development [1]. A strengthened effort to enhance the resilience and adaptation of farmers through increasing the adaptation toward difficulties and the risk needs to be carried out [2, 3]. The purpose of this research is to identify and determine the determinants of environmental dimensions that support sustainable production in coffee farming, especially in the surrounding watershed area. Determinants of environmental dimensions from local communities that support resilience and mitigation are very useful as a trigger for community participation in implementing sustainable production.

Resilience in facing risks is vital in ensuring farming sustainability. Sustainable production to achieve long-term prosperity is a global pillar of agricultural development in the SDGs (Sustainable Development Goals) [4]. Sustainable agricultural systems are determined by socioeconomic characteristics that differ between behaviours [5, 6]. Institutions play a central role in achieving community empowerment goals through innovation and technological adaptation to improve sustainable production systems [7, 8, 9]. Adaptive management policies are needed for economic and ecological goals with minimum environmental risk [6, 10].

Environmental risks occur across a wide range of fields, including climate change [11], extreme weather [12, 13], water scarcity [14, 15], deforestation, land degradation, loss of biodiversity [16], ozone depletion, to chemical pollution [17, 18]. Environmental stress disrupts production stability and has the potential to reduce people's income. Therefore, increasing the ability to adapt to difficult conditions or the risk of business unsustainability is needed [3, 19]. A socioeconomic and environmental risk management roadmap developed to strengthen the capacity farmers face the threat of unsustainability is closely related to adopting technology for sustainable production (resilience). The resilience of farmers in upstream watersheds in facing risks is closely related to adaptation to changing facts r-socioeconomic and environmental factors.

The ecological environment tends to change gradually and creates vulnerability due to various destruction and degradation of natural conditions. Ranging from evident susceptibility to recessive susceptibility depends on the effects of sensitivity, exposure, and adaptability. Without efforts to maintain a stable ecosystem balance, the vulnerability of agricultural forests will worsen [20]. The risk of the environmental vulnerability assessment is linked with a temporal and spatial distribution [21].

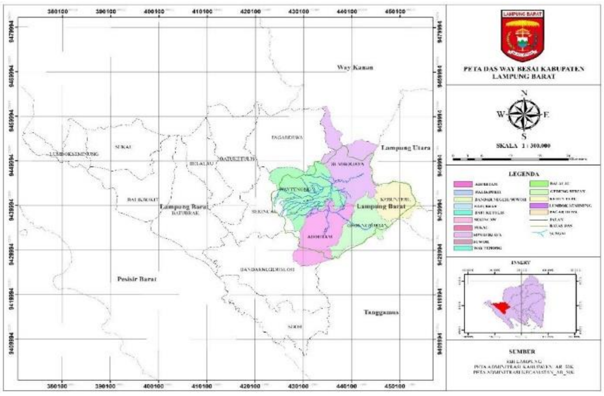
This research is integral to developing sustainable agricultural production in plantation crops (coffee, cocoa, pepper) in the upstream watershed area. It also includes the resilience of farming actors to environmental changes/extreme climatic disturbances. The originality of this research lies in exploring the determinants of local wisdom that strengthen the resilience and ability of local farmers in dealing with and overcoming disturbances in production and family income. The vulnerability of agricultural households due to production disturbances from external environmental factors can be traced through farmers' responses to changes in environmental elements. Farmers' responses to environmental dynamics develop along with civilization and capacity building of local wisdom. Resilience based on local wisdom will support the ability of farmers to make decisions on the application of good agricultural practices for sustainable production and further improve their standard of living and welfare. Sustainable production decisions are essential considering the advantages of the latest innovations and the ability of farmers to adopt the technology. This study identified and determined the environmental dimensions that supported the resilience of sustainable coffee production in watersheds areas.

2. METHODS

2.1. Study sites

The study included three sub-districts in West Lampung that lying the Way sub-watersheds, Lampung, Indonesia. They were Sumber Jaya, Way Tenong, and Air Hitam sub-district. Way Besai River Watershed has about 405.846 km2 of area and is located in 5 sub-districts: Sumber Jaya, Gedung Surian, Air Hitam, Kebun Tebu, and Way Tenong, as shown in Figure 1.

The land use of the Way Besai watershed has four types of land cover, and they were for residential areas, agriculture, plantation, and forestry areas. The Besai sub-watershed is part of the upstream of the Tulang Bawang watershed, which is downstream in the East Lampung region. Administratively, the Besai sub-watershed is in the Sumber Jaya sub-district, West Lampung Regency. As the headwaters of the Tulang Bawang watershed, Sumber Jaya plays a vital role in maintaining the sustainability and function of the Tulang Bawang watershed.



Sub-watersheds of Way Besai involved five sub-districts:
1. Sumber Jaya,
2.Gedung Surian, 3. Air Hitam,
4.Kebun Tebu, and 5. Way Tenong

Figure 1 Site-research location sub-watersheds of Way Besai.

2.2. Data collection and analysis

The research was conducted by survey method, and the primary data was collected from the coffee farmers households during April–May 2021. Households were randomly selected, considering the representation of land tenure, land conservation program, and catchment area. The sample size counted proportionate consider 95% confidence level. The total number of the respondent was 167 farmers. The questioner set used the Likert scale with the range value: (1) Very bad; (2) Bad; (3) Moderate; (4) Good; (5) Very good.

Table 1. Short cut keys for the template

Environmental attribute
Disaster preparedness (X1)
Erosion/landslide (X2)
Flood (X3)
Drought (X4)
Climate (X5)
Disaster incident (X6)
Ecosystem care (X7)
Land-use (X8)
Land carrying capacity (X9)
Biodiversity (X10)

The estimation model for environmental dimension determinants uses binary logistic regression with the stepwise forward (Wald) method. Generally, the formula of the basic regression model is as follows [22, 23, 24, 25, 26, 27]:

$$\frac{Pi}{\ln\ln\frac{Pi}{Px}} = Y \quad (1)$$

$$Y = \alpha + X + \quad (2)$$

If n observations are used to make this regression model, then the model for each observation are:

$$Yi = \alpha + Xi + I \quad (3)$$

$$Yi = \alpha + 1X1i + 2X2i + + k\,Xki + I \quad (4)$$

The binary logistic regression model for this study was defined as follows: Y was constructed by vulnerability categorical as binary (vulnerable=0; resilience=1) from PX / P1-PX = Odd ratio, which is a comparison of the opportunity of people who tend to be vulnerable (0) or resilience (1) as Y variable. X1…X10 are explanatory environmental risk attributes as displayed in Table 1. 1 …10 are estimated regression coefficients/parameters associated with the explanatory variables. Respectively, α is a constant, and i is a random error.

3. RESULTS AND DISCUSSION

Smallholders scale farming usually cultivate most of the coffee plantations in Indonesia. The land topography of coffee farms is categorized as a sloped land in the surrounding area of mountainous and watersheds. The characteristics of the coffee farms' environmental conditions are related to topography, climate, biodiversity, land class, and soil nutrient content quality. Therefore, the biophysical condition of the land is an indicator of the carrying capacity of the environment. The carrying capacity of coffee farming land results from efforts to apply sound agricultural cultivation principles with land conservation techniques. The primary disturbances to coffee growing areas in sloped areas are landslides, erosion, extreme climate disturbances that cause floods and droughts, attacks by plant-disturbing organisms, the loss of biodiversity, and disturbances to the hydrological cycle [30]. In areas with a risk of natural disturbances to agricultural production, farming actors are very vulnerable to environmental stresses that can lead to disturbances in the condition of food security [29], health, and environmental damage. The vulnerability of coffee farmers at high elevation shows from poor access to infrastructure, restrictions on shade management, and reported higher dependence on income from coffee [30].

The response of coffee farmers in dealing with environmental dynamics that create vulnerability is related to demographic conditions, including regional/ethnic origin, gender, education, experience, and land management rights. Based on the results of the household surveys of farmers, the following are the

Table 2. Demographic characteristics of respondents

Gender	Man	159	96
	Woman	7	4
Ethnic	Javanese	94	57
	Sundanese	65	39
	Semendo	7	4
Experience (years)	<5	38	23
	5-10	17	10
	>10	20	12
Age (years)	21-36	54	33
	37-51	73	44
	52-66	29	17
	67-80	10	6
Education level	Elementary School	88	53
	Yunior High School	43	26
	Senior High School	35	21
Coffee farm (are)	0.5-1.66	133	80
	1.67-2.83	21	13
	2.84-4.0	7	7

demographic conditions as the main characteristics of the respondents. The information related to the demographic situation includes gender, ethnicity, experience, age, education, and coffee plantation area. The demographic conditions of the respondents are presented in Table 2.

Table 3. The result of binary logistic analysis of vulnerability analysis

Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Drought	1.016	.215	22.302	1	.000	2.763
	Constant	-2.878	.538	28.618	1	.000	.056
Step 2[b]	Drought	.881	.219	16.179	1	.000	2.413
	Land_scape	1.104	.269	16.875	1	.000	3.015
	Constant	-6.954	1.191	34.072	1	.000	.001
Step 3[c]	Drought	1.059	.244	18.841	1	.000	2.883
	Climate	-.703	.280	6.316	1	.012	.495
	Land_scape	1.165	.274	18.082	1	.000	3.208
	Constant	-5.330	1.337	15.890	1	.000	.005

Respondents were dominated by men, with coffee farming experience between 5-10 years. Generally, respondents were in the age range of 21-51 years, classified as productive age. Javanese and Sundanese were dominant. Respondents with an education equivalent to primary school looked were 51%. The coffee plantation area of 80% of respondents is in the range of 0.5-1.66 ha. Furthermore, based on the information on the characteristics of the respondents, cross-tabulation was carried out using a boxplot diagram, which juxtaposed the condition of the plantation area with the status of land tenure and ownership (Figure 2).

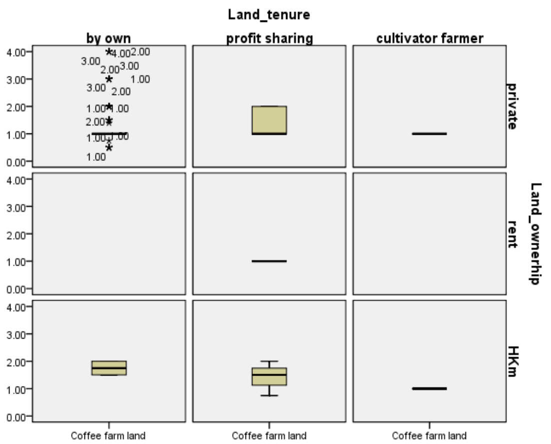


Figure 2 Boxplot coffee farmland based on land tenure and land ownership.

Based on the paired sample test on gender-ethnic conditions and experience and age, it was found that the results were significantly different. Coffee farmers in the research area are mainly male and come from Javanese and Sundanese ethnic groups. This condition illustrates that gender and ethnicity, experience, and age provide the respondent's performance in coffee farming activities.

The surveys conducted on coffee farmers household indicated that resilience level categorizes as vulnerable and resilience. Most coffee farmers were at a vulnerable level (81.6%). The results of the binary logistic analysis are shown in Table 3-binary logistic trough stepwise forward with the Wald approach. The Hosmer and Lemeshow test in the second step showed the significance level.

The analysis revealed that drought, climate, and the landscape became the primary determinants of the vulnerability of coffee farmers in upstream watersheds. It is known that the factors of drought, climate, and landscape are the determinants of the causes of coffee farmers vulnerability in the watershed area. The odd value of the drought ratio of 2.8 indicates that coffee farmers face 2.8 times the risk of being vulnerable if there is a drought in their farming process. Climate disruptions have impacted several types of agricultural products, and the direct impacts threaten the yield of crop viability. The potential impacts of global climate change broadly severe food production farms and disrupt the food supply chains. It may be challenging for farmers with low-profit margins. The adverse effects are across the agricultural system, so strain and failures compound problems and make farming less viable. Response to drought varies widely based on crop and pheno-phase [28].

The current study linked with the coffee-related climate change impacts and risks focuses heavily on ecological niche modelling, mostly coupled with machine learning techniques. Dangerous climate hazard and exposure impacts for coffee-producing regions could be potentially offset by targeting climate adaptation support to these high-risk regions. It relies heavily on current understanding of the correlates of climate vulnerability in rural regions, and for coffee expressly, the causes of climate vulnerability are poorly understood. Future studies should supplement this research by analyzing the mechanisms underlying coffee farmers' vulnerability, including in-depth field interviews [31].

Meanwhile, changes in the landscape of agricultural land use have an odds ratio value of 3.2. This value means that land-use changes in agricultural areas 3.2 times can lead to the vulnerability of coffee farming households in the upstream watershed area. This condition is also explained by Morel [30] that land farms with elevations between 1500 m and 1600 m with canopy openness between 40% and 45% as being consistently low yielding. They have poor access to infrastructure, restrictions on shade management; they tend to be vulnerable.

4. CONCLUSION

The result performed that drought, climate, and landscape changes caused the vulnerability of coffee farmers communities. The landscape changes became the most severe cause of vulnerability to coffee farmers in upstream watersheds. The odd value of the drought ratio of 2.8 indicated that coffee farmers faced 2.8 times the risk of being vulnerable if there was a drought in their farming process. It could be understandable that those determinants became the most critical elements of environmental exposure. The primary determinant of the vulnerability of coffee farmers communities in the environmental dimension would be considered in developing a resilience model in upstream watersheds.

AUTHORS' CONTRIBUTIONS

All authors conceived and designed this study. All authors contributed to the process of revising the manuscript, and at the end all authors have approved the final version of this manuscript.

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