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Abstract. This study aims to analyze the vulnerability of Gayo highland smallholder coffee farmers in Indonesia. On the one hand, this region produced premium quality arabica coffees, but on the other hand, it is prone to flooding and landslides. This study employs household survey data of 34 affected coffee farmers collected in 2020. A Livelihood Vulnerability Index (LVI) approach was employed to evaluate the vulnerability to floods and landslide impacts using different indicators along with three major components i.e. sensitivity, exposure, and adaptive capacity. The results showed that the livelihoods of Gayo coffee farmers are vulnerable to floods and landslides impacts and necessarily need efforts to improve their adaptive capacity.

1. Introduction

Indonesia is the fourth biggest coffee producing country in the world with a total Robusta and Arabica production of around 10,000 thousand of 60kg bags annually [1]. Geographically, Aceh Tengah and Bener Meriah districts of Aceh Province have been known as the largest Arabica coffee producing regions in Indonesia [2]. On May, 13t^{h} 2020, Paya Tumpi village of Aceh Tengah District was hit by floods and landslides and resulted in considerable losses for the community, especially in terms of coffee estates (Figure 1). Dozens of hectares of coffee plantations and 35 houses were reported affected [3]. Coffees have generally been the main livelihood for local residents for decades.

Globally, coffee production is an important income for millions of farmers living in tropical regions [4]. Coffees have also been one of the agricultural commodities that is most actively traded and about 90 percent of the coffee supply comes from developing countries such as Indonesia, Brazil, Vietnam, and Colombia [1]. However, the production risks are increasing due to global climate change which is expected to raise the temperature in coffee growing regions, changing precipitation patterns, and increase climate variability [4,5]. The gradual changes in

the coffee environment will eventually affect the growth and development of the coffee crop [6]. In the end, a decreasing yield and coffee quality will have negative effects on farmers' livelihoods around the world.

Figure 1. The damages on coffee plantations and housings due to flooding and landslides in Paya Tumpi Village

The overall objective of the current study is to conduct an indicator-based livelihood vulnerability assessment of the Gayo smallholder coffee farmers at floods and landslides affected areas in the Paya Tumpi Village in the Aceh Tengah district. For crops cultivated in sloopy land, low degrees of temperature and high intensity of rain such as coffee, floods and landslides are the common risks causing substantial losses. It takes 3-4 years for coffees to be first harvested whereas the disaster events may occur periodically. The events greatly hampered the local community's livelihood physically, socially, and economically. In this area, coffee farming is their main source of income and some of the households were forced to stop completely due to severe damage to their coffee plantations. Worse yet, they had to evacuate and were unable to find work outside the village.

2. Method

2.1. Study Area and Households Survey

This study selected Paya Tumpi Village in the Kebayakan Sub-District of Aceh Tengah District (Aceh Province, Indonesia) as the main study area. The flood and landslides damaged this area on May 13th, 2020 including approximately dozens of hectare of coffee farms. Although the size of the affected coffee farms was relatively small, the disaster caused a significant impact on 135 coffee farmers living in this area. We are interested in surveying the current impacts of the disaster on smallholders' coffee farmers' vulnerability. We surveyed 33 households from July, 3 - 11th 2020 and conducted interviews using structured questionnaires to collect the data related to lose and damage figures on coffee production, demography, and the change in livelihood vulnerability components.

2.2. Livelihood Vulnerability Index (LVI)

The LVI consists of seven components: Socio-Demographic Profile, Livelihood Strategies, Social Networks, Health, Food, Water, Natural Disasters and Climate Variability [7–10]. In this study, we combined Food and Health into one component and added another component called Institutional Capacity [16]. Each component is divided into several indicators [11,12]. For example, there are 11 indicators of Socio-Demographic including dependency ratio, head of the household's school attending period, etc. (Table 2).

Similar to rural communities, coffee farmers are characterized by a poor-resource environment [7]. Limited data and responses were available. Therefore, simplification should be

adapted to presenting the result. For example, using natural disaster data in the province or district levels will be irrelevant since floods and landslides only affected limited areas in the Paya Tumpi village. Therefore, we preferred to list historical data using online news and entered keywords such as "paya tumpi flood or paya tumpi landslide" from the year of 2010 to 2020. Another challenge was data collection on temperature and daily precipitation. We are reluctant to apply national or provincial data supplied by the national climate body as these approaches have been used broadly in previous study [7,13–16]. We consider that coffee-producing regions tend to be colder with the gap approximately around 10-15 degrees celsius compared to other areas in the same province. Secondly, there are only three climate stations within Aceh Province where their location cannot be used for the references, nor the 30-year data is available. Other than data on natural disasters and climate variability, we used data based on the field survey.

Sullivan *et* al. proposed an equal balanced weighted average approach where each of the sub-components has an equal contribution to the overall index even though each of the major components comprises a different number of sub-components [17]. Additionally, we applied standardization on each sub-component score using the UNDP Human Development Index on Life Expectancy Index [18] in order to obtain a common index because each sub-component was quantified on a different scale:

$$index_{sd} = \frac{S_d - S_{min}}{S_{max} - S_{min}}$$

where s_d is the original sub-component for district d, and s_{min} and s_{max} are the minimum and maximum values.

After the index for each of the eight sub-components is calculated, they are averaged using Eq. (2) to obtain LVI at the village level

$$LVI_d = \frac{\sum_{i=1}^{8} W_{M_i} M_{di}}{\sum_{i=1}^{8} W_{M_i}} \quad (2)$$

which can also be expressed as

$$LVI_d = \frac{W_{SD}SD_d + w_{LV}LV_d + w_{SN}SN_d + w_{IC}IC_d + w_{FH}FH_d + w_{LA}LA_d + w_{ND}ND_d + w_{CV}CV_d}{w_{SD} + w_{LV} + w_{IC} + w_{SN} + w_{FH} + w_{LA} + w_{ND} + w_{CV}} \quad (3)$$

where LVI*d*, Livelihoods Vulnerability Index for district d, is equal to the weighted average of the eight main components. In this study, LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

3. Result

3.1. Coffee Production and Household Characteristic

Table 1 shows that the area of coffee owned by farmers ranges from 1 to 3 Hectares and approximately 72 percent of the farmers owned 1 Ha. Meanwhile, for land ownership status, 96 percent of respondents claimed that the land was privately owned, either because they bought the land or it was inherited by their parents. Experience in coffee cultivation is quite diverse, mentioned between 5 to 15 years. The age of coffee crops varies greatly, starting from 5 to 20 years. Most of the capital used by farmers comes from private funds or savings from the previous harvest as well as non- agricultural income if any. Farmers are generally living in semi-permanent houses that are prone to disasters such as floods and landslides.

Table 1 Coffee Production and Household Characteristic

Demographic Characteristic	Type	Sample (%)	
		Freq	Percent
Land size	1	24	72.73
	2	5	15.15
	3	4	12.12
Land status	Owned	32	96.97
	Rent	1	3.03
Experience	5	5	15.15
	10	6	18.18
	15	22	66.67
	5	12	36.36
Year of Coffee Crops	10	10	30.3
	15	7	21.21
	20	4	12.12
Capital	loan	2	6.06
	Self-owned	31	93.94
Farm group	No	20	60.61
	Yes, active	8	24.24
	Yes, but not active	5	15.15
Cooperative	No	28	84.85
	Yes	5	15.15
House Structure	Permanent	13	39.39
	Semi-permanent	17	51.52
	temporary	3	9.09
Main Job	Farmer	25	75.76
	Non-Farmer	8	24.24
Gender	Female	11	33.33
	Male	22	66.67
Dependants	0	5	15.15
	1	1	3.03
	2	8	24.24
	3	9	27.27
	>3	10	30.3
Member of the family working on agriculture	1	5	15.15
	2	24	72.73
	3 or more	4	12.12

3.2. Livelihood Vulnerability Index

Table 2 shows the organization of the three major components in the LVI framework. The exposure of the study is measured by the components of Natural Disaster (ND) and Climate Variability (CV). The natural disaster accounted for the number of floods and landslides that have occurred in the 10 years while climate variability is measured by the mean standard deviation of the maximum and minimum monthly temperatures and monthly precipitation over a 1982-2012 period. In the case of sensitivity, it is represented by the Food and Health (FH), and the Land and Agricultural Activity (LA). Last, the adaptive capacity is quantified by four components e.g. Socio-Demography (SD), Livelihood Strategy (LV), Social Network (SN), and Institutional Capacity (IC). Table 2 revealed that the result of the indices of the major component ranged from 0.311 to 0.475. Overall, the LVI in Paya Tumpi village was estimated at 0.366 implying a medium level of vulnerability. The results of the current study support the previous research on households' vulnerability to social capital, human capital, and natural hazards within the context of the different livelihood frameworks [19–21].

Table 2 Livelihood Vulnerability Index

Code	Indicator	Unit	min	max	LVI indicator
ND01	average annual flood events over the last 10 year	times	0,00	2,00	0,300
ND02	average annual landslides over the last 10 year	times	0,00	2,00	0,250
	Natural Disaster				**0,275**
CV01	mean, std. deviation monthly average min-temperature (1982-2012)	Celcius	11,7	13	0,325
CV02	mean, std. deviation monthly average max-temperature (1982-2012)	Celcius	21,3	23,10	0,360
CV03	mean, std. deviation monthly average precipitation (1982- 2012)	mm	70	231	0,358
	Climate Variability				**0,348**
FH01	food insufficiency over the last 3 months	scale	0,00	0,50	0,561
FH02	healthcare support over the last 3 months	scale	0,00	0,50	0,530
FH03	health expenses over the last 3 months	IDR	0,00	0,50	0,114
	Food and Health				**0,402**
LA01	land size per family member	ratio	0,03	5,00	0,091
LA02	years of coffee plantation	years	2,00	26,00	0,327
LA03	land status	binary (1/0)	0,00	1,00	0,030
LA04	number of coffee stem over the total of coffee areas	Unit/ Ha	156,63	6000	0,265
LA05	size of arable land	Ha	0,10	10	0,195
LA06	percentage of watered land size	percent	0,00	100	0,390
LA07	crop diversity index	unit	0,33	1,00	0,608
LA08	uncultivated land due to landslide	m2	0,00	625	0,122
LA09	uncultivated land due to flooding	m2	0,00	1200	0,070

LA10	chemical fertilizer usage	kg	0,00	900	0,104
LA11	source of coffee seeds	binary (1/0)	0,00	1,00	0,091
LA12	coffee disease	binary (1/0)	0,00	1,00	0,364
	Land and Agricultural Activity				**0,221**
SD01	dependency ratio	scale	-	-	0,478
SD02	head of household's education	scale	0,00	0,80	0,394
SD03	family member with computer literacy	binary (1/0)	0,00	3,00	0,253
SD04	family member with internet literacy	binary (1/0)	0,00	3,00	0,323
SD05	family member with english literacy	binary (1/0)	0,00	2,00	0,212
SD06	structure of building	scale	0,00	1,00	0,348
SD07	highest education level in the family	scale	0,00	0,90	0,310
SD08	coffee farming years of experience	1/years	0,02	0,66	0,171
SD09	mobile banking experience	scale	0,25	1,00	0,859
SD10	internet payment experience	scale	0,25	1,00	0,869
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SD08	coffee farming years of experience	1/years	0,02	0,66	0,171
SD09	mobile banking experience	scale	0,25	1,00	0,859
SD10	internet payment experience	scale	0,25	1,00	0,869
SD11	ATM payment experience	scale	0,25	1,00	0,616
	Socio-Demographic				**0,439**
LV01	member of family working outside agriculture	binary(1/0)	0,00	1,00	0,455
LV02	dependency on agriculture as main livelihood	binary (1/0)	0,00	1,00	0,758
LV03	capital source	binary (1/0)	0,00	1,00	0,061
LV04	member of family working in coffee states	1/person	1,00	4,00	0,283
LV05	raising cattle	binary (1/0)	0,00	1,00	0,576
	Livelihood Strategy				**0,426**
SN01	member of coffee farmer group	scale	0,00	1,00	0,712
SN02	member of the certified coffee cooperative	binary (1/0)	0,00	1,00	0,879
SN03	member of the cooperative committee	binary (1/0)	0,00	1,00	0,970
SN04	family member involved in communities	1/person	0,00	1,00	0,539
SN05	nearest relatives	1/person	0,14	2,00	0,259
SN06	subsidy from government	1/frequency	0,20	1,00	0,783
SN07	number of recognized collector	1/person	0,16	1,00	0,281
SN08	number of recognized wholesaler	1/person	0,25	1,00	0,686
	Social Networks				**0,639**
IC01	access to agricultural inputs	km	1,00	24,00	0,189
IC02	access to main roads	km	0,00	8,00	0,249
IC03	access to education	km	0,10	7,00	0,300
IC04	access to drinking water	km	0,00	3,00	0,197
IC05	access to health facilities	km	1,00	10,00	0,256
IC06	access to the nearest city	km	1,00	10,00	0,460
IC07	access to credit facilities	binary (1/0)	0,00	1,00	0,788
IC08	access to weather information	binary (1/0)	0,00	1,00	0,576
IC09	access to agricultural extension	binary (1/0)	0,00	1,00	0,545
	Institutional Capacity				**0,396**
	Exposure (ND+CV)				**0,311**
	Sensitivity (FH+LA)				**0,311**
	Adaptive Capacity (SD+LV+SN+IC)				**0,475**
	Livelihood Vulnerability Index				**0,366**

Paya Tumpi village recorded the highest index on the adaptive capacity at 0.475 which was mainly sourced from the social network (0.639). The respondents reported less involvement in the farmer groups as well as coffee cooperative (including certified coffee schemes). However, the respondents reported that their nearest relatives live in the same village and they have close relationships with a number of local coffee collectors.

In terms of natural disaster and climate variability, the respondent in Paya Tumpi reported a relatively medium level of vulnerability (0.275 and 0,348). Based on the historical online news, we recorded one to two floods and landslides per year. Due to the limitation of the information, we could not manage the analysis related to the duration, the height of the water, or the size of affected areas in the past.

We prefer to combine Food and Health as a single component due to their minor influence on the major component of sensitivity. Most of the previous studies [13,15] put their interest in the African countries where the environment may changes extremely eg. severe dry season that causes food insufficiency. However, such cases are rare in Indonesia and in the study area. Shortage of food and water might occur due to short supply or transportation issues rather than failed harvest due to extreme seasons. During the post-flood recovery period (at the same time we conducted a survey), Paya Tumpi respondents reported a higher level of vulnerability on food insufficiency at 0.561. Land and agricultural activity reported a relatively lower level of vulnerability since the highly affected coffee planting (totally destroyed by the floods and landslides) was owned by a limited number of farmers (5 persons). However, this study found that the crop diversity index poses a higher level of vulnerability in the affected areas in comparison to typical rural areas.

4. Discussion

4.1. Impact of Disaster on Household Vulnerability

Most of the respondents in this study were male (67%) and we found that none of the households were female-headed. The absence of this vulnerable group may reduce the vulnerability of the Socio Demography component significantly. However, we found that the dependency ratio is quite high (0,478). Furthermore, the typical house structure in the affected areas was prone to floods and landslides (51,52% of the total housing was semi-permanent) contributing to a vulnerability index at 0,348. We also looked at the respondent's financial digitalization experiences and this study found that these indicators reported a higher vulnerability level (e.g. mobile payment: 0,869, internet banking: 0,859, ATM payment:0,616). Since the victim lost their houses and needed to evacuate just after the event, the households have to deal with a number of dependents and cash for daily life. Those indicators on the Socio Demography component have been played important factors.

4.2. Coping Strategy and Social Capital

Land ownership is the main factor in which the farmers are more independent. The respondents recorded that the coffee lands were inherited by their ancestor (rented land was only 2% of the total respondents) rented with a relatively large size (1 ha or above). Moreover, it was seldom to meet farmers whose capital was credit from the banks. Therefore, the increase in land rental fees and loan interest rate will not affect their financial vulnerability. However, Gayo coffee farmers in Paya Tumpi village showed greater vulnerability to agricultural dependency (0.758). A lower percentage of Paya Tumpi households reported having side-occupation or working in other areas (member of family working outside agriculture index: 0.455). These imply the limitation of coping strategies to minimize the negative impacts of the disaster.

The village is characterized by a semi-urban, short distance to the central business district, higher diversity of socio-economic structure, and weaker bonds of social groups. These characteristics contribute to the lower bond on their social interactions. Social Network, which is normally dominant in the rural areas, were found to have a higher degree of vulnerability in this

study. The respondents reported a lower degree of involvement in the community groups e.g coffee farmer groups, coffee cooperatives as well as joining in the community meetings. During the flooding, the victims depended more on aids from the governments rather than from their internal communities. The role of social capital such as social networks seemed to be reduced and this situation increased their vulnerability.

5. Conclusion

This study presented the LVI for assessing the vulnerability of Gayo coffee farmers at Paya Tumpi communities to floods and landslide impacts using indicators that have been extracted from the three major components i.e. sensitivity, exposure, and adaptive capacity. The results showed that the livelihood of coffee farmers are vulnerable to floods and landslides impacts and necessarily need efforts to improve their adaptive capacity.

The main implication of the current study is the need for the responsible stakeholder of the Aceh Province to improve disaster awareness and preparedness to mitigate the vulnerability of smallholder coffee farmers to future floodings and other events. While exposure can be difficult to manage due to its geographical and environmental conditions in the coffee farmings, the coffee farmers' vulnerability relies on the level of sensitivity and adaptive capacity. In terms of sensitivity, Paya Tumpi coffee farmers were more vulnerable after the disaster, mainly because of the delay and insufficiency of basic needs such as food, etc during the response, insufficient health care, and less diversity in crops. The farmers relied on a single commodity and coffee states were their most important assets. Therefore, the impacts of the disaster are very sensitive to their livelihood. Moreover, this study reveals that the community adaptive capacity is the main concern since the social network plays an insignificant role in their resilience.

The main policy implication is that the government should reform environmental, institutional, and economic conditions to promote resilience and reduce negative impacts due to potential disasters in the future. Landslides and floods which occurred more frequently in the study area are one of the indirect impacts of historical illegal lodging and land-use changes. The government and the communities should work together to maintain coffee competitiveness as well as to protect forest sustainability. Moreover, comprehensive plannings and risk assessment initiatives e.g risk mapping and housing relocation are necessary to be delivered to reduce Gayo smallholder coffee farmers' vulnerability.

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