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Assessment of Livelihood Vulnerability to Climate Change Using Three Index Methods

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ABSTRACT

Vulnerability assessment based on composite indices such as Livelihood Vulnerability Index (LVI) or Sistem Informasi Data Indeks Kerentanan (SIDIK) is widely used, and it is practically known as the initial step to determine the adaptation policies for climate change. Various vulnerability assessment methods that have been developed including LVI and SIDIK raise the possibility that different methods can lead to different conclusions. This research aimed to assess whether the results of vulnerability analysis using different methods on the same data offer consistent results. Comparative studies on this topic based on the different indexing methods may also provide a beneficial insight for stakeholders. We tested LVI, LVI-IPCC, and SIDIK methods in Tanah Merah and Lobuk villages in Sumenep Regency, East Java. We collected the primary data based on interviews with households in the field. Climate data (monthly rainfall, maximum, and minimum air temperature) with 0.05° spatial resolution from 2001-2020 was obtained from CHIRPS and TerraClimate. Our results showed that both villages were consistently categorized as vulnerable according to LVI, LVI-IPCC, and SIDIK methods. This result is also consistent at village and household levels. The findings showed difference in the key indicators driving the vulnerability in both villages. The key indicators in Tanah Merah Village were households without waste management, training from government, and no early warning system. In contrast, the key indicators driving the vulnerability for Lobuk were households with small land ownership and households with debt. Further, action recommendations for Tanah Merah are providing waste banks and waste sorting facility, upgrading public capacity through workshops, and adopting social media to share climate-related information. For Lobuk, the recommendations are the determination of regulatory instruments related to space utilization in the coastal area, mapping area affected by climate change, and financial literacy improvement especially promoting savings in the community.

KEYWORDS
household vulnerability, livelihood strategies, Livelihood Vulnerability Index (LVI), LVI-IPCC, SIDIK

INTRODUCTION

Climate change has become a global problem with various impacts that vary among regions and society. Community in developing countries such as Indonesia is one of the most affected and most vulnerable groups to climate change impact as their low adaptive capacity and limited access to production infrastructure (Rozari et al., 2011; Sekaranom et al., 2021; Suciantini et al., 2008). Assessing climate change vulnerability and evaluating the contributing factors of the vunerability are the initial step required to develop adaptation policies and strategies for risk reduction (Huong et al., 2019). Vulnerability assesment shall integrate and test the interaction between human and their physical, social, economic, and political environment (Pachauri et al., 2014; Sarjana et al., 2009). Diverse behavior caused by difference in age, gender, or ethnicity characteristics are also important factors to be taken into account in vulnerability assessment, especially in household level (Fahad et al., 2018).

Various interpretations regarding the application of aspects of exposure, sensitivity, and adaptive capacity in quantifying the vulnerability of a system are usually reflected in differences in scale, method of selection, grouping, and aggregation of indicators, as well as methods for displaying results. (Hahn et al., 2009). Example of vulnerability assessments that have been carried out includes the Municipal Vulnerability Index (MVI) method by Menezes *et al.* (2018) in Amazonas Brazil by utilizing social and environmental characteristics; *Coastal Vulnerability Index* (CVI) by Addo (2013) on the Accra coast of Ghana; *Livelihood Effect Index* (LEI) by Ahmad dan Ma (2020) in a mixed farming-livestock system of Punjab Province, Pakistan; *Household Vulnerability Index* (HVI) by Pepela *et al.* (2019) in Baringo household, Kenya; *Sustainable Livelihoods* (SL) by Muringai *et al.* (2020) who investigated food security in fisher communities in Lake Kariba, Zimbabwe; and *Livelihood Vulnerability Index* (LVI) (Amuzu et al., 2018; Hahn et al., 2009; Huong et al., 2019).

Hahn et al., (2009) developed LVI (Livelihood Vulnerability Index) as a versatile approach in vulnerability assessment based on indicators that can be modified for broader context. The results of LVI assessment could provide specific information regarding demographics, social, or economics that contributed to climate change vulnerability for local government to build resilience and minimize climate change impact in the community (Ali and Hossen, 2022; Mahmudah et al., 2021; Minh et al., 2020). Apart from LVI, another method in vulnerability assessment was developed by the Ministry of Environment and Forestry, Republic of Indonesia, in 2015. The method was named Information System of Vulnerability Data Index (*Sistem Informasi Data Indeks Kerentanan*, SIDIK), which integrates village profile data and evaluates climate change vulnerability in Indonesia within IPCC framework (KLHK, 2015).

Because of its versatility, previous studies have utilized LVI and SIDIK for various research. For instance, Suryanto and Rahman (2019) measured households vulnerability in flood-prone areas in Sukoharjo and Klaten, Indonesia. Hahn et al., (2009) provided the use of LVI for vulnerability assessment of coastal populations in Mozambique. Another study in Southeast Asia assessed climate vulnerability of three agricultural and natural resources dependent commune in northwest Vietnam (Huong et al., (2019). Richardson et al., (2018) further see LVI as a basis for predicting food security in a region.

However, although both methods were developed for the same objective, different weighting calculation for each methods raise the possibility that different methods can lead to different conclusions. This research aimed to assess whether the results of vulnerability analysis using LVI, LVI-IPCC, and SIDIK methods on the same data situated in rural landscape Indonesia offer consistent results. Therefore, the research aims to assess and compare livelihood vulnerability in Tanah Merah and Lobuk to climate change using LVI, LVI-IPCC, and SIDIK methods.

RESEARCH METHODS

Data Sources

The field activities to collect primary data based on interviews was carried out on January to March 2021. We selected two villages in Sumenep Regency, East Java namely Lobuk and Tanah Merah. The primary data was obtained from interview with household in Tanah Merah and Lobuk, while secondary data consisted of several supporting data such as climate and socioeconomic data. Data of village potency in Sumenep Regency in 2018 was obtained from CCROM-SEAP (Centre for Climate Risk and Opportunity Management Southeast Asia Pacific) IPB. Data of village profile in Sumenep Regency in 2020 was obtained from Sumenep Beaurou of Statistic (https://sumenepkab.bps.go.id/). Monthly climate data (rainfall, maximum and minimum air temperature) from 2001 to 2020 at spatial resolution of 0.05^o (~5km) for Sumenep Regency were derived from TerraClimate (https://www.climatologylab.org/terraclimate.html). For daily climate data (rainfall, maximum and minimum air temperature) from 2001-2020 was obtained from Kalianget Meteorological Station.

Questionnaire Construction and Interview Preparation

The respondents were selected randomly according to Slovin formula with 10% significance (Equation 1). The difficulty of obtaining a good estimate of population variance has increased the popularity of sample size based on proportion formula. Slovin formula is a simplified formula for an approximation of sample size, which best suited for categorical variables (Adam, 2020). According to the calculation result, the final sample size was 91 households for Lobuk and 93 households for Tanah Merah.

$$n = \frac{N}{1+N(e)^2} \quad (1)$$

Where n is total sample, N is total population, and e is significance level of 10%. A structured questionnaire was constructed based on several previous research (Amuzu et al., 2018; Hahn et al., 2009; Huong et al., 2019) to gather information on sociodemographics, livelihoods, social networks, health, food and water security, natural disasters, and climate variability component.

Data Normalization

The first step in calculating the vulnerability index is to normalize each indicator value (Hahn et al., 2009). The normalization was performed based on the relation of each indicator to the vulnerability score (Table 2). Indicators that are directly proportional to the vulnerability score were normalized using Equation 2. On the contrary, indicators that are inversely proportional to the vulnerability score were normalized using Equation 3.

$$I_d = \frac{x_d - x_{min}}{x_{max} - x_{min}} \quad (2)$$

$$I_d = \frac{x_{max} - x_d}{x_{max} - x_{min}} \quad (3)$$

Where I_d is normalized score of indicator d, x_d is actual score of indicator d, x_{min} is minimum score of indicator d, and x_{max} is maximum score of indicator d.

Livelihood Vulnerability Index (LVI) Calculation

The main components used in the LVI are sociodemographic profiles, livelihood strategies, social networks, health, food, water, natural disasters and climate variability, housing and land, finance, as well as knowledge and skills (Amuzu et al., 2018; Huong et al., 2019; Shah et al., 2013). Each main components of LVI are calculated using Equation 4.

$$K_d = \frac{\sum_{i=1}^{n} I_d}{n} \quad (4)$$

Where Kd is main component score, Id is normalized score of indicator d, n is number of indicators. The village-level LVI is calculated using Equation 5.

$$LVI = \frac{\sum_{i=1}^{n} wKd.K_{di}}{\sum_{i=1}^{n} wK} \quad (5)$$

Where LVI is Livelihood Vulnerability Index score, wK is the weight of the main component K, or the ratio of the number of indicators in K component to the total number of indicators, Kdi is main component score. The vulnerability profile was determined by linear scoring within 0-0.5 interval. The range of 0 – 0.2 is classified as not vulnerable, 0.21 – 0.4 is classified as vulnerable, and 0.41 – 0.5 is classified as very vulnerable (Suryanto and Rahman, 2019).

LVI-IPCC Calculation

Main components in LVI-IPCC were grouped based on contributing factors in IPCC framework, namely exposure (E), sensitivity (S), and adaptive capacity (AC). Each of these component was calculated using Equation 6 to Equation 8.

$$E = \frac{\sum_{i=1}^{n_e} I_e}{n_e} \quad (6)$$

$$S = \frac{\sum_{i=1}^{n_s} I_s}{n_s} \quad (7)$$

$$AC = \frac{\sum_{i=1}^{n_a} I_a}{n_a} \quad (8)$$

Where E is exposure index, S is sensitivity index, AC is adaptive capacity index, ns is number of sensitivity indicators, ne is number of exposure indicators, na is number of adaptive capacity indicators, Ie is normalized exposure index, Is is normalized sensitivity index, Ia is normalized adaptive capacity index. Afterwards, LVI-IPCC was calculated using Equation 9.

$$LVI_{IPCC} = (E - A) \times S \quad (9)$$

Similar to LVI, LVI-IPCC also used linear scoring in determining vulnerability profile within -1 to +1 interval (Hahn et al., 2009). The range of -1 - (-0.4) is classified as not vulnerable, -0.41 – 0.3 is classified as vulnerable/moderate, and 0.31 - 1 is classified as very vulnerable (Mudasser et al., 2020).

SIDIK Index Calculation

SIDIK calculation was based on indicators selected from PODES (village potency) data to represent exposure and sensitivity (formulated in Sensitivity-Exposure Index, SEI, and Adaptive Capacity Index, ACI) (KLHK, 2015). This approach combines the exposure and sensitivity components into a Sensitivity-Exposure Index (SEI) along with the Adaptive Capacity Index (ACI). SEI and ACI are calculated using Equation 10 and 11.

$$SEI = \frac{\sum_{i=1}^{n_s+n_e} I_{es}}{n_e+n_s} \quad (10)$$

$$ACI = \frac{\sum_{i=1}^{n_a} I_a}{n_a} \quad (11)$$

Where ns is number of indicators for sensitivity, ne is number of indicators for exposure, na is number of indicators for adaptive capacity, Ies is normalized score of sensitivity and exposure indicators, Ia is normalized score of adaptive capacity. Vulnerability profile determination for SIDIK was performed based on quadrant system. There are 5 types of vulnerability profile as a result from SEI and ACI score combination, namely not vulnerable, slightly vulnerable, moderately vulnerable, vulnerable, and very vulnerable (Boer et al., 2019).

Principal Component Analysis (PCA)-based Weight Calculation

In IPCC framework, a weight was assigned for every indicator in each contributing factor to describe their importance to the final component score. The weight calculation was performed using principal component extraction method with Varimax rotation. Varimax rotation aims to simplify variable dimension and to make each variable statistically independent (Cutter and Finch, 2008). Principal component also aims to eliminate multicorrelation between variables (Dintwa et al., 2019). The weight was determined based on the proportion from principal component, which then paired with matrix of rotated factor with the highest value. The weight is then used in the LVI-IPCC calculation for Equation 12 to Equation 14. This weighting method is also used in calculating SEI and ACI in SIDIK method using Equation 15 and Equation 16.

$$E = \sum_{i=1}^{n_e} w_e I_e \quad (12)$$

$$S = \sum_{i=1}^{n_s} w_s I_s \quad (13)$$

$$AC = \sum_{i=1}^{n_a} w_a I_a \quad (14)$$

$$SEI = \frac{1}{2}\left(\sum_{i=1}^{n_e} w_e I_e + \sum_{i=1}^{n_s} w_s I_s\right) \quad (15)$$

$$ACI = \sum_{i=1}^{n_a} w_a I_a \quad (16)$$

Where We is PCA-based weight for exposure indicator, Ws is PCA-based weight for sensitivity indicator, Wa is PCA-based weight for adaptive capacity indicator. Afterwards, the calculation process was performed according to previous step.

Identification of Vulnerability Key Indicators

The key indicators that were driving the vulnerability were determined by grouping all indicators into 5 categories according to Guillard-Gonçalves and Zêzere (2018) (Table 1). Indicators with very high influence are regarded as key indicators in the two villages.

Table 1. Classification of indicator scores and their influence (Guillard-Gonçalves and Zêzere, 2018)

Indicator Score	Influence
0 – 0.2	Very low
0.2 – 0.4	Low
0.4 – 0.6	Medium
0.6 – 0.8	High
0.8 – 1	Very high

Action Recommendations for Climate Change Adaptation

Action recommendations for climate change adaptation for Lobuk and Tanah Merah were determined based on vulnerability key indicators. Literature studies from journal articles, publications, and general research results related to climate change mitigation and adaptation actions were carried out to provide the recommendation.

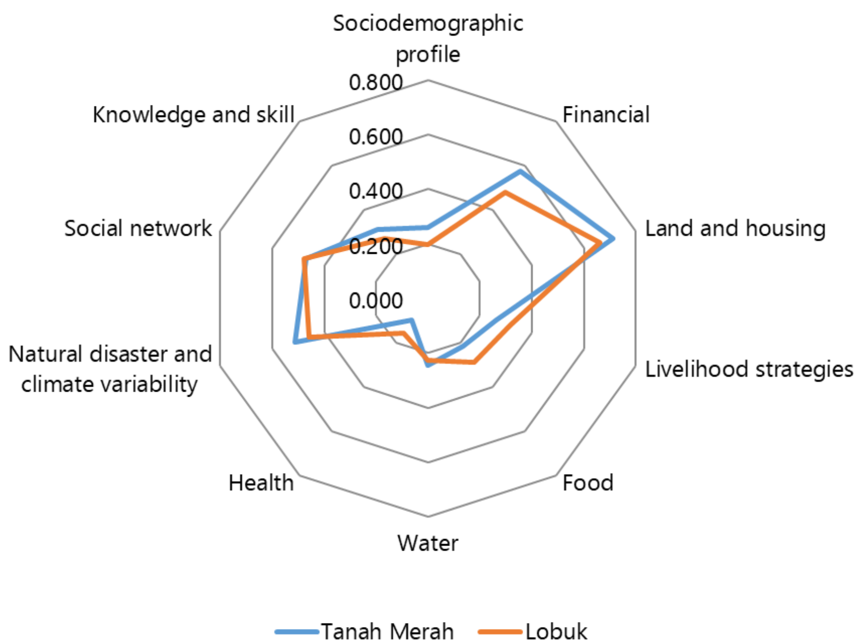


Figure 1. Spider graph of LVI main components in Tanah Merah and Lobuk

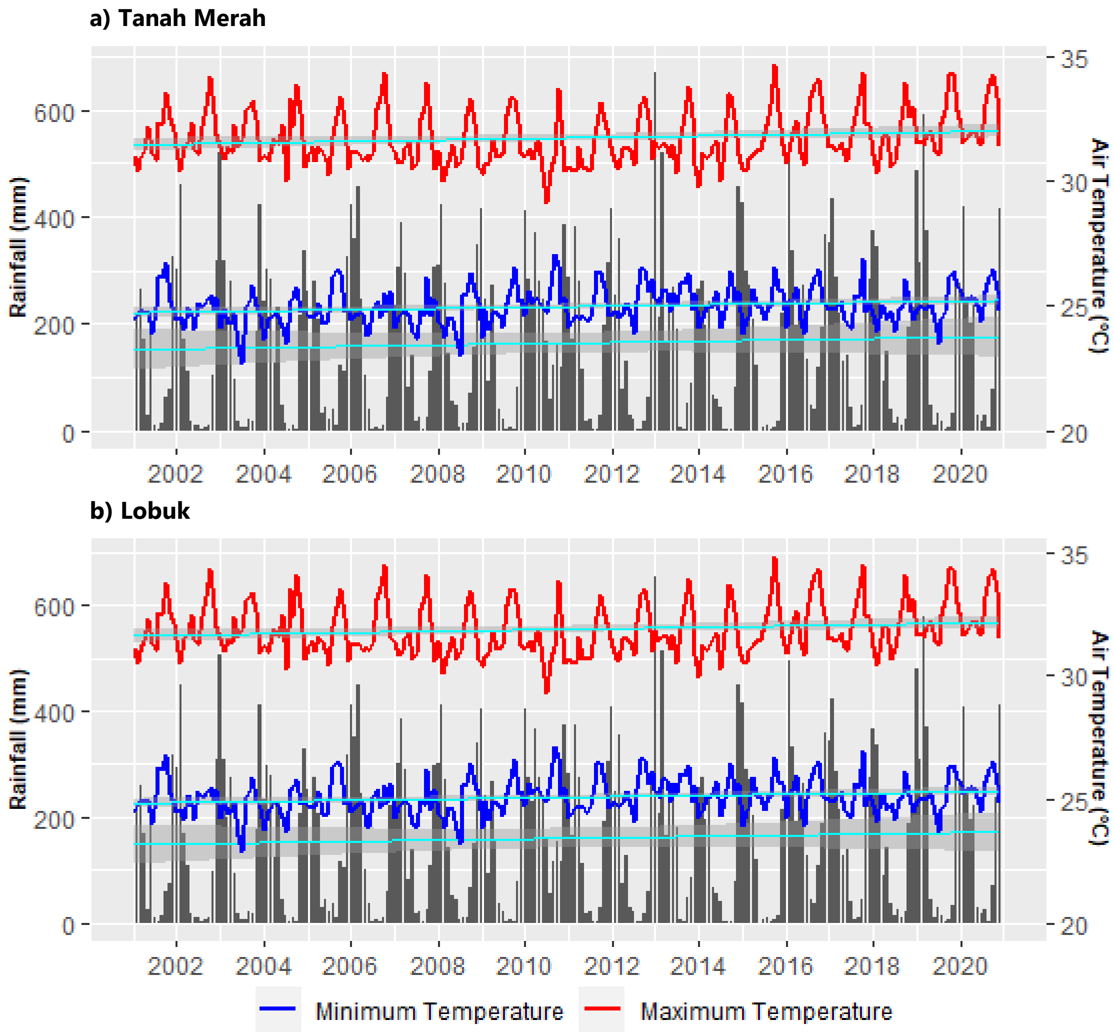


Figure 2. Annual rainfall, maximum, and minimum temperature in a) Tanah Merah and b) Lobuk from 2001-2020

RESULTS AND DISCUSSION

Livelihood Condition in Tanah Merah and Lobuk

Percentage of households with female household head in Tanah Merah is higher than Lobuk. Female household heads are considered more vulnerable because women have many disadvantages in terms of the double workload in earning a living and completing domestic work, limited employment opportunities, as well as physical and biological conditions (Cerrato and Cifre, 2018). The dependency ratio, which represents the age distribution within the household of Tanah Merah (0.541) scored lower than Lobuk (0.617) (Table A1). The overall sociodemographic profile result shows that Tanah Merah (0.261) has a higher vulnerability than Lobuk (0.198) in this component.

The financial component assessed the economic condition of the family. The income indicator defined poor households by household with lower income than regional minimum wage of Rp. 1,950,000/month as the threshold (Kepgub Jatim, 2019). The score was not far apart since most respondents has similar occupation. The percentage of household without savings in Tanah Merah (71%) is higher than in Lobuk (49.5%). According to the respondents, people are reluctant to save money since they prioritize paying off debt first. In contrast to Tanah Merah, respondents in Lobuk preferred savings, which was usually managed by BMT (*Baitul Maal wa Tamwil*) or a shari'a cooperative that often went around and provided financial assistance. Households without access to credit or loans explains household adaptive capacity from their ability to provide guarantees to receive access to credit, as well as their ability to pay for it. Overall, the financial component index for Tanah Merah is 0.575 while that for Lobuk is 0.481.

In land and housing component, indicator of household without yard in their housing may indicate a densely populated settlement. Lobuk scored higher (0.758) than Tanah Merah (0.570) since it has a higher population density (BPS, 2020). However, Lobuk scored lower (0.626) than Tanah Merah (0.903) for household without waste management (Table A1). The waste management can be in the form of composting facilities, recycling waste, etc. The majority of Lobuk respondents preferred sorting cardboard and plastic waste and then exchanged it for shallots at the exchangers who went around the village, while Tanah Merah respondents chose to burn their household waste directly. The final score for the housing and land components for Tanah Merah was 0.710 and 0.663 for Lobuk.

The livelihood strategy component assessed household adaptive capacity in terms of the adopting strategies to meet their daily needs. Household whose main livelihoods depends on nature had an uncertainty due to weather, seasonal and climate change, as well as disasters (Wibowo and Satria, 2015). People livelihoods in Tanah Merah are more varied, especially in the lower region. This area is more strategic and accessible to provincial road, allowing the residents to have higher mobility. People livelihoods in this area are mostly government employees, merchant, and a small number of farmers. In the upper region, most of the people make a living as farmers with the main commodities being maize, green beans and peanuts.

Meanwhile, Lobuk consisted of coastal and lowland areas. The livelihoods of the majority of the people in the coastal areas are seaweed farmers, fishermen, porters for the fishery factory, or fish collectors, while in the lowlands, most of the population are farmers. Another indicator is households with family members who work outside the village territory. Tanah Merah scored higher (0.387) than Lobuk (0.143) due to the wider variety of livelihoods, which often requires them to work outside the village (Table A1). People in Lobuk, who mostly depend on nature for their livelihoods simply utilize the sea and agricultural field located within the village territory.

Aside from average number of months in which households experienced food shortages, the food component also assessed household security in providing food using indicators of households that still use traditional stoves (*tomang*) and firewood. This indicator described household sensitivity in terms of dependence on nature for cooking purposes. The results showed Lobuk scored higher than Tanah Merah. However, respondents in both villages explained that the stoves are usually used as spare cooking utensils, to make forage, or in a celebration that requires a large amount of cooking.

Similar to the food component, the water resources component assessed household sensitivity in terms of their water access and availability. Tanah Merah scored higher than Lobuk in the indicator of household using natural sources such as rivers, springs, lakes, or seas as their main water source. Household with natural main water source have a higher sensitivity because the water availability tends to be uncertain and influenced by weather, soil conditions, and pollution (Gavrilescu, 2021).

Respondents in Lobuk and Tanah Merah mainly use water from either a private or a shared well. The upper part of Tanah Merah had experienced drought in 2015 and before so that almost all of the respondents have water reservoirs measuring 1,000 to 15,000 liters (Table A1). The average time required to access water for the upper part of Tanah Merah is 15 minutes since the water is usually supplied from lower part of Tanah Merah or Bluto. The water conflicts reported in Tanah Merah were related to water pipes management, differences in water prices, and water distribution strategy to avoid conflict between residents. The water conflict in Lobuk is the receding of the well in the dry months. The health component composed of 6 indicators related to health condition of family members and access to the nearest health facility (Puskesmas/ Polindes). The score of this component between Tanah Merah and Lobuk did not differ much (Table A1).

In the component of natural disasters and climate variability, respondents from Lobuk who live on the coastal area stated that the most frequent disasters were strong winds. This resulted in material damage of the house walls and roofs but did not result

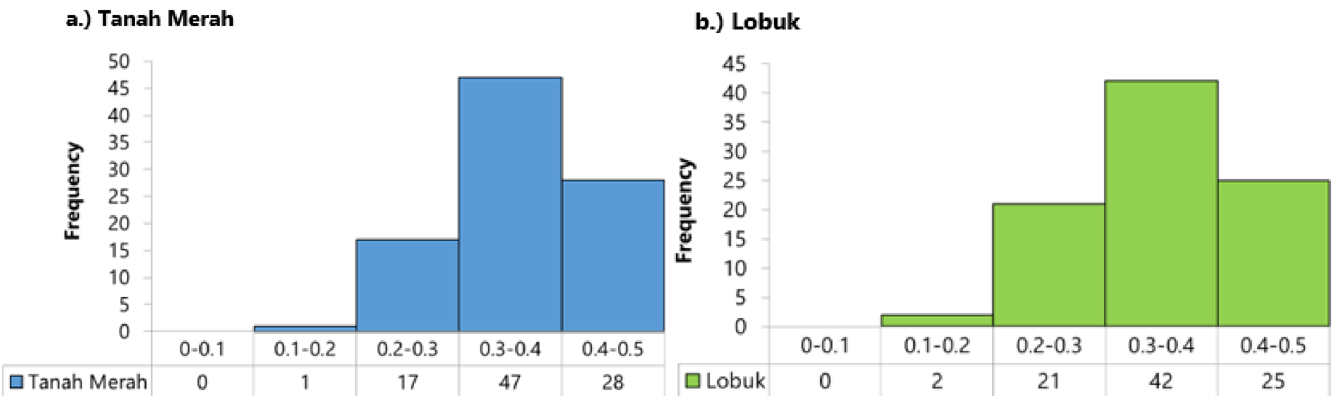


Figure 3. Household vulnerability distribution based on LVI in a) Tanah Merah and b) Lobuk

in casualties. Households that do not receive disaster early warnings provided an example of the local government preparedness in disaster mitigation. Tanah Merah (78.5%) scores higher than Lobuk (63.7%) (Table A1). Respondents from both villages reported that the warning was spread via WhatsApp, mosque microphones, and from informants. Another indicator is the Mean Standard Deviation (MSD) of the monthly average of the daily precipitation, minimum, and maximum air temperature in 2001-2020. A higher standard deviation value indicates a greater diversity of climate data, which can be associated with extreme climates (Lewis et al., 2019). This condition will lead to a higher exposure, which will also result in higher climate change vulnerability. Figure 1 showed the annual rainfall, maximum, and minimum air temperature used for LVI calculation in research area from 2001-2020. The trendline showed that there was an increasing tendency in rainfall data for both Tanah Merah and Lobuk.

The social network component assessed the strength of the relationship in communities, since it may indicate the adaptive capacity of a society (Tanzil, 2019). A strong social networks can be found in community with a tradition of mutual assistance, social norms, and sense of trust (Carmen et al., 2022). The score of this component between Tanah Merah and Lobuk did not differ much. Receive:Give ratio and Borrow:Lend money ratio measured the extent to which household depends on help from others to meet their needs and overcome problems (Hahn et al., 2009). Households that receive more but do not provide assistance much are considered more vulnerable than households with excess resources to give to other households (Hahn et al., 2009).

The knowledge and skills component assessed household adaptive capacity from their access to information facilities and communication infrastructure. This component is composed of family members who can read, electricity, average travel time to communication and expeditions facilities, and skills training from the government. The result indicates that the ease of access of the community in the two study villages to the flow of information through news broadcasts, SMS, telephone, as well as social media and the internet is good. However, 81.7% of respondents in Tanah Merah and 70.3% in Lobuk have never received skills training from the local government. Respondents who had received training said that the training was usually in the form of agricultural counseling, while in Lobuk Village it was more diverse including agricultural counseling, fishermen counseling, entrepreneurship training, village product development and halal food concepts, diesel engine training, to disaster response training.

Household Livelihood Vulnerability Distribution in Tanah Merah and Lobuk

The LVI score of Tanah Merah is 0.344 while for Lobuk is 0.333. According to Huong et al. (2019), this score may indicate that Tanah Merah and Lobuk were classified as vulnerable. Household vulnerability distribution according to LVI is shown in Figure 3. The distribution pattern in Tanah Merah and Lobuk was similar. Majority of the household in Tanah Merah (68.8%) and Lobuk (69.2%) was in vulnerable category with LVI score ranging from 0.21-0.4. Next highest percentage is very vulnerable category (30.1% in Tanah Merah, and 28.6% in Lobuk).

Not much different from the LVI, result from LVI-IPCC and SIDIK approaches also classified Tanah Merah and Lobuk into the vulnerable category. The result applies both to the arithmetic mean and PCA weighting. The distribution pattern of household vulnerability based on LVI-IPCC (Figure 4 and SIDIK also centered on the vulnerable category (Figure 5).

Despite the similarity in household vulnerability distribution pattern of the two villages, there was a slight difference in the pattern between LVI or LVI-IPCC with SIDIK. This may occur mainly due to a different weighting method used in each approach. LVI

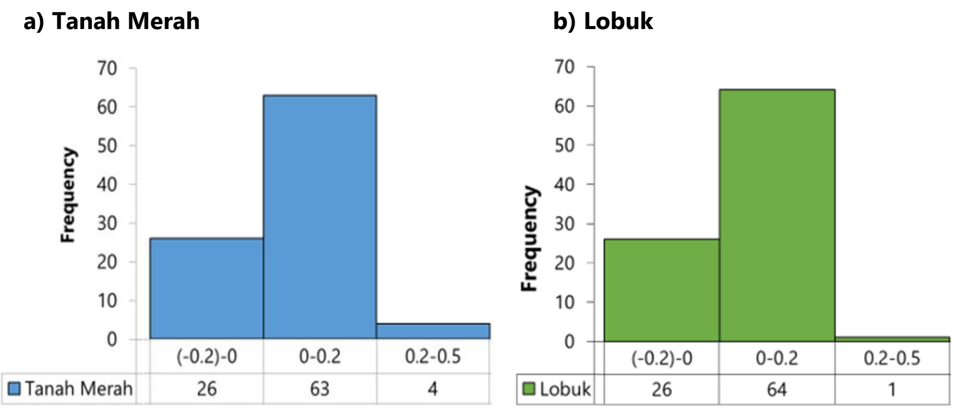
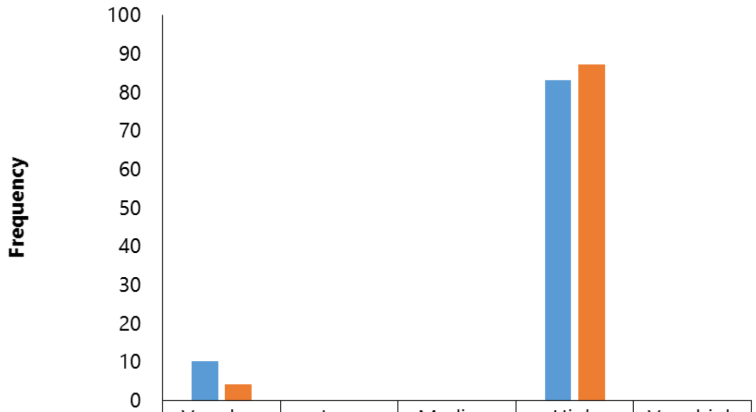


Figure 4. Household vulnerability distribution based on LVI-IPCC in a) Tanah Merah and b) Lobuk



	Very low	Low	Medium	High	Very high
Tanah Merah	10	0	0	83	0
Lobuk	4	0	0	87	0

Vulnerability Type

Figure 5. Household vulnerability distribution based on SIDIK approach in Tanah Merah and Lobuk

and LVI-IPCC utilized arithmetic mean weighting, which is an equal weighting that assign an equal weight for each indicator used. This method assumed that every indicator give equal contribution to the final vulnerability score (Ha-Mim et al., 2020). Equal weighting is mostly used in vulnerability assessment especially in social context when information about indicator importance is unavailable (Tate, 2012).

On the other hand, SIDIK utilized PCA weighting, which is data driven. The weight was obtained from a rotated factor matrix based on data variance proportion explained by the factor. Higher weight was assigned to less diverse indicators so that high variance among indicators will not interfered other indicator contribution to the final vulnerability score (Žurovec et al., 2017). The difference may also occur due to different scoring method. LVI and LVI-IPCC utilized a linear scoring, which divided the data into 3 vulnerability types based on a final vulnerability score. Through linear scoring, more than 95% of household in both villages is vulnerable (Figure 4). Meanwhile, SIDIK utilized quadrant indexing, which divided the data into 5 vulnerability types based on a combination of SEI and ACI score. More than 50% of household in both villages is vulnerable (type 4) (Figure 5). However, the slight difference in the pattern was not considered significant since it falls in the same vulnerability category.

Another slight difference can also be noticed in Figure 5 between the household classified as not vulnerable in Tanah Merah and Lobuk. This may occur due to the distinct characteristics of Tanah Merah and Lobuk. Tanah Merah was divided as upper and lower region, which was separated by a main road. The residential area in upper region is located further from the main road, which later affect household mobility. On the contrary, lower region of Tanah Merah is next to Saronggi, which is the government activity center. Household livelihood in the lower region is also more varied compared to the upper region. As mentioned before, household majority in lower region of Tanah Merah have a livelihood in agriculture with main commodity being corn and beans green, while in Lobuk was farmers and fishermen.

Comparison of Vulnerability Scores According to Each Method

The vulnerability scores resulting from the two weighting methods do not differ much. This difference in results can also be seen in the distribution of vulnerability at the household level. In general, the number of households in each vulnerability class does not differ much and is 2-10 households adrift.

Through quadrant indexing, the number of households in vulnerability type 4 or vulnerable in Tanah Merah Village using the arithmetic weighting method is 60 households. As for the PCA weighting method, there were 69 households with the same type of vulnerability. Not much different from Tanah Merah Village, the number of vulnerable households in Lobuk Village from the arithmetic weighting method is 65, while from the PCA weighting it is 72 households.

The distribution of household vulnerabilities between the two weighting methods shows that both through the arithmetic mean weighting method and PCA, most households are in vulnerability type 4 (vulnerable), followed by 3 (moderate), 1 (not vulnerable), and finally 5 (very vulnerable). There are no households that fall into vulnerability type 2. The arithmetic weighting method shows that as many as 14 households in Tanah Merah Village and 11 households in Lobuk Village are not vulnerable, while from the PCA method, the numbers are 4 and 2 households, respectively (Figure 5).

Table 2. Indicator classification based on Guillard-Gonçalves and Zêzere, (2018)

Indicator Score	Influence	Tanah Merah	Lobuk
0 – 0.2	Very low	I16, I26, I42, I21, I27, I23, I24, I14, I28, I41, I43, I40, I29, I20	I21, I24, I40, I42, I16, I14, I23, I26, I27, I4, I2, I28, I41, I13, I1, I20, I30
0.2 – 0.4	Low	I4, I25, I30, I19, I1, I2, I12, I15, I3, I17, I36, I35, I13, I18	I43, I25, I19, I36, I29, I8, I35
0.4 – 0.6	Medium	I37, I8, I6, I34, I9, I5	I17, I37, I3, I5, I7, I12, I18, I34, I15, I39
0.6 – 0.8	High	I39, I11, I7, I38, I31	I6, I11, I10, I31, I44, I9
0.8 – 1	Very high	I22, I44, I10	I38, I22

Differences in vulnerability scores and the distribution of household vulnerabilities can occur due to differences in the weighting method used. The arithmetic mean weighting includes the equal weighting method which assigns the same weight value to each indicator used. This weighting assumes that each indicator contributes equally to the vulnerability component score (Ha-Mim et al., 2020). Equal weighting is commonly used in vulnerability calculations especially in social contexts when there is insufficient information about the importance of one indicator compared to another (Tate, 2012).

In contrast, the PCA weighting method is data-driven. The weight value is obtained from a factor matrix that has been rotated based on the proportion of data diversity that can be explained by the factor. Higher weights will be given to indicators with lower data diversity so that high diversity among indicators does not affect the contribution of other indicators to the final score (Žurovec et al., 2017). Differences in vulnerability distribution patterns can also occur due to differences in scoring. Linear scoring divides the data into 3 types of vulnerabilities based on one final vulnerability score. This final score is obtained from arithmetic operations involving E, S, and AC. Meanwhile, quadrant indexing divides the data into 5 types of vulnerabilities based on a combination of E, S, and AC scores.

Although there is a difference in the results of the two methods of weighting and scoring, the resulting difference is not large and is still in the same vulnerability category. This can happen due to several factors. The first factor is the use of the same input data. The whole calculation process uses primary data from the questionnaire results. This data is then processed using the same data transformation method, namely minimum-maximum linear normalization to produce 44 indicators on a scale of 0-1. This transformation aims to make each indicator on the same scale so that it can be compared (Baptista, 2014).

Secondly, the same method is used to reduce the data. Data reduction is performed to minimize the redundancy of correlated variables. The method used to perform data reduction is a simple correlation table that can help identify which indicators are correlated with each other. The results obtained indicate that none of the selected indicators has a Pearson correlation value of more than 0.7 so that all indicators can be used in subsequent calculations.

Vulnerability Key Indicators and Adaptation Recommendations

Key indicators identification process was performed according to classification by Guillard-Gonçalves and Zêzere, (2018). Each indicator was grouped into 5 classes based on an order of influence. The indicators in class 5 (very high influence) are considered as key indicators driving vulnerability. The classification showed that 3 most influential indicators regarded as vulnerability key indicators for Tanah Merah are I10 or household without waste management (0.903), followed by I44 or household who did not receive any training from the local government (0.871), and I31 or household who did not receive a warning about natural disasters (0.785). Meanwhile, 3 vulnerability key indicators for Lobuk is I38 or household that have not gone to local government for any kind of assistance in past 12 month (0.802), followed by I9 or household without yard (0.758), and I6, or household with debt (0.604). Both Tanah Merah and Lobuk also scored high for I22 due to a wide gap in community ownership of water reservoir or *jeddhing*.

Multiple successful mitigation and adaptation actions implemented in several locations in Indonesia were summarized in ProKlim (Program Kampung Iklim). ProKlim is an effort to overcome climate change and declared as a national movement in 2016. In implementation, ProKlim covered various objectives with various supportive programs.

For waste management, several actions can be performed. Improper waste disposal could be prevented by providing adequate amount of trash bin and waste sorting facilities. An alternative facility to support this objective is *Bank Sampah* (waste bank).

Afterwards, organic waste can also be processed through composting. The composting result then could be utilized as fertilizer.

Regarding waste bank, method of sorting existing trash varies. The sorting could be carried out by special officers, or by each household in their settlement. Reduce, Reuse, and Recycle (3R) concept can be introduced later, after the community was accustomed to separate inorganic and organic waste at home for composting in their household or community composter (Yolanda et al., 2019). They may also sell recyclable plastic or cardboard waste to collector.

Upgrading skill and human resource capacity could be done through training for targeted community supported by local government. In a community with majority of farmers such as Tanah Merah, government involvement for capacity improvement was done through training and workshop such as introduction for new superior varieties or technology, or training for postharvest activity (Perdinan et al., 2018). However, the result sustainability of this workshop and training also requires local government accompaniment (Perdinan et al., 2008).

Related with disaster and extreme weather early warning, the local government of Tanah Merah can adopt familiar social media such as WhatsApp. The news spread can also be done from mouth to mouth. Meanwhile, disaster mitigation could be performed through several actions, such as construction of a good drainage network, construction of dam or water reservoir in individual or communal scale (Zhang et al., 2018).

More household without yard could be associated with narrow settlement or high population density. Thus, the action recommendation will be related with overcoming density population and spatial planning (DNPI, 2012). Lastly, debt could be an indicator of household who experience difficulty in fulfilling their needs, which also an indicator of financial vulnerability (Hahn et al., 2009). A number of interventions that can be performed mainly related to policies that provide financial literacy including promoting savings (Noerhidajati et al., 2021).

Nevertheless, any climate change adaptation recommendation will be more suitable if it was community-based. Community-based adaptation was determined based on participatory study result (Focus Group Discussion or interview with the community), mainly about how change climate affect people livelihood, also proposed adaptation. This meant to ensure that the recommendations taken are in line with community needs, which in turn will be more capable to minimize the impact.

CONCLUSIONS

Tanah Merah and Lobuk were consistently categorized as vulnerable according to both LVI, LVI-IPCC, and SIDIK methods. This result is also consistent at village and household levels. The vulnerability score falls in the same category despite the difference in weighting and scoring method used. This indicated that despite difference in vulnerability assessment methods, applying the same data to the assessment will likely lead to a similar result. The key indicators driving the vulnerability in Tanah Merah Village are households without waste management, households that have never received training from the government, and households that do not receive disaster early warning. The key indicators driving the vulnerability in Lobuk are households with small land ownership and households with debt. Hence, action recommendations for Tanah Merah are providing waste bank and waste sorting facility, upgrading public capacity through workshops, and adopting social media to share climate-related information, while for Lobuk, this includes the determination of regulatory instruments related space utilization in coastal area, mapping area affected by change climate, and financial literacy improvement especially promoting savings in the community.

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ANNEX

Table A1. Livelihood Vulnerability Index (LVI) indicator score for Tanah Merah and Lobuk

Ind-ex	Indicator	Tanah Merah	Lobuk
I1	Dependency Ratio	0.27	0.15
I2	Percentage of households with female heads	0.28	0.10
I3	Average number of family members	0.29	0.45
I4	Percentage of households with family members required daily treatment	0.20	0.09
I5	Percentage of households with income less than minimum wage	0.57	0.47
I6	Percentage of households with debt	0.52	0.60
I7	Percentage of households without savings	0.71	0.49
I8	Percentage of households without access to a bank loan	0.51	0.35
I9	Percentage of households without yard	0.55	0.76
I10	Percentage of households without waste management facilities	0.90	0.63
I11	Percentage of households with no land or small land ownership (< 0.5 ha)	0.68	0.60
I12	Percentage of households whose main livelihood depends on nature	0.28	0.52
I13	Percentage of household with family members working outside the village	0.39	0.14
I14	Percentage of households that do not own a vehicle	0.10	0.05
I15	Percentage of households not working during extreme weather	0.28	0.55
I16	Average number of months of food difficulty/insecurity	0.00	0.04
I17	Percentage of households that do not save their harvest for personal consumption	0.29	0.41
I18	Percentage of households that do not save seeds for planting next year	0.39	0.53
I19	Percentage of households that still use traditional stove stoves	0.23	0.27
I20	Percentage of households reporting a decrease in availability of firewood in the last 10 years	0.18	0.20
I21	Percentage of households that use natural sources as the family's main water source	0.02	0.00
I22	Inverse number of liters of household water reservoir	0.85	0.83
I23	Average time required for household to reach main water source	0.03	0.06
I24	Percentage of households reporting conflicts related to water resources	0.08	0.01
I25	Percentage of households with family members suffering from infectious diseases in the last 2 weeks	0.20	0.24
I26	Percentage of households with family members suffering from diseases due to pollution	0.00	0.07
I27	Percentage of household with family members suffering from sanitation problems	0.02	0.07
I28	Percentage of household with family members suffering from chronic illness	0.10	0.10
I29	Average time for household to reach the nearest health facility	0.17	0.30
I30	Average number of hydrometeorological disasters incident in the last 5 years	0.21	0.20
I31	Percentage of households that do not receive early warnings for natural disasters	0.78	0.64
I34	Mean Standard Deviation of 20 years average monthly precipitation	0.55	0.54
I35	Percentage of household without family members joining the village group	0.37	0.40
I36	Receive:Give Ratio	0.32	0.28
I37	Borrow:Lend Ratio	0.46	0.42
I38	Percentage of households who did not ask for assistance from the village in the past year	0.73	0.80
I39	Index of the number of literate family members	0.66	0.57
I40	Percentage of households without electricity available at all times	0.12	0.02
I41	Percentage of households without a TV	0.11	0.10
I42	Percentage of household without a mobile phone	0.01	0.02
I43	Average time for household to reach communication facility	0.11	0.21
I44	Percentage of households that have never received skills training from the government	0.87	0.70