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Adaptive Garlic Farming to Climate Change and Variability in Lombok

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ABSTRACT

Climate change impact in Indonesia is generally characterized by changes in daily temperature, rainfall patterns, and sea level rise. These changes mainly influence agricultural practices for various crops, including garlic (*Alium sativum L.*). Current knowledge on climate vulnerability related to agricultural impact in Indonesia is limited. This study aims to identify the level of vulnerability of garlic farmer households to climate change and provide recommendations for adaptation activities for garlic farmers. The household vulnerability profile was assessed using Livelihood Vulnerability Index (LVI) and LVI-IPCC approaches. We carried out interviews for 100 respondents in four villages in Lombok to obtain primary data related to agricultural practices. Relation between climate variables and garlic productivity was determined using linear regression approach. The results showed that rainfall and temperature had a negative correlation with garlic productivity as indicated statistical indicators used, namely R^2. According to LVI and LVI-IPCC approach, Sembalun Timba Gading and Sajang have the highest level of vulnerability (0.60) and Sajang Village has the lowest level of vulnerability (0.55) among all villages. The findings suggested that climate information should be considered in agricultural sector for climate change mitigation and adaptation.

KEYWORDS
agricultural practices, garlic productivity, household vulnerability, Livelihood Vulnerability Index

INTRODUCTION

Climate change is one of the most important problems to overcome nowadays. IPCC stated that by the end of the 21st century, the global temperature is projected to exceed 1.5-2°C relative to the year of 1850-1900 in most scenarios (Rogelj et al., 2018; Smith et al., 2018; Stocker et al., 2013). East Lombok Regency in Nusa Tenggara is one of the impacted regions related to climate change. One study mentioned that Nusa Tenggara will likely have an increase of temperature by 2020 (McGregor et al., 2016). Other climate change occurence was identified by a decreased rainfall and humidity in the region (Faqih et al., 2016; Sipayung et al., 2019).

Predicted climate change may increase vulnerability for agricultural practices, especially related to water availability (Schilling et al., 2020). The agricultural sector is greatly influenced by climate change because of its reliance on water and weather cycle to maintain productivity (Arora, 2019). One of the crops commodities that is very sensitive to water availability is garlic. Water scarcity can inhibit garlic growth and development (Hidayah et al., 2020; Sánchez-Virosta et al., 2020). On the other hand, excessive amounts of water will accelerate rotting process (Oliveira et al., 2020). Desta et al. (2021) reported that rainfall amount also influenced the total harvested area or the yield of garlic. The requirements for optimal garlic cultivation are temperatures in range of 20-25°C and annual rainfall of 1,200-2,400 mm (Atif et al., 2020). Dong et al. (2019) and Mojtahedi et al. (2013) also confirmed that low temperature is the main factor affecting garlic bulbs formation.

Sembalun District, as the national centre of garlic production in East Lombok (Ministry of Agriculture, 2017), is at the foot of Mount Rinjani (390-1180 masl) with a total area of 217.08 km² (BPS, 2019). The area receives annual rainfall of 1,826-2,000 mm with peak rainfall in January to March, and the lowest rain in April and May. Within June to December, Sembalun experienced dry season with an average temperature ranging from 29-35°C. Garlic cultivation in Sembalun District usually performed at the beginning of the dry season around April-June, which according to Gomes et al. (2020), were the most suitable time.

Considering the dependence of agricultural sector to climate, it is necessary to identify household vulnerability profile of garlic farmers on climate change and variability, as well as adaptation recommendation to minimize the impacts that may arise.

RESEARCH METHODS

Study Area

This research was carried out from January 2019 to June 2020 in Sembalun District, East Lombok Regency. There were four villages where we did our field survey, namely Sembalun Bumbung, Sembalun Lawang, Sembalun Timba Gading, and Sajang Village (Figure 1).

Questionnaire Data Preparation

The respondents were selected according to purposive sampling method. Purposive sampling is a sampling technique with certain considerations (Campbell et al., 2020; Valerio et al., 2016). In this case, the consideration was household with garlic farmers. The number of respondents designed was 100 respondents, where each village was represented by 25 respondents.

We employed climate data (2001-2016) to analyze impact of climate change on garlic productivity. Air temperature was obtained from CMIP5, whereas rainfall data from CHIRPS (iridl.ldeo.columbia.edu). In addition, we collected garlic production from BPS (Beaurou of Statistic, Indonesia) and local agriculture services. The climate data was then resampled with a spatial resolution of 0.05° (~5 km) for 1981/2001 to present with daily temporal resolution.

Productivity Data

The annual productivity of garlic was calculated by dividing the annual garlic production by the total planting area. Productivity data is expressed in tons/ha in Equation (1). Annual production and total planting area in Sembalun District were obtained from Central Statistic Agency and the Agriculture Service for East Lombok Regency.

$$Productivity = \frac{\sum Annual\ garlic\ production}{\sum Total\ planting\ area} \quad (1)$$

Effect of Rainfall on Garlic Productivity

The influence of rainfall on garlic productivity was identified based on linear function. We firstly standardized the rainfall data using Equation (2).

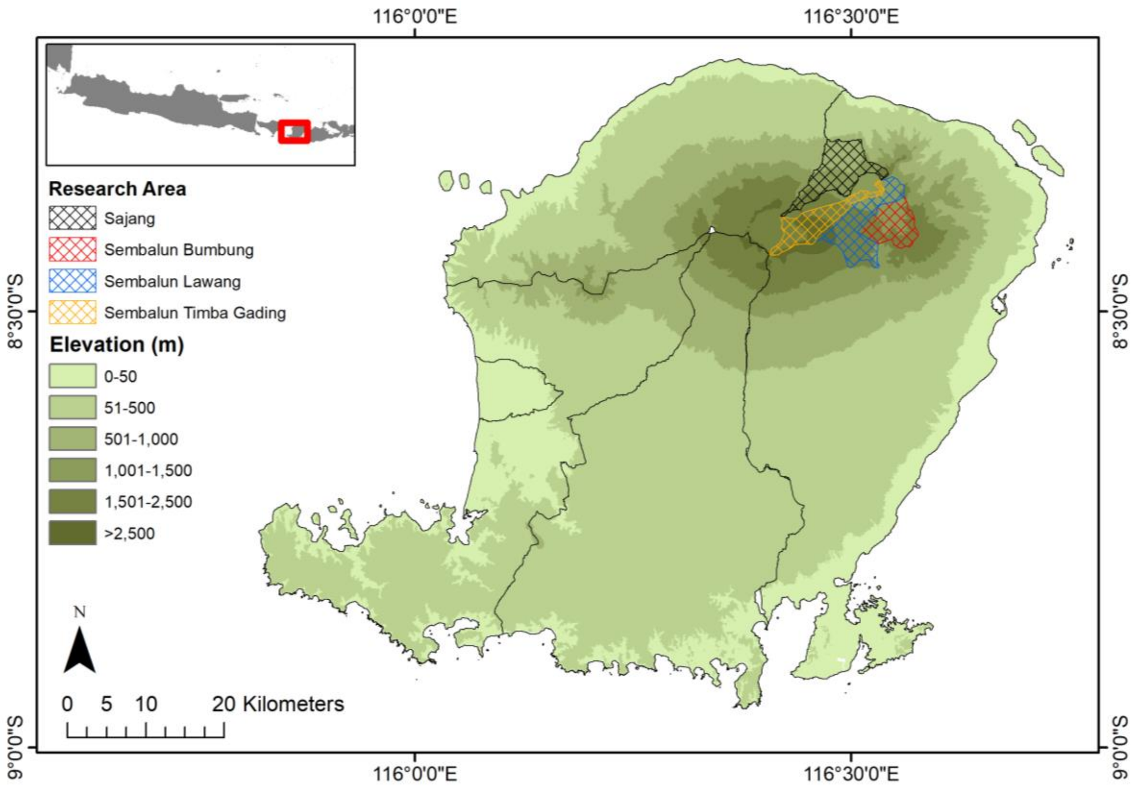

Figure 1. Study site in Lombok Island, West Nusa Tenggara. Location for field survey is indicated by the gridded area.

$$Z_{i,j} = \frac{x_{i,j} - \mu}{\sigma} \quad (2)$$

where $Z_{i,j}$ rainfall anomalies in month i and year j, $x_{i,j}$ rainfall in month i and year j, μ mean rainfall amount in month i, σ rainfall standard deviation in month i. Afterwards, the influence of rainfall anomalies on garlic productivity was identified using linear regression (Equation 3).

$$Y = a + bx \quad (3)$$

where Y garlic productivity, x rainfall anomaly, a and b constant value derived from the regression function. We performed a statistical test using a partial t-test to identify the influence of rainfall on garlic at significant level (α) 5%.

Livelihood Vulnerability Index (LVI) analysis

There were two approaches to calculate LVI score namely the combined vulnerability index approach (LVI) and the IPCC framework approach (LVI-IPCC) (Hahn et al., 2009; Huong et al., 2019). Both LVI and LVI-IPCC score was constructed from several major components that assumed to have an equivalent value (Asfaw et al., 2021; Simane et al., 2016; Tran et al., 2021). The major component consisted of several sub-components. Each sub-component was standardized into index values using Equation (4).

$$S = \frac{S - S_{min}}{S_{max} - S_{min}} \quad (4)$$

where S sub-component score, S_{min} minimum score of the sub-component, S_{max} maximum score of the sub-component.

1) Exposure Index

Parry et al. (2007) defined exposure as the extent to which climate change intersect with the system. Contributing factor of exposure to LVI-IPCC score was calculated using Equation (5).

$$CF_E = \frac{\sum_{i=1}^{n} W_{NDCV} * NDCV}{W_{NDCV}} \quad (5)$$

where CF_E contributing factor of exposure to LVI-IPCC score, $NDCV$ score of main components of Natural Disaster and Climate Variability, W_{NDCV} measure of each specific indicator of natural disasters and climate variability.

2) Adaptive Capacity Index

Adaptive capacity describes the ability to manage adverse impacts and utilizing any opportunities that arise (Chepkoech et al., 2020; Thonicke et al., 2020). Contributing factor of adaptive capacity to LVI-IPCC score was calculated using Equation (6).

$$CF_A = \frac{W_{SDV} * SDV + W_{LS} * LS + W_{SN} * SN}{W_{SDV} + W_{LS} + W_{SN}} \quad (6)$$

where CF_A contributing factor of adaptive capacity to LVI-IPCC score; SDV, LS, SN score of the main components for socio-demographic, livelihood strategies and social networks; W_{SDV}, W_{LS}, W_{SN} measure of each socio-demographic indicator, livelihood strategies and social networks.

3) Sensitivity Index

Sensitivity is defined as the degree of influence of a system to climate change and climate variability (Adu et al., 2018). Contributing factor of sensitivity to LVI-IPCC score was calculated using Equation (7).

$$CF_S = \frac{W_L * L + W_W * W + W_f * F}{W_L + W_w + W_f} \quad (7)$$

where CF_S sensitivity score to climate change impacts; L, W, F score of the main components for land, water, and food, W_L the size of each land indicator, W_w the measure of each water indicator, W_f the measure of each food indicator.

The exposure, sensitivity, and adaptive capacity index score ranges from 0 to 1 where higher value indicates a higher household vulnerability to climate change (Swami and Parthasarathy, 2021).

4) Calculate LVI score

The LVI score was calculated based on Equation (8).

$$LVI_d = \frac{\sum_{i=1}^{5} W_{M_i} M_{d_i}}{\sum_{i=1}^{5} W_{M_i}} \quad (8)$$

where LVI_d livelihood vulnerability index in d region, W_{M_i} number of sub-indicators for each indicator, M_{d_i} score of each indicator.

5) LVI-IPCC score

The LVI-IPCC score was calculated based on Equation (9).

$$LVI_{IPCC_d} = (e_d - a_d)\, S_d \quad (9)$$

where LVI_{IPCC_d} livelihood vulnerability index in IPCC framework in d region, e_d exposure index, a_d adaptive capacity index, S_d sensitivity index. The LVI value ranges from 0 to 1, the higher the value, the higher the vulnerability of an area (Phu and De, 2019).

RESULTS AND DISCUSSIONS

Climate Condition

Sembalun District is a mountainous region, spanning at 390-1180 meters above sea level. The peaked dry season occured in July–September, while the peaked rainy season in December–February (Figure 2a). The highest monthly rainfall occured in January (296 mm), while the lowest monthly rainfall occured in

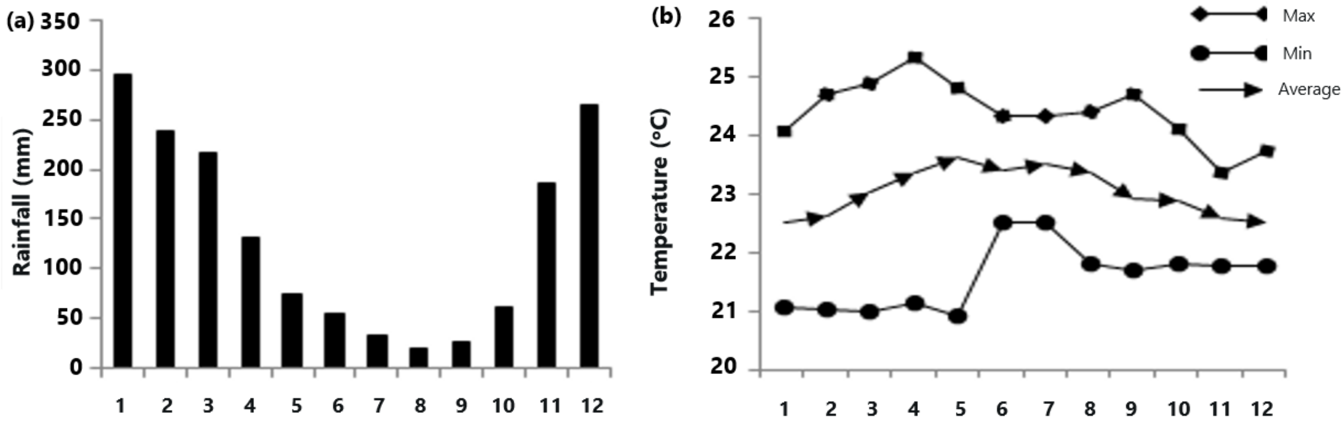

Figure 2. Variability of monthly average: (a) rainfall, and (b) temperature in Sembalun District from 1990 to 2019.

August (19 mm). Monthly average, maximum, and minimum air temperature ranged 22.0-23.6°C, 23.4-24.9°C, and 20.9-22.5°C, respectively (Figure 2b).

The highest temperature occurred in April (25.4°C), while the lowest temperature occurred in May (20.9°C). Generally, garlic planting was started in dry season. Farmer normally begins garlic cultivation on April-June each year. Our questionnaire confirmed this pattern.

Analysis of Rainfall and Air Temperature Influence on Garlic Productivity

Crop production was strongly influenced by climatic variable (Atmojo, 2002; Noor et al., 2005; Perdinan et al., 2008). Excessive rainfall will accelerate garlic rotting, while low rainfall will inhibit garlic growth. Figure 3 presents the relationship between the annual rainfall anomaly and the annual garlic productivity in Sembalun District. It is likely that rainfall will reduce garlic productivity but the influence was not significant ($r = -0.2$, $\alpha = 0.05$).

A negative correlation value suggests that higher annual rainfall will result in lower productivity and vice versa. However, the correlation coefficient between productivity and rainfall had a very low value, which indicated that the annual rainfall had an insignificant effect on garlic productivity in Sembalun. It is reasonable since the planting season was generally started in the dry season. Muhammad and Soelistyono, (2021) also reported that climatic variables such as rainfall had an insignificant influence on garlic productivity in Malang Regency.

Questionnaire results related to the garlic cultivation system in Sembalun revealed that during the rainy season, farmers do farming in higher fields and build deeper beds or ditches to prevent inundation. In contrast, during the dry season, farmers will cultivate in lowland area and they utilized water spring from Mount Rinjani.

The influence of air temperature is presented in Figure 4. Air temperature likely have a not strong correlation with garlic productivity, and it showed a negative correlation. A low temperature is a major inhibitor in garlic bulb growth, which was able to delay their development (Atif et al., 2020). On the other hand, an increased temperature will lead to a high evapo-transpiration, which was able to trigger water stress in the crops (Léllis et al., 2021). However, in the study, the correlation coefficient was low value with p value greater than 0.05. This indicated that air temperature has a no significant effect on garlic productivity.

Climate Change Projection

Agriculture is a vulnerable sector to climate change due to the impact on cropping patterns, planting time, and yield quality (Apriyana et al., 2021; Duku et al., 2018; Parker et al., 2019). On Lombok island, there has been a shift in wet and dry months from 1971 to 1980 and from 2001 to 2008 leading to a prolonged dry season (Nandini and Narendra, 2011).

Future climatic conditions in the study site likely indicated a drying pattern, which leads to arid condition. Sipayung et al. (2019) mentioned that the temperature in East Lombok was predicted to increase by 1°C annually. Other study, McGregor et al. (2016) predicted more days without rainfall in West Nusa Tenggara for

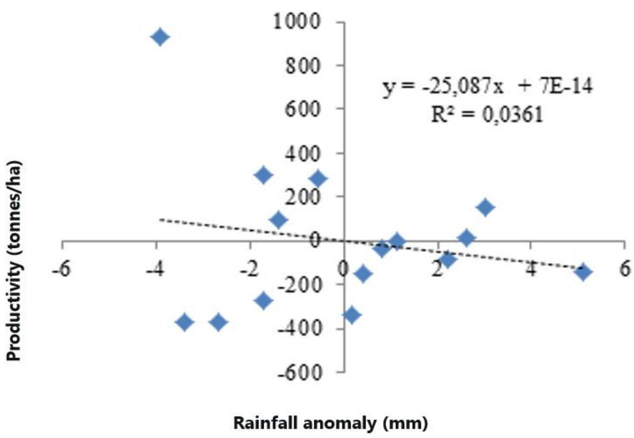

Figure 3. Relationship of annual rainfall anomaly with annual productivity.

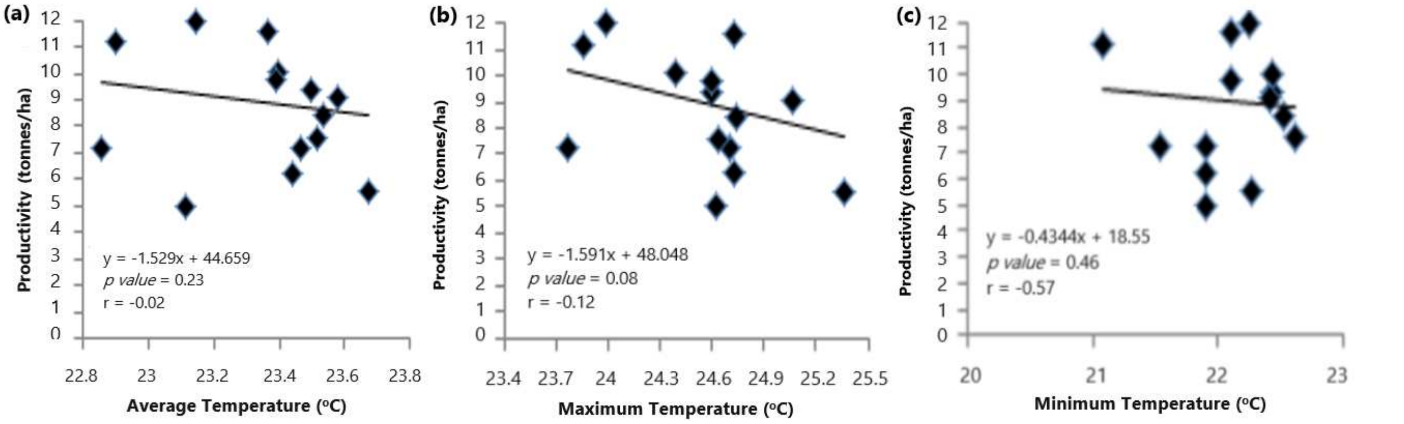

Figure 4. Correlation between annual garlic productivity and air temperature in the value of: (a) average; (b) maximum; and (c) minimum.

2016 to 2035 based on RCP 8.5 scenario. In addition, area with a decreased rainfall in Lombok Island will extend in 2050 based on the SRESA2 and SRESB1 scenarios (McGregor et al., 2016).

Yasin and Ma'shum (2006) reported that East Lombok likely had a dry climate, which characterized by less annual rainfall compared to other Indonesia region and short period of rainy season (4 months). Apart from drought threat, rainfall fluctuation could also aggravate pest attack and plant diseases (Koesmaryono et al., 2005). Under these conditions, mitigation and adaptation action is vital to minimize the climate change impact on garlic farming.

Livelihood Vulnerability of Garlic Farmers in Sembalun

Livelihood vulnerability of garlic farmers consists of three aspects, namely exposure, adaptive capacity, and sensitivity. Exposure index calculation aims to summarize the impact of climate change experienced by farmer households. The index score for the four villages was fairly high due to the villages' status as disaster-prone areas, especially for volcanic eruptions and earthquakes. Sembalun Bumbung and Sajang had the highest exposure levels with a score of 0.97, while the lowest was Sembalun Lawang with a score of 0.85.

Adaptive capacity index calculation aims to identify farmer households capability in doing efforts to cope with climate change impact. Sembalun Timba Gading was most vulnerable in terms of adaptive capacity with an index score of 0.54. This was driven by a higher score in socio-demographic and social networks component compared to other villages. In contrast, the highest index score was Sembalun Bumbung (0.50) where each major component score were the lowest.

Household Vulnerability According to LVI Approach

Sensitivity defined as the degree of influence of a system to climate change and variability (Žurovec et al., 2017). Sembalun Timba Gading and Sajang had the highest sensitivity index score (0.22). In general, the villages had a relatively low sensitivity index ranging from 0.20 to 0.22. Food and water components score had the same value (0) for all villages (Figure 5a). Farmer household in Sembalun District utilized springs from Mount Rinjani as their main water source.

Regarding food component, farmer used garlics from their first harvest as seed for next planting and for daily consumption, while for the yield from next harvest to be sold. According to LVI Approach, farmer households in Sembalun Timba Gading and Sajang villages were the most vulnerable than those in the other two villages with an LVI score of 0.46, while Sembalun Lawang Village was the least vulnerable (LVI score of 0.42).

The direct and indirect impacts of climate change were divided into two categories, namely biophysical impacts and socio-economic impacts (Kapitza et al., 2021). Several risks faced by farmer households in Sembalun District due to climate variability included social, economic, and institutional risks.

a. Social Risk

Most of the population in the four villages had a job related to agricultural sector. With uncertain onset of dry and rainy seasons gave a threat on planting season, then garlic productivity. This condition may affect the farmer household income and their capability to meet basic household needs, which may further lead to unemployment and social inequality.

b. Economic Risk

Floods and droughts are examples of climate change impacts. This unpredictable phenomenon can lead to excessive usage of plant drugs (fungicide, herbicide, pesticide) to overcome pests and plant diseases, which may increase farmer expenses.

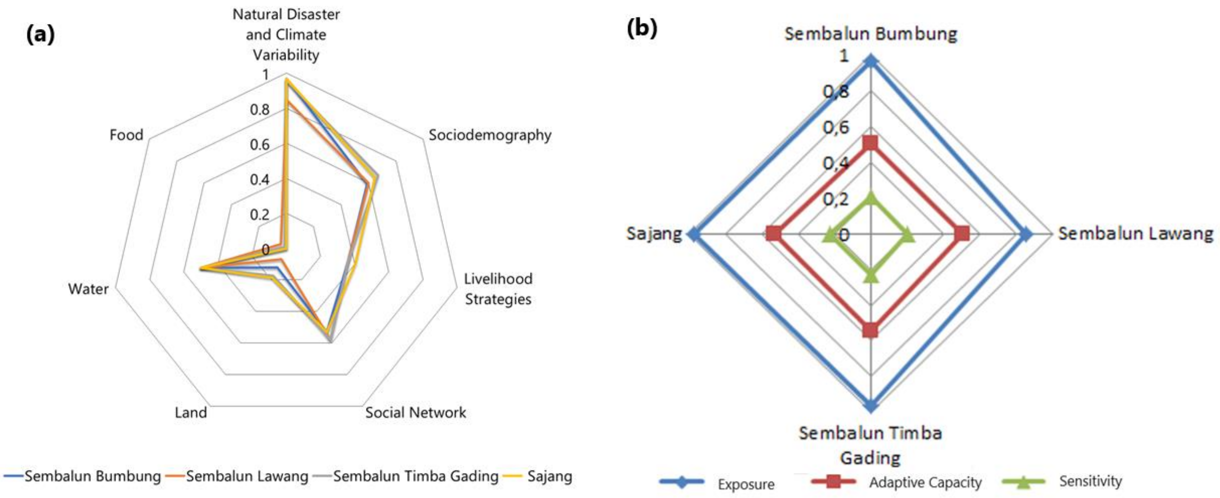

Figure 5. The spider diagram of LVI analysis in study areas: (a) the main LVI components of farmer households, and (b) components of LVI-IPCC index.

c. Institutional Risk

In general, garlic farmers in Sembalun District were unfamiliar with the phrase "climate change and variability". However, these changes could be understood by the local community. Related to this, the role of Agricultural Field Extension (PPL) was very vital to provide enlightenment and information related to climate problems.

Household Vulnerability According to LVI-IPCC Approach

The farmer households in Sembalun Timba Gading and Sajang were the most vulnerable as indicated by LVI-IPCC score (0.57). The high vulnerability score was driven by high exposure and low adaptive capacity score (Figure 5b). Meanwhile, Sembalun Lawang had the lowest vulnerability score (0.55) due to low exposure and high adaptive capacity.

Recommendations for Adaptation to Variability and Climate Change

a. Agricultural Training

Based on questionnaire outputs, indicators of social network showed that farmers had lack of information about agricultural practices, as well as cultivation training provided by extension workers or related agencies. In fact, the training was expected to provide the farmers with some knowledge about climate change, and related innovations to address climate change.

b. Climate Prediction

At this time, garlic farmers in Sembalun District mostly predicted the onset and the end of planting season based on traditional ways. They used the historical record of climate condition to guess the planting date, instead of employing the climate information provided by the related agency. Therefore, to ease and clarify the farmer about the planting season, there should be a scientific-based planting period information as well as the climate prediction informed directly from the related agency.

c. Adaptation Technology

This adaptation aimed to adjust the agricultural practices to become more resilient in dealing with climate change. Furthermore, it could be a preventive action to reduce the risk of crops failure in the future. Recently, some sophisticated practices had been adopted by the farmers, including irrigation machine utilization, modern land management process, and superior varieties.

CONCLUSIONS

Climate variables (rainfall and air temperature) were negatively correlated to garlic productivity in the four villages. According to LVI and LVI-IPCC approaches, Sembalun Timba Gading and Sajang villages were the most vulnerable villages, while Sembalun Lawang was the least vulnerable. The suggested recommendations to adapt climate change, which comprised of agricultural training, climate prediction, and adaptation technology.

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