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Full Length Article

Livelihood vulnerability of smallholder farmers to climate change: A comparative analysis based on irrigation access in South Sulawesi, Indonesia

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ABSTRACT

Bulukumba Regency is one of the major rice-producing areas in South Sulawesi, Indonesia and has experienced frequent climate disasters over the past decade. Several downstream villages within the Bettu River irrigation area have been affected by the drought, culminating in reduced lowland rice production and increasing the vulnerability of farmers' livelihoods. This study aims to evaluate the vulnerability of the livelihood system among rice farmers in the Bettu River irrigation area by classifying the area into two zones based on the distance from the main irrigation canal, namely the upstream area and downstream area. The livelihood vulnerability index (LVI) framework and livelihood vulnerability index-Intergovernmental Panel on Climate Change (LVI-IPCC) approach were applied by selecting geographic and socio-demographic indicators that affected the farmer households, including 8 major components and 26 sup-components. The data for LVI-IPCC estimation were collected by randomly selecting 132 households from villages in the two areas. The empirical results showed that farmers in the downstream area were more vulnerable to climate change than farmers in the upstream area. The major components causing the livelihood vulnerability of the downstream farmers were livelihood strategy, food, water, land, health, as well as natural disasters and climate variability. In particular, the sub-components of agricultural livelihood diversification, consistent water supply for farming, and drought events were important in the downstream area. Farmers in the upstream area were vulnerable to socio-demographic profile and social network components. The LVI-IPCC findings suggested that the government should prioritize farmers in the downstream area to develop resilience strategies, particularly by increasing irrigation infrastructure and the number of reservoirs and drilling holes. Furthermore, to increase their adaptive capacity in terms of diversification of agricultural livelihood systems, the government and donor agencies need to provide trainings on the development of home food industries for poor farmers and vulnerable households that were affected by disasters.

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1. Introduction

The increasing frequency of disasters due to the impact of climate change has affected the livelihood systems of small farmers, especially in agrarian-based developing countries (H. Guo et al., 2021). Indonesia, an agriculture-based country, is vulnerable to the impacts of climate change, including floods, droughts, changes in rainfall patterns, and rising temperatures (Government of the Republic of Indonesia, 2021). It is ranked as the third country with the highest climate risk exposure to floods and droughts that threaten agricultural production and food security (Saptutyningsih et al., 2020; World Bank, 2021). Several reports show that the temperature rise in Indonesia will range from 0.8°C to 1.4 °C by 2050 (World Bank, 2021; IPCC et al., 2022).

Fluctuations in temperature and rainfall have a significant impact on rice productivity, which is the primary product of the Indonesian agricultural industry. The productivity of Indonesia's lowland rice has decreased by approximately 8.23% as a result of climate change in 2020 (BPS-Statistics Indonesia, 2021). Bulukumba Regency is one of South Sulawesi's major rice-producing regions. This region has suffered from numerous natural disasters brought on by the effects of climate change, including droughts, floods, and pest attacks, which caused production to fall by 4.80% in 2020 (Arifah et al., 2021).

Farmers in Bulukumba Regency are most affected by drought. During the long dry season, irrigation facilities can only irrigate the upstream area, leaving the downstream rice fields to rely on other water sources like pumps and reservoirs. This causes a disparity in income earned by farmers in the downstream and upstream areas. These impacts significantly affect the vulnerability of farmers' livelihood systems (Yuliawan and Handoko, 2016; R. Guo et al., 2021). It is crucial to analyze the vulnerability of livelihood system at household level (Adzawla et al., 2020; Shen et al., 2022), because the vulnerability of livelihood system varies over time and location (Asfaw et al., 2021). The impact of climate change can only be clearly understood when the livelihood system, vulnerability level, and adaptive capacity are well explored at the micro-level to formulate optimal adaptation policies (Qin et al., 2022) Vulnerability measurement is a commonly used tool to explain the potential impact of disaster on humans and ecological systems caused by climate change (Handayani et al., 2017). The vulnerability of people's livelihood systems is determined by their sensitivity to exposure to stressors, and capacities to resist, recover from, and adapt to the effects (Jamshidi et al., 2019; Asfaw et al., 2021; Shen et al., 2022).

Various studies on the vulnerability of livelihood system have been carried out with different scopes and findings. According to the findings of these studies, differences in vulnerability are caused by differences in household characteristics, a lack of infrastructure, technological facilities, diversification of livelihoods, and access to financial institutions and extension services (Dendir and Simane, 2019; Ghosh and Ghosal, 2020; Ho et al., 2022; Tran et al., 2022). Furthermore, previous studies have focused on vulnerability due to climate change impacts in Asian regions with specific socioeconomic characteristics and climatic conditions (Huong et al., 2019; Puspitasari et al., 2019; Kumar et al., 2020; Shen et al., 2022; Zhang et al., 2022). However, studies on vulnerability in specific ecological zones are still lacking, making it difficult to implement appropriate livelihood system adaptation strategies for dealing with the effects of climate change (Murken and Gornott, 2022). The location of lowland rice (for example, in the downstream and upstream areas) and access to resources are important factors that determine the level of vulnerability in rural communities. However, the differences between the downstream and upstream irrigated rice farmers have not been well examined.

This research attempts to fill the gaps in the current literature by analyzing the vulnerability of farmers' livelihood systems due to the impact of climate change in downstream and upstream irrigation areas. The majority of the farmers in the study area are sharecroppers rather than landowners and the vulnerability of livelihood system is affected by their land ownership status (Brown et al., 2019; Murken and Gornott, 2022). Therefore, this study also aims at analyzing the factor of land ownership on the vulnerability of farmers' household livelihood systems. Identifying the vulnerability form and level of livelihood system plays a significant role in increasing the adaptive

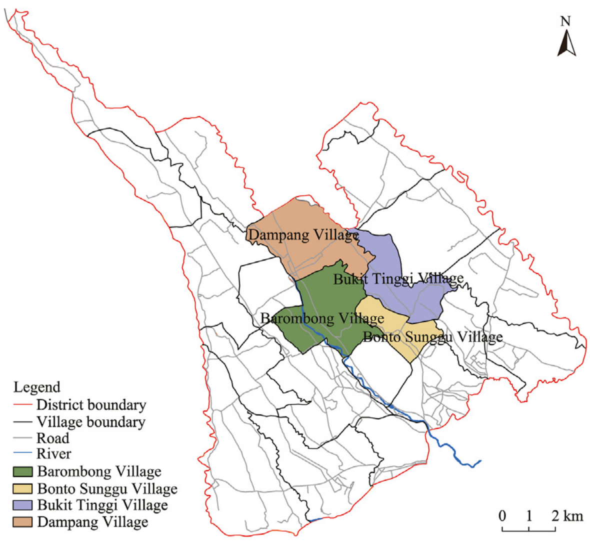

Fig. 1. Overview of gantarang district (Statistics Indonesia Bulukumba Regency, 2021).

capacity of poor farmers. The findings can be used in determining appropriate interventions for the development program, particularly in terms of increasing the resilience of farmers' livelihood systems affected by climate change.

2. Methodology

2.1. Study area

The study was conducted in Gantarang District, Bulukumba Regency, South Sulawesi, Indonesia, the location with the most irrigated rice fields that are frequently subject to drought and flooding. Gantarang is the largest district in the Bulukumba Regency with an area of 173.51 km^2 and 21 villages (Statistics Indonesia Bulukumba Regency, 2021). Geographically, this district is located between 5°20′–5°40′S and 119°58′–120°28′E, with an altitude approximately 500–700 m a.s.l. (Fig. 1). It is the largest rice-producing district in Bulukumba Regency with an area of 1.54×10^5 km^2 of lowland rice, and around 40.00% of the total population (81,170 people) are farmers (Statistics Indonesia Bulukumba Regency, 2021).

This area has irrigation facilities for water rice fields, namely the *Irigasi Bettu* (Bettu Irrigation), which irrigates 1817 km^2 covering the villages of Dampang, Barombong, Bialo, Bonto Sunggu, Paenre Lompoe, and Bukit Tinggi (Statistics Indonesia Bulukumba Regency, 2021). During a long dry season, the condition of Bettu River irrigation area is usually uncertain, which usually results in a lack of water for rice fields, particularly in the downstream area. Several villages, such as Bukit Tinggi and Bonto Sunggu, often experience water shortages. This is due to the area's location, which is far from the main pumping station of Bettu Irrigation. Despite the availability of irrigation access, the downstream rice fields often rely on rainwater to begin the planting season. This leads to an inequality of harvest yields for the downstream and upstream farmers, threatening the livelihood systems of the farmers. The long dry season is often common from April to September. Aside from these months, drought has recently occurred in December and January.

2.2. Sampling and data collection

Four villages were chosen to represent the downstream and upstream irrigated areas. The villages of Bukit Tinggi and Bonto Sunggu were chosen to represent the downstream area as their location was approximately 6–7 km from the main irrigation system. Dampang and Borombong villages represented the upstream area with a distance of 0–2 km from the irrigation source. Farmers with at least ten years of farming experience were chosen as respondents. This timescale was chosen because farmers can best recall a disaster that affected their finances. There were 270 farmers who met these criteria in the downstream irrigation area and 143 in the upstream area. The sample size was calculated using the Slovin formula (Yamane, 1967):

$$n = \frac{N}{1 + Ne^2} = \frac{270}{1 + 270 \times 0.1^2} = 72.9(\text{approximately 73 farmers in the downstream area}), \tag{1}$$

$$n = \frac{N}{1 + Ne^2} = \frac{143}{1 + 143 \times 0.1^2} = 58.8(\text{approximately 59 farmers in the upstream area}), \tag{2}$$

where n is the sample size; N is the number of farmers in the study area who meet the criteria for more than ten years of farming experience; and e is 10.00% of N. The sample size is the reason for determining the 10.00% significance level. Since the number of people that meet the criteria was small, a larger sample size was required.

Natural disaster and climate variability data were obtained from extension workers and the National Agency for Disaster Management to supplement farmer information. Metrological data for this study were gathered for the Gantarang District from 2011 to 2020. To facilitate the flow of information from farmers, interviews were conducted in two languages: Indonesian and local dialects (Bugis). The data were collected between May and August in 2021.

2.3. Data analysis

This study adopted an indexation approach which included several indicators that were considered to affect vulnerability. In measuring the vulnerability of farmers' livelihood systems, the livelihood vulnerability index (LVI) developed by Hahn et al. (2009) considers several variables to calculate the level of exposure to natural disasters and climate changes, the adaptive capacity of households, and their sensitivity to impacts.

To determine the vulnerability level among lowland rice farmers, this study used the concept of Intergovernmental Panel on Climate Change (IPCC) (Hahn et al., 2009; Adu et al., 2018; Huynh and Stringer, 2018; Gupta et al., 2020). According to IPCC (2014), climate change vulnerability is determined by exposure, sensitivity, and adaptative capacity. Hahn et al. (2009) created the LVI and the livelihood vulnerability index- Intergovernmental Panel on Climate Change (LVI-IPCC) to analyze household-level data for future planning in the Mabote and Moma districts of Mozambique. They discovered that households in the study area were vulnerable to seven major factors: natural disasters and climate variability, livelihood strategy, socio-demographic profile, social network, health, food, and water. By using the study of Murken and Gornott (2022), we added a factor of land condition that affects vulnerability in the study area.

Natural disasters and climate variability data were collected through surveys of households that experienced weather-related shocks. This method was considered to be more accurate because each farmer has different experiences and perceived impacts from extreme climate events. Furthermore, this approach could overcome the lack of data obtained from secondary data, since long-term weather data

Table 1
Major components of the livelihood vulnerability index-Intergovernmental Panel on Climate Change (LVI-IPCC) framework in this study.

Contributing factor	Major component	Definition	Reference
Adaptive capacity	Livelihood strategy	Farmers' strategies for dealing with the impact of climate change, such as diversifying agricultural livelihood systems or working in different communities	Ellis (1998); Liu et al. (2018)
	Socio-demographic profile	Farmer characteristics that influence knowledge and response to climate change impacts, including age, gender, educational background, farming experience, etc.	Hahn et al. (2009); Shen et al. (2022)
	Social network	A set of specific relationships among a group of people, in which the characteristics of those relationships can be used in dealing with the impacts of climate change	Mitchell (1969); Nguyen and Leisz (2021)
Sensitivity	Food	Food security and factors that contribute to farmers' vulnerability in the face of climate change, such as crop diversification and the ability to store seeds and crops	Hahn et al. (2009); Adu et al. (2018)
	Water	Water availability for farmers to water their agricultural land in the face of climate change impacts	Adu et al. (2018); Ho et al. (2022)
	Land	Land conditions and factors that contribute to livelihood vulnerability to the effects of climate change, such as location, area, and land ownership status	Mitchell and McEvoy (2019); Murken and Gornott (2022)
	Health	Health status that contributes to the vulnerability of farmers' livelihood systems to the impacts of climate change, including the awareness of farmers to visit health services when sick	Hahn et al. (2009); Adu et al. (2018)
Exposure	Natural disasters and climate variability	Natural disasters due to climate variability experienced by farmers in the last ten years, including droughts, floods, and pest attacks	Hahn et al. (2009); Ho et al. (2022)

The LVI analysis stages are as follows.

at the local level were extremely limited, as is often the case in developing countries (Nguyen et al., 2020). Table 1 shows the eight major components of vulnerability in the LVI-IPCC framework.

The LVI analysis stages are as follows.

Step 1. standardization of each sub-component.

Each sub-component is measured using a different scale, therefore, to compare the sub-components and the major components, the initial step is standardization using the formula:

$$\text{Index}_{sd} = \frac{s_d - s_{\min}}{s_{\max} - s_{\min}}, \tag{3}$$

where Index_{sd} is a standardized value of each sub-component; s_d is the observed value of each sub-component in each area; and $s_{\max}$ and $s_{\min}$ are the maximum and minimum values for each sub-component, respectively.

Step 2. average of each sub-component.

After standardization, each sub-component is averaged by calculating the value of the major component using Equation (4).

$$M_{di} = \frac{\sum_{i=1}^{m} \text{Index}_{sdi}}{m}, \tag{4}$$

where M_{di} is one of the eight major components of livelihood vulnerability in each area; Index_{sdi} represents the sub-components for each area that make up each major component; and m is the number of sub-components in each major component ($m = 8$).

Step 3. calculation of the LVI:

$$\text{LVI}_d = \frac{\sum_{i=1}^{m} W_{mi} M_{di}}{\sum_{i=1}^{m} W_{mi}}, \tag{5}$$

where LVI_d represents household livelihood vulnerability of each area; W_{mi} indicates the weight of livelihood vulnerability of each major component. Adopting the Food, Agriculture and Natural Resources Policy Analysis Network (FANRPAN) value range, the LVI was classified as not vulnerable from 0.00 to 0.30, 0.31 to 0.60 as moderately vulnerable, and 0.61 to 1.00 as highly vulnerable (Ho et al., 2021).

Step 4. After the value of each major component is calculated, then each contributing factor is calculated by combining the categorization scheme in Table 1 using Equation (6).

Table 2
Sub-components of the LVI-IPCC framework in this study.

Major component	Sub-component	Description	Reference
Livelihood strategy	Agricultural livelihood diversification	The inverse of (the number of agricultural activities+1) reported by a household, e.g., a household growing rice, watermelon, and livestock would have a livelihood diversification index = 1/(3 + 1) = 0.25	Hahn et al. (2009); Ho et al. (2021); Shen et al. (2022)
	Household dependent solely on agriculture	Percentage of households that reported only agriculture as a source of income	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Family members working in different communities	Percentage of households that at least one family member who works outside the community for their primary work activity	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
Socio-demographic profile	Dependency ratio	Percentage of dependent people (<15 years and >60 years old)	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Education level of household head	Average level of education of the head of the household	Nguyen and Leisz (2021); Shen et al. (2022)
	Farming experience of household head	Average years of farming experience of the household head	Dendir and Simane (2019)
Social network	No membership with any community	Percentage of households that do not associated with any organization	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Households with media access in the house	Percentage of households with access to information resources.	Nguyen and Leisz (2021)
	No access to credit loans	Percentage of households had no access to credit	Hahn et al. (2009); Ho et al. (2021); Nguyen and Leisz (2021)
	Receive:give ratio	Ratio of (the number of types of help received by a household in the past month+1) to (the number of types of help given by a household to someone else in the past month+1)	Adu et al. (2018); Hahn et al. (2009); Nguyen and Leisz (2021)
	No access to local government assistance in the past 12 months	Percentage of households that do not receive any assistance from the local government in the past 12 months	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
Food	Crop diversity index	The inverse of (the number of crops grown by a household+1). e.g., a household that grew rice, watermelon, corn, and cassava would have a crop diversity index = 1/(4 + 1) = 0.20	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Do not save crops	Percentage of households that do not save crops from each harvest	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Do not save seeds	Percentage of households that do not save seeds from year to year	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
Water	Do not have consistent water supply	Percentage of households reported that the availability of water for farming was not consistent	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Utilize a natural water source for farming	Percentage of households that reported a river, borehole, pool, and dam as their alternative water source for farming	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Water conflict	Percentage of households that reported having heard about conflicts over water for farming in their community	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
Land	Land location	Average distance of the rice field location to the main irrigation access	Nguyen and Leisz (2021)
	Area of rice field	Average area of a farmer's rice field	Mitchell and McEvoy (2019); Murken and Gornott (2022); Tran et al. (2022)
	Land tenure	Percentage of households reported as land owner	Mitchell and McEvoy (2019); Murken and Gornott (2022); Tran et al. (2022)
Health	Travel time to a health facility	Average time of getting to the nearest health facility for household	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Family members did not see a doctor (medical services) during their illness	Percentage of households that do not visit doctor during illness	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
Natural disasters and climate variability	Number of drought events in the past ten years	Household reported the number of drought events in the past ten years	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Number of flood events in the past ten years	Household reported the number of flood events in the past ten years	Hahn et al. (2009); Adu et al. (2018); Ho et al. (2021)
	Number of pest attacks events in the past ten years	Household reported the number of pest attacks events in the past ten years	Mallari and Ezra (2016); Kamaluddin (2019); Skendžić et al. (2021); Shen et al. (2022)
	Lost crops due to disaster	Percentage of households that reported yield lost due to disaster	Hahn et al. (2009); Adu et al. (2018); Nguyen and Leisz (2021)

$$CF_d = \frac{\sum_{i=1}^{m} W_{mi} M_{di}}{\sum_{i=1}^{m} W_{mi}}, \quad (6)$$

Table 3
LVI values of the downstream and upstream areas of Gantarang District.

Sub-component	LVI		Major component	LVI	
	Downstream area	Upstream area		Downstream area	Upstream area
Agricultural livelihood diversification	0.72	0.36	Livelihood strategy	0.62	0.48
Household dependent solely on agriculture	0.60	0.56			
Family members working in different communities	0.55	0.52			
Dependency ratio	0.41	0.49	Socio-demographic profile	0.34	0.42
Education level of household head	0.24	0.36			
Farming experience of household head	0.36	0.42			
No membership with any community	0.54	0.44	Social network	0.43	0.50
Households with media access in the house	0.44	0.12			
No access to credit loans	0.30	0.51			
Receive:give ratio	0.38	0.54			
No access to local government assistance in the past 12 months	0.47	0.90			
Crop diversity index	0.54	0.13	Food	0.55	0.52
Do not save crops	0.49	0.69			
Do not save seeds	0.62	0.75			
Do not have consistent water supply	0.95	0.54	Water	0.91	0.37
Utilize a natural water source for farming	0.97	0.29			
Water conflict	0.81	0.27			
Land location	0.59	0.26	Land	0.59	0.26
Area of rice field	0.22	0.11			
Land tenure	0.56	0.51			
Travel time to a health facility	0.54	0.38	Health	0.49	0.44
Family members did not see a doctor (medical services) during their illness	0.44	0.49			
Number of drought events in the past ten years	0.83	0.34	Natural disasters and climate variability	0.52	0.35
Number of flood events in the past ten years	0.15	0.27			
Number of pest attacks events in the past ten years	0.51	0.50			
Lost crops due to disaster	0.59	0.29			
Overall				0.53	0.42

where CF_d is an IPCC-defined contributing factor (exposure, sensitivity, or adaptive capacity) for each area.

Step 5. After the values of exposure, sensitivity, and adaptive capacity contributing factors have been calculated, then the three contributing factors are combined using Equation (7).

$$\text{LVI-IPCC}_d = (e_d - a_d) s_d, \quad (7)$$

where LVI-IPCC_d is the value of LVI for each area using the IPCC vulnerability framework; e_d is the calculated exposure score for each area which is equivalent to the major component of natural disasters and climate variability; a_d is the adaptive capacity score calculated for each area, namely the weighted average of the major components of livelihood strategy, socio-demographic profile, and social network; and s_d is the sensitivity score calculated for each area, namely the weighted average for the major components of food, water, land, and health. The LVI-IPCC is on scale from −1 (least vulnerable) to 1 (most vulnerable) (Hahn et al., 2009).

3. Results and discussion

3.1. Farmer's livelihood vulnerability index (LVI)

The LVI-IPCC framework included 8 major components and 26 sub-components in this study. These were determined by reviewing literature, as well as the results of surveys and field interviews with farmers (Table 2).

The value of LVI and its components for the downstream and upstream irrigation areas are presented in Table 3. Farmers in the downstream area had a higher vulnerability index (0.53) than farmers in the upstream area (0.42), and both were classified as moderately vulnerable. The major components causing vulnerability in the downstream area were livelihood strategy (0.62), food (0.55), water (0.91), land (0.59), health (0.49), and natural disasters and climate variability (0.52). Farmers in the upstream area were more vulnerable than in the downstream area due to two major components: social demography profile (0.42) and social network (0.50).

Farmers in the downstream irrigation area were highly vulnerable (0.62) in terms of livelihood strategy because they had less diverse agricultural livelihoods (0.72), where they only grew rice and fruit crops. Other factors that contributed to the vulnerability were their reliance on agricultural products as a source of income (0.60) and limited opportunities to work outside the community (0.55). Crop diversification and livelihood system diversification are strategies for reducing production risks caused by climate shocks (Ellis, 1998; Khan et al., 2020; Shen et al., 2022).

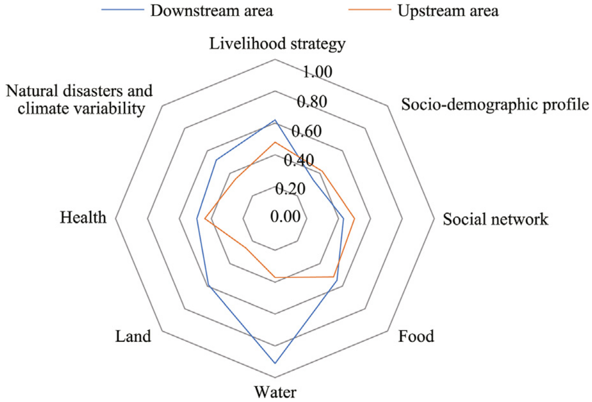

Fig. 2. Spider web diagram of the major components of livelihood vulnerability index (LVI) for the downstream and upstream areas of Gantarang District.

In terms of socio-demographic profile, the level of vulnerability of farmers in the downstream and upstream irrigation areas was moderate (0.34 and 0.42). Farmers in the upstream area had a higher dependency ratio (0.49) than in the downstream area (0.41). Based on education level, most of the household heads in the upstream area did not complete elementary school, limiting farmers' ability to diversify their livelihood system when affected by climate change. Low levels of education limit access to information, especially from written sources, thereby increasing vulnerability to climatic stresses (Dendir and Simane, 2019; Tran et al., 2022). In terms of farming experience, farmers in the upstream irrigated area were more vulnerable (0.42) than farmers in the downstream area (0.36). Experience is a valuable source of knowledge in farming, allowing farmers to identify climate change or other threats (Jezeer et al., 2019).

Farmers in the downstream and upstream irrigation areas were moderately vulnerable, according to the social network component (0.43 and 0.50). Farmers' vulnerability in the upstream area was caused by three sub-components: restricted access to credit loans, receive:give ratio, and access to local government assistance. Farmers in the upstream area had limited access to local government assistance, making them highly vulnerable (0.90) to the effects of climate change. For receiving assistance and/or support from relatives and neighbors, farmers in the upstream area were more vulnerable (0.54) than the downstream farmers (0.38). Farmers in the upstream area were vulnerable because they lacked capital, had no personal savings in banks, and had no access to credit or loans. Instead, they relied on informal financing systems and borrowed money from family and friends. Farmers who had access to credit, on the other hand, were less vulnerable (Adzawla et al., 2020). Similarly, the tradition of gotong royong (mutual cooperation) and mutual trust in society were the most important values in reducing vulnerability (Liu et al., 2018; Saptutyningsih et al., 2020; Zhang et al., 2020; Salman et al., 2021).

The downstream and upstream areas were moderately vulnerable to food components (0.55 and 0.52, respectively). Farmers' ability to save seeds and crops indicated that they had anticipated climate threats but their ability to save seeds and crops was influenced by storage space facilities and financial conditions. Farmers who lacked storage and adequate financial resources must sell seeds and crops to meet household needs during climate shocks (Blackmore et al., 2021; Ho et al., 2022).

Farmers in the downstream irrigation area were highly vulnerable to water (0.91). As a result of drought, rice yields decreased almost every year over the last decade. Further, they were highly vulnerable to using natural water sources, with a score of 0.97. Farmers used other sources of water when irrigation supply was reduced, such as reservoirs or bore wells. Due to the drought events, the potential for conflicts over water use in the downstream irrigation area was high (0.81). A study conducted in Vietnam reported that conflict occurred when water was shared between rice cultivation and other utilizes, particularly for domestic uses such as drinking water and washing, as well as other uses by hydropower, and other crops (van Huynh et al., 2019).

In terms of the vulnerability of the land major components, the downstream area was moderately vulnerable (0.59), whereas the upstream area was not vulnerable (0.26). Both the downstream and upstream areas were classified as moderately vulnerable (0.51 and 0.56, respectively) in terms of agricultural land ownership, but neither was vulnerable in terms of area of rice field (0.22 and 0.11, respectively). Farmers in the downstream area are primarily sharecroppers, who faced constraints when making decisions during a drought, such as the costs of purchasing water pumps. In terms of the effect of land ownership, Brown et al. (2019) and Sundar Pani and Mishra (2022) reported that land tenure was essential for increasing agricultural production, generating income, and gaining access to loans.

Based on the overall health vulnerability score, the downstream and upstream areas were moderately vulnerable. The downstream area was more vulnerable (0.54) in terms of the average time for a household to reach a health facility than the upstream area (0.38). Farmers in the downstream and upstream areas were moderately vulnerable (0.44 and 0.49, respectively) due to a lack of awareness about visiting health facilities when family members were sick. Farmers preferred alternative medicine, including herbal medicine, as a treatment. They visited a doctor only when their illness was severe. The average time traveling to health care facilities is an important indicator of vulnerability (Huong et al., 2019).

The vulnerability of natural disasters and climate variability in both regions were moderately vulnerable (0.52 and 0.35,

Table 4
Values of the LVI-IPCC contributing factors for the downstream and upstream areas of Gantarang District.

Contributing factor	LVI-IPCC	
	Downstream area	Upstream area
Adaptive capacity	0.46	0.47
Sensitivity	0.66	0.42
Exposure	0.52	0.35
Overall	0.04	−0.05

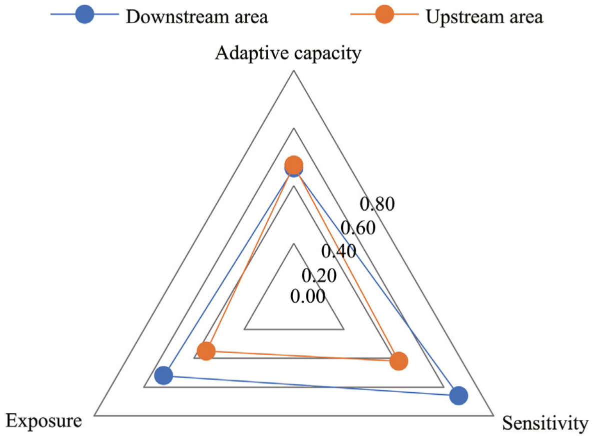

Fig. 3. Triangle diagram of the livelihood vulnerability index-Intergovernmental Panel on Climate Change (LVI-IPCC) for the downstream and upstream areas of Gantarang District.

respectively). The sub-component of the number of droughts showed that the downstream area had high vulnerability (0.83). The increase in pest attacks contributed to moderate vulnerability in both areas, with a score of 0.51 in the downstream and 0.50 in the upstream. The index values in the upstream area were 0.15 and 0.27 in the downstream area, indicating that the two study locations were not vulnerable to flooding. Farmers experienced a decrease in rice production with a vulnerability score of 0.59 in the downstream and 0.29 in the upstream. The result of this study indicated that drought, pest attacks, and flooding all have an impact on lowland rice productivity. These was consistent with the findings of Arifah et al. (2021) and Rahman et al. (2022), who found that droughts, floods, and pest attacks have the greatest impact on rice production by reducing rice yield and vegetative growth.

The results of the eight major components of LVI are summarized in a spider web diagram in Fig. 2. This shows the vulnerability index of the livelihood system ranging from not vulnerable (0.11) to highly vulnerable (0.97).

3.2. LVI-IPCC for the downstream and upstream areas of Gantarang District

The LVI-IPCC results indicated greater vulnerability in the downstream area (0.04) than in the upstream area (−0.05) (Table 4). Fig. 3 depicts the impact on the criteria for adaptive capacity, sensitivity, and exposure. This shows that the downstream area was more exposed to climate change impacts (0.52) than the upstream area (0.35).

Based on the contributing factor of sensitivity, farmers in the downstream area were vulnerable to all major components, with a very high vulnerability to the water availability component, and a moderate vulnerability to the food, land, and health components. In terms of adaptive capacity, the downstream and upstream areas were in the moderate vulnerability range (0.46 and 0.47, respectively). The sensitivity and exposure components in the downstream area had a higher vulnerability index than the adaptive capacity. Consistent with this finding, Ehsan et al. (2022) stated that households with low adaptive capacity will struggle to deal with the harmful effects of climate hazards, as this is the foundation for managing vulnerability and taking adaptation actions. It can be stated that farmers with a high exposure value and relatively low adaptive capacity become more sensitive to climate change and are affected by its negative effects, increasing their vulnerability.

4. Conclusions

This study applied the LVI and LVI-IPCC to assess the climate vulnerability of farmers' livelihood systems in the downstream and upstream areas of Gantarang District, South Sulawesi, Indonesia, with information collected at the household level. This study found that these indices were useful tools for assessing livelihood vulnerability. Due to their high sensitivity to natural disasters and climate variability, farmers in the downstream area were found to be more vulnerable to the effects of climate change than farmers in the upstream area. The major components that contributed to vulnerability in the downstream area were livelihood strategy, food, water, land, health, and natural disasters and climate variability. The downstream area was found to be highly vulnerable in the sub-components of agricultural livelihood system diversification, adequacy of water supply for farming, and drought events.

This research provides contributions to the current literature on vulnerable groups, as well as the factors that contribute to the vulnerability of livelihood system due to the impacts of climate change. The findings can be used by local governments to develop climate risk assessments. In adaptation planning, especially at the local level, priority should be given to poor farmers, especially sharecroppers who rely heavily on agricultural products. Government intervention in sustainable livelihood strategies and sustainable intensification techniques is needed, such the introduction of drought-tolerant rice varieties, integrated pest management, flood management, and early warning systems. Providing education and training to increase adaptive capacity is one of the appropriate adaptation strategies for vulnerable households. Moreover, priority programs for farmers in downstream area in developing drought resilience strategies, particularly by improving irrigation infrastructure, are critical. Several limitations of this study should be considered for future research. The primary data used were affected not only by climate change but also by the COVID-19 pandemic, particularly in the components of livelihood strategy, food, and health. Apart from that, disaggregating vulnerability at the household level would enable future research to identify context-specific factors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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