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Agroforestry Practices and Community Resilience to The Impact of Climate Change in Sesaot Forest Area, Lombok, Indonesia

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Abstract: Climate change affects agroforestry production and community resilience in forest areas. This study aims to: (1) identify vulnerabilities of forest products to climate change; (2) analyze community adaptation strategies; and (3) assess resilience levels of forest-adjacent communities. The research applied descriptive methods via field observations, interviews, and focus group discussions. From 74 residents, random sampling was used (Slovin method, 10% margin of error). Variables included economic, psychological, and social-institutional aspects. Resilience was assessed using a scoring system integrating Reivich & Shatté's theory and a Likert scale, categorized into five levels: very high to very low. Results show that key vulnerabilities in the Sesaot forest area include harvest failures of major crops (e.g., durian, mangosteen, avocado, rambutan, cacao, coffee), with losses reaching 60–80%. Communities adapted through stratified agroforestry systems and strengthening local institutions. Resilience levels were high overall—economically moderate, but socially and psychologically strong. The study recommends improving economic resilience by reducing crop failure risks, including through the establishment of plant health clinics.

Keywords: Agroforestry; Climate change; Forest Communities; Resilience

Introduction

One of the biggest issues currently in the global, national and local scope is climate change(Adger et al., 2018; Dietz et al., 2020; Jhariya et al., 2019; Raven & Wagner, 2021). The impact of climate change has caused vulnerability in various aspects of life, especially in the forestry sector (Esquivel et al., 2019; Jhariya et al., 2019; Thorne et al., 2018), agriculture (Karimi et al., 2018; Sohail et al., 2022), marine (Rizal & Anna, 2019), and health (Raimi et al., 2021). Vulnerability is indicated by disruption of crop production, limited water availability, intensity of pest and disease attacks and increasing disease endemics (Cianconi et al., 2020; Ebi et al., 2021; Mousavi et al., 2020). Other impacts that are no less worrying are the intensity of flooding, erosion (Barnard et al., 2019; Dayrit et al., 2018; Eccles et al., 2019), landslides (Crozier, 2010; Rianna et al., 2016), robberies (Correa et al., 2023; Marsooli et al., 2019), and wind anomalies (Cheng et al., 2012; Wagena et al., 2018).

Good forests will guarantee good environmental management and the implications will minimize social, economic and health vulnerabilities. In the climate change constellation, the forestry sector is in a paradoxical situation (Markum et al., 2017), in the sense that forestry is a strategic sector as a climate control factor (Jhariya et al., 2019; Mansoor et al., 2022), reducing emissions in the air (Mackey et al., 2020; Raihan & Tuspekova, 2022), erosion and flood prevention (Milutinović & Živković, 2022; Tzioutzios & Kastridis, 2020), and water supply function (Abessa et al., 2019; Octavia et al., 2022; Xie & Ma, 2023). However, on the other hand, the current condition of forests continues to experience degradation and deforestation which is

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difficult to control. Forests, which should be a barrier in reducing the rate of climate change, are actually triggering climate change (Fadrique et al., 2018; Mostegl et al., 2019; Sousa-Silva et al., 2018).

The Sesaot Forest Area covers a protected forest area of 3,042 ha. This forest area has experienced changes in forest cover since 2000 due to illegal logging and encroachment (Mukhtar & Jannah, 2018). In line with this, based on the interpretation of Landsat 5 TM imagery in the Sesaot forest area, there has been a decline in primary forest cover of 22% since 1995-2010 (Suhartanto et al., 2019). The change in primary forest cover has shifted to secondary forest with various land use systems, including the use of agroforestry systems.

The land management system in the Sesaot forest area is based on the Community Forest Permit (HKm) scheme with the aim of empowering communities around the Sesaot forest area. The HKm program is a strategic compromise step in preserving forests and increasing community income, in accordance with Minister of Environment Regulation No. 83 of 2016. In practice, communities around the Sesaot forest area manage HKm land by implementing an agroforestry system (Markum et al., 2014). The application of agroforestry systems by communities is quite diverse, characterized by diversity of vegetation types, diversity of plant structures, diversity of understory vegetation species, and diversity of plant density. The diversity in the application of agroforestry patterns certainly has an impact on various incomes and various carbon stock values (Heryandi et al., 2022; Reppin et al., 2020; Toppo & Raj, 2018; Van Noordwijk et al., 2020).

The results of previous research in the Sesaot Forest Area show that the application of various potential agroforestry patterns can provide farmers with income in the range of 22-45 million/ha/year (Markum et al. 2021). This income is relatively higher when compared to the income of HKm farmers in other locations such as Aik Berik, Santong and Aik Bual, which is in the range of 8-32 million/ha/year (Hadi et al., 2016). One of the agroforestry patterns that provides the largest income is the mixed agroforestry pattern, consisting of a variety of Multipurpose Tree Species plants: *Durio zibethinus, Garcinia mangostana, Persea americana, Artocarpus heterophyllus, Nephelium lappiceum, Arenga pinnata, Coffea canephora,* and *Theobroma caca.* The various crops above have been proven to have contributed quite a high income to the HKm farming community. However, on the other hand, the various types of plants mentioned above are sensitive to climate change. These plants require growth, flowering and fruiting phases at certain temperatures, humidity, sunlight intensity and nutrients. If these elements are not in harmony, production failure will occur (Nurdin, 2018). Changes in climate components certainly affect the production of crop varieties that are sensitive to climate change (Cassamo et al., 2023; Gomes et al., 2020; Pérez et al., 2018; van der Geest et al., 2019).

Vulnerability to production failure will have a major impact on farmers' income, because communities around forest areas are very dependent on forest resources, as research results from Maulidia, (2018) show that the dependence of communities around forest areas on forest resources is high, reaching 70% - 100%, and For farming families who depend entirely on forests for their source of livelihood, disruption of forest product production will have a major impact on threats to their livelihoods, including the impact of climate change. How much influence climate change has on community resilience in adaptation and mitigation efforts will of course be influenced by various factors (Carmen et al., 2022; Singh et al., 2016).

The aim of the research is to identify forms of vulnerability to climate change in communities around the Sesaot forest and analyze the ways in which communities adapt and mitigate climate change and analyze the level of community resilience to climate change in the Sesaot forest area, West Lombok district.

Method

Study Area

The research location was carried out in the Sesaot Forest area with an area of 19088 ha (116°14'10''-116°17'50''E and 8°28'43'' - 8°34'10''S), research was carried out in June-September 2023.

Research procedure

The research method was carried out using a descriptive approach based on qualitative (behavioral, social and institutional) and quantitative data (farmers' income towards aspects of the impact of climate change). Data collection techniques were carried out through field observations, interviews with questionnaire instruments, measurements, field verification and documentation using random sampling.

The respondents used as the object of this research were farmers who are members of the Forest Conservation Community Group in the village of Lebah Sempage. The total number of farmers in Lebah Sempage village is 74 people. Determining the number of respondents using the Slovin formula with the estimation error used is 10% with the following equation Formula 1.

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

Description:
n = Sample size
N = Population size (74)
d = Estimation error (10%)

Research variable

Identify forms of vulnerability due to climate change on forest resource management, including: rainfall, number of rainy days, types of plants susceptible to being affected, production of non-timber forest products (NTFPs), number of points of soil erosion, number of locations flooded and affected by flooding.

Analysis of Community Resilience Against

Climate Change Analysis of community resilience to the impact of climate change refers to psychological aspects (emotional regulation, impulse control, optimism, empathy, analysis of the causes of problems, self-efficacy and increasing positive aspects), economic aspects (various livelihoods, sources of family income, and the value of income from within forest areas and outside forest areas), social aspects (individual participation attitudes in climate change adaptation and mitigation), and institutional aspects (Reivich & Shatté, 2002).

Data analysis

To analyze the level of resilience, a score assessment model is used which combines resilience theory according to Reivich & Shatté, (2002) with a scoring system according to a likert scale, as follows of Table 1.

Table 1. Score assessment for resilience in various aspects

Components	Assessment components	Range of score values
Psychological aspects	▪ Emotion regulation	0-20
	▪ Impulse control	0-20
	▪ Optimism	0-20
	▪ Empathy	0-20
	▪ Thinking style	0-20
	▪ Self-efficacy	0-20
	▪ Increasing positive aspects	0-20
	Total scores (1)	0-140
Economic aspects	▪ Variety of farmer livelihoods	0-40
	▪ Source of family income	0-40
	▪ Income from forests	0-60
	▪ Income outside the forest	0-60
	Total scores (2)	0-200
Social aspect	▪ Participation in crop cultivation	0-20
	▪ Participation in disaster management	0-20
	▪ Participation in social protection	0-20
	▪ Participation in institutions	0-20
	Total scores (3)	0-80
Institutional aspects	▪ Availability of community institutions for climate change adaptation and mitigation	0-20
	▪ There are agreed rules for climate change adaptation and mitigation	0-20
	▪ Community compliance with rules	0-20
	▪ Individual activities in groups	0-20
	Total scores (4)	0-80
Total score range		0-500

To assess the level of community resilience to the impacts of climate change, five decision criteria are used (Table 2).

Table 2. Assessment of scores for the level of community resilience to climate change

Resilience criteria	Criteria for obtaining scores	Description
Very high	>400 – 500	▪ Communities are quickly responsive to climate change, can immediately adapt to negative impacts and immediately find ways to mitigate them. Social capital and the role of institutions are very good in responding to the conditions faced and the possibilities that will occur. ▪ Climate change has no impact on society at all.
High	>300 - 400	▪ The public has good knowledge about the impacts of climate change and considers it important to immediately take steps to prevent, overcome and reduce the risks. The role of institutions is running well and community participation is also good, but the spirit of the community relies more on the figures of certain people.

Resilience criteria	Criteria for obtaining scores	Description
		▪ Climate change has only a small impact on non-economic aspects
3. Currently	>200 - 300	▪ The public has fairly good knowledge about climate change, stating that there have been losses and problems due to climate change. However, it is not accompanied by a responsive attitude to immediately deal with it. ▪ Climate change has an impact on several components, including economic aspects
4. Low	>100 - 200	▪ The community has sufficient knowledge, but this is not followed by the emergence of a responsive attitude. Participation in adaptation and mitigation efforts is based more on just joining in. ▪ This group of people is vulnerable to the impacts of climate change, but still tries to respond by receiving direction and examples from other individuals.
5. Very low	< 100	▪ People consider the problem of climate change to be something that is a given condition (destiny), and there is no need to respond excessively to its impacts. ▪ This community group has the highest vulnerability, but is also low in taking initiatives for adaptation and mitigation.

Result and Discussion

Result

Based on the results of research related to agroforestry production in the Sesaot forest area, it shows that there is an influence on the vulnerability of production results in several types of productive plants to changes in the local rainy season cycle in the Sesaot forest area. The range of Sesaot forest production results starts from the flowering and fruiting process, especially in plants with high economic value (Table 3).

Table 3. Types of plants that are vulnerable to the impacts of climate change

Plant Name	Forms of Vulnerability	Economic Value
Durio zibethinus	Flowers and fruit fall off, fruit is attacked by caterpillars, fruit rot occurs	High
Garcinia mangostana	Flowers and fruit fall off, fruit rots	High
Persea americana	Flowers and fruit fall off	Moderate
Nephelium lappiceum	Flowers and fruit fall off	High
Theobroma cacao	Rotten fruit	Moderate
Coffea canephora	Black rotting fruit	Moderate

On the other hand, there are several types of fruit plants in agroforestry areas that are not affected by rain fluctuations, such as: *Aleurites moluccana, Arenga pinnata, Baccaurea racemose, Artocarpus heterophyllus, Musa Paradisiaca, Carica papaya* (Table 4). Based on observations, the amount of production will increase in October-January each year as the harvest season. Even though it is not influenced by fluctuations in climate change, the amount of production from this fruit plant is more influenced by the number of stands and planting age. The economic value of this fruit plant is lower compared to the results of agroforestry production on plants that are easily influenced by climatic conditions.

Table 4. Types of plants that are resistant to climate change

Plant Name	Forms of Resilience	Economic Value
Aleurites moluccana	Can be harvested 3-4 times a year	Moderate
Arenga pinnata	Can be harvested every day	High
Baccaurea racemose	Harvest once a year	Low
Artocarpus heterophyllus	Harvest 3-4 times a year	Low
Understory plants (*Colocasia esculenta, Zingiber officinale, Curcuma longa, Curcuma zanthorrhiza,* and *Kaempferia galanga*)	Can harvest monthly	Moderate
Other plants (*Musa Paradisiaca* and *Carica papaya*)	Can be harvested weekly	High

Increased Pests and Diseases

Apart from changes in the rain cycle, pest and disease attacks are factors in the decline in Sesaot forest agroforestry production. A common pest attack is a type of fruit fly, which lays its eggs into the fruit when it is still small or large, so that the fruit has brown spots containing caterpillars. Fruit can fall due to rot or it can survive, but the quality of the fruit becomes unfit for consumption or sale.

Meanwhile, the most common disease attacks are bacteria that cause stem rot or fruit rot. The fruit becomes black, dries up or rots and then falls off easily. These two types of pest and disease attacks were found on several types of plants as follows (Table 5).

Table 5. Types of pest and disease attacks on several types of plants

Plant name	Attack by	Form of attack
Durio zibethinus	Fruit flies	Blackish brown spots on one or several points of the fruit, inside which there are caterpillars
Garcinia mangostana	Bacteria	The fruit hardens, inside it is yellow
Persea americana	Bacteria	Fruit rots
Nephelium lappiceum	Bacteria	The fruit dries black
Theobroma cacao	Bacteria	The fruit dries black and the fruit rots
Coffea canephora	Bacteria	Blackened fruit
Artocarpus heterophyllus	Fruit flies	The fruit is rotten and there are caterpillars inside

Based on the results of observations and interviews in vulnerable areas in 2019-2021, climate change has an impact on decreasing forest product production in the range of 60-80% in several types of plants such as: *Durio zibethinus, Garcinia mangostana, Nephelium lappiceum, Theobroma cacao,* and *Coffea canephora*. Based on variations in the value reduction rate for each type of plant, income has decreased by 40%. So from the interval farmer income of IDR 3,790,450 – IDR 41,566,050 (ha/year) fell to the interval IDR 2,274,270 – IDR 24,939,650 (ha/year).

Forest Community Resilience Level

The results of the data findings on the resilience of the Sesaot forest community show a high level of resilience in the psychological aspect with a score of 100 and the social institutional aspect with a score of 100. Meanwhile, the economic aspect is relatively more vulnerable with a score of 100 in the 0-200 interval (Table 6). Apart from that, the score assessment for the level of community resilience to climate change is in Table 7.

Table 6. Score assessment for resilience in various aspects

Components	Assessment Components Score	Score Range	Score Acquisition
Psychological aspects	▪ Emotion regulation	0-20	20
	▪ Impulse control	0-20	20
	▪ Optimism	0-20	10
	▪ Empathy	0-20	20
	▪ Thinking style	0-20	10
	▪ Self-efficacy	0-20	10
	▪ Increasing positive aspects	0-20	10
	Total score (1)	0-140	100
Economic aspect	▪ Variety of farmer livelihoods	0-40	30
	▪ Source of family income	0-40	30
	▪ Income from forests	0-60	20
	▪ Income outside the forest	0-60	20
	Total scores (2)	0-200	100
Social aspect	▪ Participation in crop cultivation	0-20	10
	▪ Participation in disaster management	0-20	20
	▪ Participation in social protection	0-20	20
	▪ Participation in institutions	0-20	10
	Total scores (3)	0-80	70
Institutional aspects	▪ Availability of community institutions for climate change adaptation and mitigation	0-20	0
	▪ There are agreed rules for climate change adaptation and mitigation	0-20	10
	▪ Community compliance with rules	0-20	15
	▪ Individual activities in groups	0-20	15
	Total scores (4)	0-80	40
Total score range		0-500	310

Table 7. Score assessment for the level of community resilience to climate change

Resilience criteria	Criteria for scores	Remarks
High	>300 - 400	The public has good knowledge about the impacts of climate change and considers it important to immediately take steps to prevent, overcome and reduce the risks. The role of institutions is running well and community participation is also good, but the spirit of the community relies more on the figures of certain people. Climate change has only a small impact, on one aspect.

Discussion

Climate changes that occur around the Sesoat forest area can have a negative impact on the risk of changes to various aspects of people's lives. Within the community around the Sesaot forest area, vulnerability can arise due to the negative risk of decreasing production of forest resources due to production failure, while the forest is the only hope for livelihood. Based on the results of interviews, there are 3 factors causing vulnerability due to climate change which have an impact on disrupting forest product production, namely: erratic rainfall, disruption of the flowering and fruiting phases of plants (Haokip et al., 2020; Menzel et al., 2020; Paltineanu & Chitu, 2020; Vanalli et al., 2021), and increasing pests and diseases (Jabran et al., 2020; Nji et al., 2022; Raza & Bebber, 2022; Skendžić et al., 2021).

This condition is similar to the research of Zubairu et al., (2021) that changes in the rain cycle affect soil fertility, susceptibility to flowering and fruiting, which influence forest production in Tanzania. Additionally, Beilhe et al., (2020) reported that climate change could influence the increase in the number of coffee pests in Nicaraguan forests.

Climate change conditions in the Sesaot forest area have occurred over the last five years, temperatures tend to be hotter and rainfall does not fall according to the season. In the months that should be dry, it suddenly rains, and when the rainy season is supposed to come, there is a long period of heat. Apart from the irregularity of the rainy season, farmers believe that rainfall is greater with a shorter duration. For example, in 2021, there will be heavy rain in June–September, this condition is inversely proportional to the previous conditions which should have entered the dry months or with low rainfall conditions.

In a situation where climate change is increasingly having an impact, the local wisdom of Sesaot forest agroforestry farmers has a strategy for adapting to overcome the impacts of climate change by implementing a random pattern agroforestry system consisting of planting a composition of various types that have different levels of adaptation. This diversity then forms biophysical resilience (Bishaw et al., 2022; Frei et al., 2020; Gupta et al., 2012; Kassam & Bernardo, 2022; Mokondoko et al., 2022; Peterson et al., 2020; Plieninger et al., 2020). The following sketch illustrates the random pattern implemented by farmers in the Sesaot forest area as an effort to adapt to climate change (Figure 1).

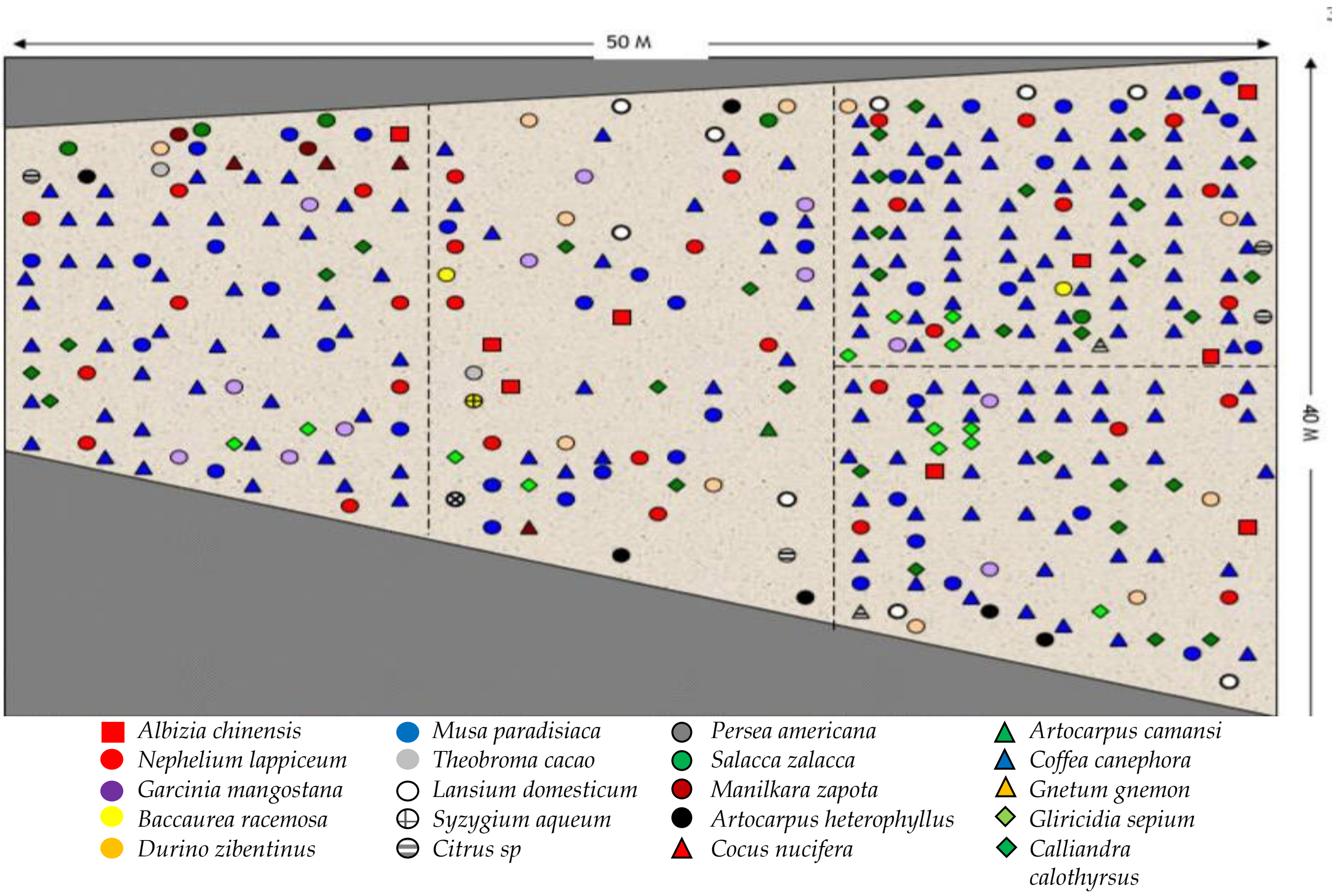

Figure 1. Random pattern of implementing an agroforestry system as an adaptation effort to climate change in one of the Sesaot agroforestry forest samples

This random pattern is quite effective in dealing with the risk of production failure for certain types of plants (Koelemeijer et al., 2021; Luo et al., 2021; Roslinda et al., 2023; Somarriba et al., 2023). At a time when several types of plants are at risk of crop failure, farmers still have hope of getting harvests from other types of plants that are more resistant to climate change (Figure 3). Especially in the production of *Arengan pinnata* which cannot be harvested every day (morning and evening). Apart from implementing a random pattern agroforestry system, farmers in the Sesaot forest area have a social institutional system of farming communities called “banjar” as a medium for communication and mutual cooperation in land management activities in forest areas and outside forest areas.

Based on psychological aspects, communities around forest areas have good resilience in facing climate change. This condition can be seen from the anxiety level value in the low category. This condition occurs because the community's mindset believes that the situation that occurs is an event that must happen, and is necessary. responded by continuing to prioritize gratitude, even though there were concerns that conditions would get worse, farmers were generally ready to face the risks. Apart from that, good food security factors can create a sense of security for the people around the Sesaot forest area in facing an uncertain climate situation, even though many crops with high economic value do not succeed, farmers can still rely on several other types of crops to meet their daily consumption needs the day.

In contrast to the psychological aspect, the economic aspect is in the low category, this condition can be caused by the community's high dependence on forest resources and is not balanced with the diversity of other sources of income, causing the community to be quite vulnerable to the risk of economic instability. This condition can be seen from the fact that the income of people living around forest areas has decreased by 40% -60% due to climate change, indicating that they are easily pushed into poverty. If we refer to the highest income from forest products reaching IDR 41.5 million and if the risk of failure reaches an average of 50%, then the value is IDR 20,750,000 with an average family of 3 people, if we calculate the daily income it will be IDR 14,212 /person/ days, values that are classified as poor or vulnerable to poverty, so that in times of need, people around forest areas will try to find additional income by working odd jobs, as farm laborers, construction workers, motorcycle taxi drivers, and selling small businesses.

On the other hand, social and institutional aspects are included in the good category and constitute good social capital for communities around forest areas, because they can help in easing the burden on possible risks due to climate change. This condition is in line with the report by Piabuo et al., (2023) that the participation of communities around forest areas in creating partnerships, networks and resource mobilization plays a role in reducing social disparities in communities regarding forest products and climate changes that occur. The collegial attitude of society is a driving factor in creating an atmosphere of harmony (Amadei, 2020; Cahyani & Winarso, 2023; Council, 2012; Minang et al., 2019). Even though there is no institution that specifically plays a special role in disaster management, the existence of the banjar system is essentially a means of handling many things, including when the community

Conclusion

In conclusion, climate change is a limiting factor in agroforestry production which has an impact on the income of communities around the Sesaot forest area. This condition is indicated by fluctuations in rain and the intensity of rain continues to change. Based on the resilience aspect, the most prominent vulnerability is in the economic aspect, in the form of production/harvest failure for superior types of commodities. Production failure can cause revenue loss of 40-60%. The adaptation made to face the risk of failure is to optimize the agroforestry system with a variety of plants that function as alternative consumption buffers. However, the level of community resilience is high, because: (1) there are alternative commodities to support food needs, (2) the community's collegial attitude is still strong (3) there is an attitude that is tolerant of change and failure. In an effort to increase community adaptability and mitigation against the impacts of climate change, it is recommended that (1) develop plant health clinics that continuously monitor the development of pests and diseases as well as factors that cause plant production failure; (2) carrying out more intensive research from universities and other research institutions to help farmers reduce production failures due to climate change.

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Author Contributions

Conceptualization, M.K. and A.I.; methodology, M.K and A.L.; formal analysis, M.K. and F.R.; investigation, M.K. and A.L.;data curation, M.K.; writing—original draft preparation, M.K. and F.R.; writing—review and editing, M.K and F.R.;

supervision, A.I.; project administration, A.L All authors have read and agreed to the published version of the manuscript.

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The authors declare that there is no conflict of interest regarding the publication of this paper.

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