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SERI Methods to Measure the Vulnerability of Shallot Farming to Climate Change in Tapin Regency, South Kalimantan

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Abstract. This study analyses the vulnerability of shallot farming to climate change in Tapin Regency, South Kalimantan. Data collection methods in this study consisted of questionnaires, in-depth interviews, observations, documentation, and a literature review. The SERI (shock–exposure–response–impact) analysis method was used to analyse the vulnerability of shallot farming to climate change in Tapin Regency. The results showed that climate change is the main shock to shallot farming in Tapin Regency. Extreme weather, namely, extreme rainfall events, causes water to become stagnant (flood) so that roots and fruit rot. These exposures extensively decreased the shallot harvest (harvest failure) and decreased the sale price of shallots (loss), and most farmers did not plant shallots again. Shallot farmers responded to the shocks that occurred by not planting shallots; however, some farmers focused extra attention on farming practices, but almost all farmers switched to planting other commodity crops. The impact of these shocks on farmers were decreases/losses in income and increases in costs. Buffer capacities that can be implemented to reduce the impact of these impacts are (1) using healthy and clean superior varieties that are resistant to extreme weather events and pest invasions; (2) setting cropping schedules and cropping patterns; and (3) increasing the capacity of farmers through education and training, especially in terms of how to conduct shallot farming during extreme weather events and how to properly control plant pests and diseases.

Keywords. vulnerability, climate change, shallots, Tapin Regency

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1. Introduction

Tapin Regency is one of the shallot production centers in South Kalimantan, but the amount of production is still insufficient to meet the consumption needs of the population; thus, this area still imports shallots from other regions in large quantities. This scenario causes the shallot price to be unstable and results in a shallot contributing greatly to inflation. Shallot production in Tapin Regency from 2013 to 2017 continued to increase but decreased sharply from 2,290.6 tons in 2017 to 890.4 tons in 2018, and this decrease continued with 40.5 tons being produced in 2021. This production decrease has caused the shallot price to be unstable and is one of the causes of inflation in South Kalimantan (BPS Tapin, 2022). Thus, it is necessary to assess and evaluate the vulnerability of shallot farming to climate change in Tapin Regency so that in the future, the data of rainfall shown in Table 2. This type of farming can be managed in a balanced and sustainable manner that improves the economy and people's welfare (Zuraida, 2016; Zuraida & Galib, 2014).

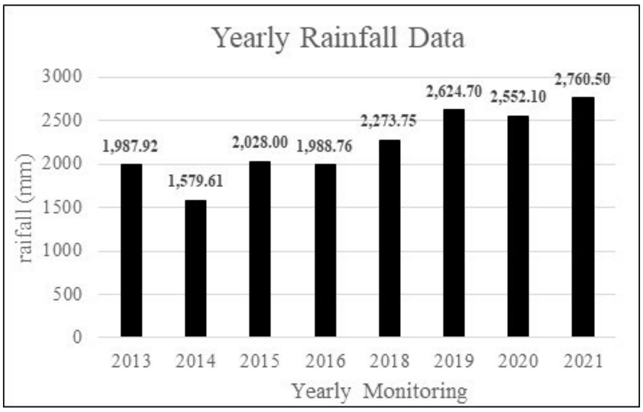

Figure 1. Yearly Rainfall Data

Based on the above information, this research focuses on determining how shallot farming is vulnerable to climate change in Tapin Regency focusing on shocks, exposures experienced by farmers, responses, and impacts then identifying buffers that can reduce the impact of the instability or effects.

2. Methodology

This research was conducted in Tapin Regency, South Kalimantan Province, in five subdistricts: Binuang District, Hatungun District, South Tapin District, Salam Babaris District and Bungur District. The selection of the research location was since shallot farming has occurred at this location for the last five years.

Other The type of data used in this study included primary data and secondary data. The primary data were obtained directly from sources, namely, shallot farmers, through field observations and the results of questions and answers using questionnaires or interviews. The secondary data included data on planting area, harvested area, shallot production and productivity in South Kalimantan Province and Tapin Regency; rainfall data; climate data series (temperature, humidity, and light duration); and general descriptive data for Tapin Regency, such as geography and climate data, population data, and infrastructure data. The sources of the data in this study were the related offices in both Tapin Regency and South Kalimantan Province.

The population in this study included shallot farmers in Tapin Regency. At the same time, the sampling technique involved using shallot farmers at the research location as the sample. The sample of respondent farmers consisted of 30 farmers, with 12 farmers still planting and 18 farmers not planting this year but having cultivated or planted shallots in previous years.

The data collection methods in this study involved questionnaires, observations, documentation, and literature/library research. The data analysis method was the SERI (shocks - exposures - response - impact) analysis method. SERI analysis is one type of analysis used to analyze vulnerability (Noordwijk

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et al., 2011). For the SERI analysis, the steps implemented were (1) identify extraordinary events/shocks that have occurred in the last few years; (2) identify exposure intensity (exposures); (3) identify how farmers responded, and (4) identify the impact of the shocks (impacts); in addition, buffers that could reduce the impact (buffers) were analyzed (Noordwijk et al., 2011).

3. Result and Discussion

3.1. SERI Analysis

Implementation of the SERI analysis process focusing on the impact of climate change (shocks) on the productivity of the shallot farming system in Tapin Regency is described in Table 1.

Table 1. SERI Analysis of Shallot Farming

Problem (shocks)	Extreme weather (high rainfall amounts)
Period	2016–2021
Effects	High rainfall amounts, flooding, production decreases
Exposures	Pest invasions, crop loss/failure due to roots and stems being submerged from flooding
Responses	- Prices decrease and sales decrease. - Pesticide costs - Extra maintenance (extra spraying) - Farmers stop farming. - Farmers change to another commodity crop
Impacts	Decreased harvests and higher costs
Buffers	- Using superior varieties (healthy and clean) that are resistant to extreme weather and pest invasions. - Setting cropping schedules and cropping patterns - Capacity building through education and training on how to conduct shallot farming during extreme weather events in an adequate and correct way to address pest invasions

Shock Analysis

The problems faced by farmers that affect the productivity of shallot farming systems in Tapin Regency based on research results are illustrated in Table 2.

Table 2. Weather Conditions from 2017 to 2020

Year	Description
2017	High rainfall, pest invasions, sales prices reduced, and excessive harvest
2018	Pest invasions, crop loss of 90% and extreme climate
2019	Extreme climate/high rainfall, pest invasions, no seed support
2020	High rainfall, no irrigation, no seed support

From the issues noted above and based on the research results, the main issue that greatly affects shallot farming in Tapin Regency is extreme weather events and pest increases as these factors result in intense shallot production declines.

The results showed that the shocks experienced by shallot farmers in Tapin Regency related to climate change (extreme weather or high rainfall) occurred from 2017 to 2021. High rainfall amounts (extreme weather events) that occurred for a prolonged period or continuously for several days caused water to stagnate and shallot plants to become susceptible to disease and damage/rot (fruit rot and root rot). Rain often occurred at night and sometimes at unexpected times, typically, before and during harvest, causing crop failures to reach 50-90% and even causing crops to fail completely because roots/tubers rot were submerged in water. In addition, the high-intensity rain events caused the climate to become too humid. It is possible that the greatest losses suffered by farmers were almost 100% (Ghozali & Wibowo, 2019; Harwood et al., 1999; Noor et al, 2022)

Shallot growth depends on altitude, temperature, and humidity. Altitude will affect the air temperature in each area. The higher a place is, the lower the air temperature. In turn, air temperature affects plant growth, which affects the shallot bulb formation process. According to (Sumarni & Hidayat, 2005), the ideal altitude for shallots is 0–800 meters above sea level (msl). The research area in this study is in the lowlands at an altitude of 17-64 msl; thus, Tapin Regency meets the ideal criteria for shallot growth in terms of altitude (BPS Kab. Tapin, 2022).

Temperatures that are too low or too high make it difficult for tubers to form. In addition, light and air humidity also greatly affect plant growth (Istina, 2016). Based on data (BPS Tapin, 2022), the average air temperature in the research area under ideal conditions is 27.7–33 °C. However, the air humidity is 75-85.2%, and the average sunlight is 63.07%, conditions that are less than ideal shallot growth. Longer sun exposure duration will provide greater opportunities for plants to utilize sunlight through photosynthesis (Ghozali & Wibowo, 2019; Harwood et al., 1999; Sopha et al., 2017; Suharno et al., 2019; Wiyatiningsih et al., 2009). In addition, the duration of irradiation also affects humidity. A summary of these data is in Table 3.

Table 3. Data on air temperature, air humidity, solar radiation, and rainfall/year

Description	Research Location	Ideal Condition
Air temperature	27.7-33.0	25–32
Air humidity	75.0-85.2%	50-70%
Solar radiation	63.07%	> 70%
Rainfall $year^{-1}$	1,579.0–2,760.5	1,000–1,500 mm

Based on the table above, the amount of rainfall in the study area (Tapin Regency) was 1,579 (lowest) in 2014 and 2,760.5 (highest) in 2021, higher than the ideal conditions for shallots. The ideal rainfall amount for shallots is 1,000-1,500 mm $year^{-1}$ (Harwood et al., 1999; Wiyatiningsih et al., 2009). Shallot plants can grow well with an amount of rainfall that is not too high because the air humidity causes the plants to become more susceptible to pests and diseases. High rainfall amounts also cause plants to fall easily. Tapin Regency has a high amount of rainfall per year, which is in accordance with field conditions in recent years; thus, shallot farmers often experience shocks when it rains for days, which makes the plants stagnant, resulting in tuber and root rot and eventually crop failure. Even if it rains for just one day, shallot plants are very vulnerable to falling, so they must be dried immediately to remove rainwater (Adnyana & Rahayu, 2016; Sopha et al., 2017; Sumarni & Hidayat, 2005).

Based on the data, the number of rainy days from 2013-2021 ranged from 109 mm in 2015 (the lowest) to 216 mm in 2021 (the highest) (BPS Tapin, 2022). In the last few years, Tapin Regency has experienced several floods, including at the research location. In 2018, floods occurred in 28 villages, including shallot planting locations such as Binuang, Hatungun, South Tapin, and Bungur Villages. In 2019, floods occurred in 20 villages, including the villages of Binuang, South Tapin, and Bungur. In 2021, floods occurred in 13 villages, including Binuang, South Tapin and Bungur. Climate change impacts, such as extreme weather, high rainfall, and many rainy days, cause inevitable floods. In addition, shallots are very vulnerable to extreme weather (high rainfall) (Adib, 2014; Ghozali & Wibowo, 2019; Harwood et al., 1999; Muttaqin, 2018; Wiyatiningsih et al., 2009) . The months with

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the highest rainfall are December and January to February. Based on research results, many farmers plant in November because seed assistance from the government arrives in November. However, plantings in this month are very vulnerable to crop failure because in December and January, the rainfall is very high and rain can continue for days and even cause flooding, which results in shallot plants being submerged and ultimately crop failure. At the same time, based on the experience of successful farmers, planting shallots is very profitable from May to October, while it is not profitable to plant them in December-February (Purba & Astuti, 2013; Sayaka & Supriatna, 2010; Winarso, 2003) .

When considering the above data, November-March have relatively high rainfall amounts, the amount of solar radiation is also relatively low, and humidity and the air temperature are relatively high. Therefore, it is very important to pay attention to the planting schedule in shallot farming. This conclusion is in line with the results of (Purba & Astuti, 2013) in Serang district, Banten, in that they note that planting in July-September is the best option, while planting in January-February is the worst option. In Figure 2. The condition of shallots farming during better growing (left) and worst (right) due to the weather.

Figure 2. Shallot Planting Condition Better (left) and Worse (right)

As a result of high and continuous rainfall for up to 2-3 days, shallots become susceptible to pest diseases, and pests that invade are very difficult to control or cannot be controlled or overcome by farmers. Farmers also have difficulty detecting plant pests and diseases. Finally, shallots can experience crop failures of 50-90% and even fail completely. The primary dangerous pest of shallots is fusarium wilt disease. The cause of this disease is the pathogenic fungus *Fusarium oxysporum* (Wiyatiningsih et al., 2009). Erratic climate change also greatly increases the intensity of this disease. In addition, the use of unhealthy (infected) seeds also plays a very important role in the disease. Farmers who continuously plant shallots without implementing crop rotation also trigger an increase in disease of *Fusarium wilt* (Sopha et al., 2017; Sumarni et al., 2012; Wiguna et al., 2013) .

In the rainy season, fusarium wilt disease are intense, as high rainfall amounts and a humid environment make the fusarium fungus grow very quickly. If the seeds used are infected, then at the age of 5-10 days after planting, the symptoms of fusarium wilt will be visible. The visible symptoms are sudden plant wilting, leaf colour turning yellow and curling, root rotting, leaf wrinkling and twisting, drooping leaves, and rotting tubers (there are white fungal colonies), and the plants eventually die (Ghozali & Wibowo, 2019; Harwood et al., 1999; Wiyatiningsih et al., 2009).

Exposure Analysis

The exposure to extreme weather experienced by shallot farmers in Tapin Regency resulted in sharp decreases in harvests by 50-90% in 2018 and 2019, and some farmers even experienced total crop failure in 2021. In addition, extreme weather (high rainfall) causes shallots to become susceptible to disease. Extreme weather (high rainfall) also causes water to stagnate and even flood, which damage the shallot crop; then, the price of shallots decreases; eventually, farmers lose money; and farmer incomes decrease. In addition, the exposure experienced by shallot farmers in Tapin Regency because of pest invasions that cause roots and fruits to rot due to fungi resulted in a decrease in yields of 50 to 90% in 2018 and 100% in 2021 due to fusarium disease. In addition, the harvested tubers were also of poor quality; thus, they were sold at a decreased price, and some were not able to be sold (Winarso, 2003).

Therefore, in general, the intensity of exposure from all the shocks that occurred caused farmers to experience crop failure and loss, thereby affecting the sustainability of shallot farming. Many farmers cannot plant shallots anymore because they are afraid of experiencing further losses (Adib, 2014).

Farmer Responses

Based on the results of the study, there were several farmer responses related to the shocks that occurred during shallot farming. Shallot farmer responses to extreme weather shocks (high rainfall) included drying submerged shallots immediately. In addition, farmers also sold shallots at low prices (losses) due to bad bulbs. Farmers also were careful because the shallots become waterlogged. However, most farmers did nothing if it rained for days, and the plants became submerged. Therefore, many farmer responses involved looking for other businesses or switching to other commodities (vegetables and fruit).

The responses of shallot farmers to pest invasions were to buy pesticides and to spray them every day. Farmers also asked for agriculture extension officer assistance to consult on pest control solutions. Some farmers did not do anything because they do not know what to do. Like the responses to extreme weather, the responses of most other farmers involved looking for other businesses or switching to other commodities (vegetables and fruit).

Looking at the response of the farmers, most of whom do not plant shallots anymore and instead plant other crops, their capacity is still low. This is due to the low education levels of most farmers. Based on the results of the study, the education levels of most of the respondent farmers were only up to the elementary level (60%), with a small portion graduating from junior high school (30%), and only 10% of the respondents received education up to the high school level (Adib, 2014; Effendi et al., 2019). In addition to education-related issues, farmer capacity is also most influenced by farmers' farming experience. Experience is needed in shallot farming based on its cultivation methods and on the various farming-related problems. The longer farmers' experiences in farming, the better they are in managing farming and overcoming various problems. Based on the results of the study, the majority (53%) of the respondent farmers had between 1-5 years of experience farming shallots. Only 20% of the respondent farmers had more than five years of experience, and as many as 27% had less than a year of experience. Respondents' experiences based on the results of the research showed that the experience level of farmers is indeed still low, and it appears that their capacity is still limited in terms of overcoming problems related to shallot farming. There are still many farmers who stop farming shallots when shocks occur and take shortcuts by selling shallots at low prices and switching to planting other commodities. There are several options that farmers have, and they include adding value to the product by processing shallots into other processed products.

Impacts of Condition

The impacts of extreme weather shocks are decreased crop yields and even crop failure. These impacts are detrimental to farmers because they cause farmer incomes to decrease and costs to increase because additional costs for needed for additional agricultural activities. Regarding the impacts felt/experienced by farmers from the shocks of plant pests and diseases, costs increased due to the purchase of pesticides to eradicate pests and plant diseases. Yields were reduced by 50-90% and caused substantial losses for farmers. In addition, this caused incomes to greatly decrease as well (loss).

3.2. Efforts To Reduce the Impact

Based on the research results, the responses of farmers in terms of addressing these problems (shocks) are still very limited and still occurring in the short term; for example, some farmers stop farming shallots or are unclear of next steps, tending to look for safe options, namely, switching to planting other commodities.

There are several options farmers can implement to address the threat of shocks and minimize the impact or loss they experience both from climate change and pest invasions and disease, as well as the absence of subsidies or assistance from the government; the main option is implementing various adaptation and mitigation strategies and efforts (Adib, 2014; Diana et al., 2019; Hilman et al., 2019; Muttaqin, 2018).

Adaptation efforts or strategies have not been carried out by farmers to reduce the impact of climate change (extreme weather) in Tapin Regency are finding and using superior (healthy and clean) shallot varieties that are resistant to extreme weather or high rainfall amounts and are suitable for the planting location. The shallot seeds donated by the government are mostly a mix of healthy and unhealthy seeds, causing shallot plants to be susceptible to disease. It is necessary to prevent pests and diseases and provide extra attention (extra care) when extreme weather occurs through activities such as elevating the base of planting area so that it is not flooded and immediately watering in the morning if it rains at night. Alternatively, if it rains in the afternoon or evening, then immediately after the rain stops, the area should be watered immediately (Sopha et al., 2017; Sumarni et al., 2012; Sumarni & Hidayat, 2005).

In addition, the planting schedule (planting calendar) should be established such that planting does not occur in months with high rainfall amounts (adjustment of planting time) (Muttaqin, 2018). Although there are some seeds that can withstand high rainfall amounts, it is still very important and necessary to avoid planting shallots in months with high rainfall amounts (Winarso, 2003) .

The planting pattern should also be a point of focus; after harvesting shallots, they should not be planted again but replaced (rotated) with other vegetable crops such as chili, or a different variety of shallots could be planted (Adib, 2014; Hilman et al., 2019; Sumarni & Hidayat, 2005; Yuniar, 2017).

Adaptation and mitigation of climate change must be carried out to prevent and reduce negative impacts such as crop failure and increased crop losses. Organic farming and polyculture also need to be considered and implemented. Adaptation strategies require knowledge, which depends on the education level of farmers, farmer experience, sources of information and education and training received. Adaptation success is influenced by the adaptive capacity of human resources and no climatic factors. Therefore, it is also very important to increase the capacity of farmers through education and training on how to conduct shallot farming when extreme weather events occur(Adib, 2014; Effendi et al., 2019; Muttaqin, 2018).

An adaptation strategy that has not been carried out by farmers to reduce the impact of pests in Tapin Regency is to use superior (healthy and clean) shallot varieties that are resistant to pest invasions (Sopha et al., 2017; Sumarni & Farid, 2007; Sumarni et al., 2012; Sumarni & Hidayat, 2005). This is very important because the use of unhealthy (infected) seeds can make shallot plants more vulnerable to diseases, and if a plant is diseased, then it is difficult to treat and requires increased costs for treatment. In addition, the arrangement of cropping patterns (crop rotation) must also be considered, i.e., after planting shallots, they should not be planted again (Yuniar, 2017). The practice of continuously planting shallots without crop rotation can increase the likelihood of fusarium disease (fusarium wilt). However, shallots can be planted again if a different variety is used so that pest invasions can be suppressed/prevented. However, it would be better to rotate the type of crops used; for example, after planting shallots, other vegetables, such as broccoli or tomatoes, could be planted to stop the life cycle of the fusarium that is in the soil or that may remain. Information and education on appropriate and effective prevention/control and management of pests and diseases also need to be conducted. The implementation of organic and semi organic farming is also a good practice (Muttaqin, 2018; Novra et al., 2021).

Therefore, in general, adaptation efforts include adjusting the planting time (planting calendar), changing cropping patterns, using high-yielding varieties that are resistant to climate change/extreme weather and pest invasions, implementing organic farming, creating marketing networks, etc. Understanding the perceptions of shallot farmers toward climate change is important so that their adaptation capacity can be increased; this adaptation strategy requires providing farmers information and communicating with them through training and education, as noted in Table 4.

Table 4 Summary of the SERI Analysis

Shocks	1. Extreme weather. 2. Pest invasions.
Exposures	1. Reduce yields. 2. Crop loss. 3. No planting.
Responses	1. Stopping farming. 2. Increase maintenance cost. 3. Switch commodity crop
Impacts	1. Reduce revenue. 2. Higher cost operational
Buffer	1. Using superior and more resistant varieties 2. Set cropping schedules. 3. Education and training on how better manage

4. Conclusion

The summary of the research results is as follows:

1. The shock to shallot farming in Tapin Regency was climate change (high rainfall amounts).
2. Exposures to the shallot farmers included decreased harvests (crop failure) and decreased selling prices (losses), leading to not planting shallots.
3. The responses of shallot farmers to the shocks that occurred were stopping shallot planting, conducting additional maintenance efforts, and replacing shallots with other commodity crops.
4. Impacts felt by farmers from these shocks were income decreases/losses and cost increases.
5. Buffers should include using superior varieties (healthy and clean) that are resistant to extreme weather and pest invasions, adjusting planting schedules and cropping patterns, and increasing farmer capacity through education and training.

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