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Mitigation and Adaptation of Chili Farmers to Climate Change in Baturiti District, Bali Province, Indonesia

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ABSTRACT

Climate change has an impact on suboptimal plant growth and development. Adaptive actions to minimize risks can prevent farmers from the impacts of climate change. This study aims to determine the impact of climate change on chili plants, production and income of farmers and adaptation efforts made by farmers. Data collection was conducted through interviews and observations of 50 respondents with descriptive and statistical analysis. The results of the analysis showed that 82.56% of respondents stated that climate change caused a decrease in chili production due to crop failure. In addition to crop failure, 82.30% of respondents stated that climate change caused a decrease in the quality of chili due to the intensity of pest attacks increasing so that production quality decreased and selling prices became low. The average planting area decreased by 13.74%, the average production decreased by 43.68% and the average income decreased by 31.79%. To minimize the risk of climate change, adaptation efforts made by farmers are to replace the planted varieties to F1 pillar varieties, reduce the planting area (13.74%), change the planting pattern from monoculture to intercropping, change the planting time, pest control, improve water management and replace the type of mulch. Climate change adaptation research for the agricultural sector is very important to conduct. The phenomenon of climate change has a direct impact on the shifting seasons which makes it difficult for farmers to determine the planting and harvesting seasons for their crops. In addition, prolonged dry seasons and uncertain rain can cause the growth and development of plant-disturbing organisms. The impact of climate on the agricultural sector is a strategic issue because this problem can threaten food security and agricultural production, especially in Bali.

1. INTRODUCTION

Climate change is a change in various climate variables whose magnitude and/or intensity deviate from the dynamics and average conditions. The main cause of climate change is human activities related to increasing Green House Gas (GHG) emissions [1, 2]. Climate change caused by greenhouse gas emissions or emissions is increasingly threatening human life and biodiversity on earth. Signs of this phenomenon are increasingly felt because Indonesia as an archipelago is very vulnerable to climate change and has caused various disasters such as floods, landslides, long droughts, strong winds, and high sea waves [3]. The threat of disasters can be even more acute and directly felt in farming and fishing communities, as well as communities living on the coast, in rural areas and in urban areas. The broader impacts of climate change are not only harmful to the environment, but also to human health as they affect food availability, economic development activities, natural resource management and infrastructure. This jeopardizes the success of socio-economic development [4, 5].

Rising global temperatures are expected to cause many changes on the Earth's surface, such as increasing intensity of extreme weather phenomena and climate change. Climate change is one of the most serious threats to the agricultural sector and has the potential to create new problems for the sustainability of food production and agricultural production systems in general.

The vulnerability of the agricultural sector to climate change phenomena has been widely stated and studied in various studies. There is general agreement that changes in temperature and precipitation cause soil and water changes that ultimately affect agricultural productivity [6-9]. Some experts predict a simultaneous decline in agricultural productivity and increase in poverty for the tropics, as the

livelihoods of the majority of the population working in agriculture are also increasingly threatened by climate change [10, 11].

The general consensus is that changes in temperature and precipitation result in changes in soil and water regimes that will ultimately affect agricultural productivity [12, 13]. Some experts predict that in the tropics the impacts of climate change will lead to a decline in agricultural productivity and an increase in poverty levels as the livelihoods of the majority of the population working in the agricultural sector become increasingly vulnerable due to the stress of climate variability [14]. Extreme climate events, especially El-Nino or La-Nina, cause various impacts in the agricultural sector such as crop failure, reduced harvest index which thereby reducing productivity and production, damage to agricultural land resources, increased drought, increased humidity, and increased attacks of crop pest and disease.

There was a La-Nina climate phenomenon in 2010 with moderate intensity, which disrupted the productivity of vegetables and fruits in Indonesia. Fruit production at that time decreased by 35%-75% and chili production decreased by 20-25% from normal climate conditions. As a result, there was a shortage of these two important products which triggered an increase in their prices in the market [15]. So far, studies on the impact of climate change in Indonesia have focused more on food crops, while horticultural commodities are still very limited. As an annual crop, horticulture is relatively sensitive to the stress of excess and lack of water. The vulnerability of plants to rain affects the area planted, productivity and quality of the crop. The vulnerability of horticultural crops to rainfall intensity will have an impact on the area of planting, productivity and quality of yield [16].

Climate change in Bali Province, Indonesia, is strongly felt by horticultural crop farmers in the highlands, especially in chili-producing areas in the District of Baturiti, Tabanan Regency. Baturiti and Bali Province in General has experienced climate change from climate type C (rather wet) to climate type D (moderate) in the period 1961-2008 reviewed by the analysis of rainfall trends, analysis of changes in air temperature, analysis of changes in climate type and analysis of shifts in wet, humid and dry months. Farmers of horticultural crops, especially chili peppers in this region, often experience crop failure so that production continues to decline. This crop failure is inseparable from climate change and the derivative effects of climate change such as pest attacks and plant diseases. Chili plants which cultivated in 2020-2022, the production continued to decline. The chili commodities are chayote, cabbage, shallots, cayenne pepper, and petsai / mustard greens [17, 18]. The development of the five commodities shows that the production pattern tends to decline, except for the shallot commodity which has a production pattern that tends to increase. Red chili (*Capsicum annum*) is a type of seasonal horticultural commodity from shrubs with fruits containing capsaicin which causes a hot and spicy taste. Red chili is categorized as one of the 12 types of staple foods that need to be considered for availability and price stability based on Presidential Regulation No. 48/2016 on the Assignment to Bulog in the Framework of National Food Security. This is because red chili is one of the strategic horticultural commodities with high economic value, both to meet domestic and export and industrial needs [19]. Red chilies are widely cultivated by farmers and are used as chilies, flavoring spices, raw materials for the food and beverage industry. Its nutritional and vitamin content is also often used as an ingredient in medicines and cosmetics [20]. The need for red chili is expected to continue to increase every year along with population growth and the increasingly diverse use of it as a raw material. This causes the demand for red chili peppers at the consumer level to tend to increase even though the price fluctuates.

Tabanan Regency as one of the chili supply centers in Bali Province, Indonesia has experienced a significant decline in harvest area continuously from year to year. In 2016, the harvest area of red chili in this district was 230/ha, decreased to 63/ha in 2020 and in 2022 only 44/ha. The decline in red chili harvest area is inseparable from the impact of changes in rainfall which causes crop failure and also pest attacks [21]. Chili plants are one of the chili plants that are very sensitive to climate change. Tabanan Regency as one of the centers of chili suppliers in Bali Province does not yet have data and analysis on adaptation to climate change. So, this research is very important in the actions that can be taken by farmers and the Tabanan Regency government in dealing with climate change.

The impact of climate change as reflected by changes in rainfall and temperature on crop productivity is highly dependent on the type of commodity being cultivated and the mitigation and adaptation efforts made by farmers [22]. Farmers who have knowledge about climate change will act reactively and anticipate the impacts that occur due to climate change. Adaptation to climate change can be planned or spontaneous. Spontaneous action is done without awareness in predicting climate change but based on experience and prevailing conditions. Farmers adapt to climate change with strategies to shift the planting period, change crop variations, change planting patterns, change the place and location of planting. This is based on their experience of climate change that takes place gradually [23, 24]. Referring to this phenomenon, this study takes the title mitigation and adaptation of chili farmers to climate change in Bali Province, Indonesia: insight from Baturiti District. This study complements other studies that only focus on strategies for climate change by adding the impact of climate change on aspects of production and income of chili farmers.

2. LITERATURE REVIEW

2.1 Climate change and its effect to horticultural crops

Climate is the synthesis or conclusion of changes in the value of weather elements (day by day and month by month) in the long term in a place or in a region. Climate is closely linked to weather change and global warming, which can reduce agricultural production by 5 to 20 percent. Climate change is characterized by changes in the world's climate patterns resulting in varied weather phenomena. Climate change is caused by changes in climate variables such as air temperature and precipitation that persist for 50-100 years. Climate change is also influenced by unstable weather patterns such as erratic rainfall, frequent storms, extreme air temperatures and strong changes in wind direction [25].

Climate change is a long-term change in the statistical distribution of weather patterns over time periods ranging from decades to millions of years. It can be interpreted as a change in average weather conditions or a change in the distribution of average weather events. Climate change can occur locally, limited to certain regions, or can occur throughout the earth's surface area. The change is

characterized by at least four things, first because of the change/increase in temperature globally, secondly the increase in sea level, thirdly the more frequent occurrence of extreme and other weather conditions, and fourthly changes in rainfall patterns. Climate change is currently characterized by an increasing frequency of hydrometeorological disasters, including reduced water availability reserves and or even excess water discharge at other times, as well as forest and land fires. These hydrometeorological disasters have the potential to increase based on projections of climate change in the future, and can affect the resilience of water, food and energy resources [26, 27].

A decrease in rainfall intensity is one of the impacts of climate change. Decreased rainfall intensity is the main cause of decreased agricultural yields in drylands. The decrease in crop yields leads to a decrease in farmers' income which is a short-term effect, while the long-term effect is the end of the dry farming profession [28]. Climate fluctuations such as the occurrence of long dry seasons have a major impact on agricultural production. Climate change has a negative impact on agricultural production. The decrease in agricultural production is due to the reduction in land area due to the influence of climate change [29].

Climate change causes changes in environmental conditions that have an impact on less than optimal plant growth and development. In less than optimum conditions, plant growth will be disrupted, which in turn reduces production and quality. Each plant requires different climatic conditions to be able to produce optimally, so climate change will have a different impact on each type of plant. There are many types of horticultural crops, making it difficult to draw conclusions about the impact of climate change on the growth and production of these commodities [30]. The impact of climate change on the production of horticultural commodities also depends on the geography and intensity of climate change itself. To determine the impact of climate change on horticultural commodities, information is needed on the physiological response of growth, development and quality, production and productivity of plants [31].

Phenology studies in Indonesia are very important for horticultural crops originating from subtropical countries such as potatoes that are very sensitive to air temperature. Phenology studies in Indonesia are also important to see projections of crop production in the future because air temperatures are projected to increase. However, these studies are still limited. Several studies have mentioned that there have been changes in the phenology of chili plants due to increased air temperatures in local fruits [32-34].

The increase in air temperature also affects the life cycle of plant pests, high temperatures will accelerate their life cycle so that the regeneration cycle is very fast [35]. Furthermore, study about dominant pests in shallot and lowland chilies found new dominant pests that had never appeared before. Changes in dominant pests are thought to be caused by an increase in air temperature [36, 37]. Increased air temperature negatively affects fruit quality, affecting apple quality in China [38], and causing damage to the color pigments of fruits in Japan [39].

Indonesia's rainfall variability is very high, both spatially and temporally. Economically, changes in rainfall intensity and frequency greatly affect Indonesian agriculture. The impact of changes in rainfall is evident in the increase in pest attacks on chili plants [40, 41]. High rainfall causes disease attacks including fusarium wilt, bacterial wilt, and anthracnose in chili. Low rainfall causes increased pest attacks, including onion caterpillars, yellow virus, chili thrips, and fruit flies [42].

2.2 Mitigation and adaptation to climate change

Mitigation involves finding ways to slow or contain greenhouse gas (GHG) emissions, or sequester them in forests or other carbon sinks. Mitigation efforts aim to reduce the rate of global GHG emissions so that the concentration of GHGs in the atmosphere remains within tolerable levels. In other words, mitigation is the effort made to reduce emissions [43].

Adaptation includes ways to deal with climate change by making appropriate adjustments to reduce its negative effects, or to utilize its positive effects [44]. Adaptation is an effort to adjust due to climate change to reduce risk or disaster. The main challenge for the agricultural sector is to increase production and adapt to the risks of changing climate conditions [45]. The agricultural sector is highly vulnerable to climate change. This is because the agricultural sector depends on the water cycle and weather to maintain its productivity. The main concern about the impact of climate change on the agricultural sector is its critical impact on food security. Climate change causes phenomena that can affect agricultural productivity, such as drought, groundwater depletion, temperature rise (global warming), flooding and others [46]. This must be addressed through preventive action or mitigation and making adjustments to the phenomena that occur or adaptation so that the negative impacts can be minimized. The crucial factor that must be known by actors in the agricultural sector, especially horticulture, is to understand climate change and its impact on the food agriculture sector.

Knowledge, understanding and adaptive actions can avoid farmers from losses due to crop failure. Farmers who have knowledge and understanding of climate change will act reactively and anticipate the impacts of climate change. Adaptation to climate change can be planned or spontaneous. Spontaneous action is done without awareness in predicting climate change but based on experience and prevailing conditions [47, 48]. Farmers adapt to climate change with strategies to shift the planting period, change crop variations, change planting patterns, change the place and location of planting, this is based on their experience of climate change that takes place gradually [49, 50]. Therefore, the most appropriate action to reduce the impact of the extreme nature of climate change is the adjustment (adaptation) of agricultural activities with climate behavior in each region. The success of adaptation is determined by physical vulnerability and adaptive capacity to climate change.

Developing countries are considered to have low adaptive capacity compared to developed countries. Adaptive capacity is influenced by many non-climate factors (infrastructure and institutions) and resources (human, social, economic and natural) [51]. At the farm level, farmers need to be equipped with the knowledge to understand and utilize climate and weather information/predictions, in order to adjust the timing, pattern and type of crops to be planted, in order to produce optimal food commodity products despite various weather disturbances. By adapting, farmers can also decide the right planting time and harvest time to avoid extreme weather/climate disturbances.

2.3 Red chili plants

Chili plants are one of the plants that are sensitive to seasonal changes. Chili plants belong to the eggplant family

(*Solanaceae*) which grows as a shrub or bush. Chili is a seasonal or short-lived plant [52]. Chili is a shrub from the eggplant family which has the scientific name Capsicum sp. This plant originated from the American continent, precisely the Peruvian region and spread to the countries of the American continent, Europe and Asia including Indonesia [53]. Chili plants have many different types of growth and fruit shapes. It is estimated that there are 20 species, most of which live in their country of origin. People in general only recognize a few types, namely large chilies, curly chilies, cayenne peppers and peppers. Red chili (Capsicum annum L.) is one of the important types of horticultural crops that are cultivated commercially, this is because in addition to chili having a fairly complete nutritional content it also has a high economic value which is widely used both for household consumption and for industrial food purposes [54]. In general, red chilies can be planted in the lowlands to mountains (highlands)+2,000 meters above sea level which requires a climate that is not too cold and not too humid. A good temperature for chili plants is 24-27°C [55].

The red chili fruit is around 6-10cm long, 0.7-1.3cm in diameter. Red chilies in Indonesia are divided into two groups, namely large red chilies and curly red chilies. The surface of the large red chili fruit is smooth and shiny and has a spicy taste, while the curly red chili is slimmer in shape with a very spicy taste. Almost all types of soil that are suitable for cultivating agricultural crops are also suitable for chili plants. To get a high quantity and quality of yield, chilies require fertile, loose, organic-rich soil, not easily muddy (stagnant), free of worms (nematodes) and soil-borne diseases. The ideal soil pH range is between 5.5-6.8 [56, 57].

Red chili is generally widely cultivated by farmers in the dry season (on-season). In the rainy season, farmers usually prefer to plant other commodities because of the high risk of red chili harvest failure. Excessive rainfall conditions are not in accordance with the adaptation of red chili plants that cannot stand stagnant water [58]. Flooding conditions will result in root rot, flowering failure, and fruit drop. Excess water also affects the growth of red chili, which is susceptible to diseases [59]. Diseases damage plants and disrupt fruiting which results in a decrease in production. Meanwhile, red chili production is generally abundant in the dry season as long as soil drainage and aeration are good, and water is available in sufficient quantities. However, a long dry season can also result in drought which causes growth to be delayed and the amount of fruit produced to decrease. Red chili requires a rather hot daytime temperature to support its flowering. Therefore, mildly dry conditions with sufficient water availability are ideal for optimum growth and yield of this crop [60].

3. METHODOLOGY

3.1 Research location

This research was conducted in Baturiti District, Tabanan Regency, Bali, Indonesia. Baturiti District located in the northern part of Tabanan Regency and in the middle of Bali Island with an altitude of 300-990m above sea level. Baturiti District has an area of 99.17km² which consists of mountainous areas. Geographically, the Baturiti District is located between 114° 54' 52" east longitude and 8° 14' 30"-8° 30' 07" south latitude. The topography of Baturiti District is flat area with a slope of 2-15% up to mountainous area with slope of 15-40%. Areas that have slopes of 2-15% and 15-40% are areas that are fertile and where farmers carry out agricultural activities as their main livelihood a slope of 40% and above, these are hilly and steep areas [61].

This research was conducted in Baturiti District because this district is one of the chilies producing centers in Bali Province. Of the 12 villages in Baturiti District, 3 villages were purposively determined as research locations, namely Baturiti Village, Perean Village, and Batunya Village. The basis for determining these villages is because farmers in these three villages almost always plant red chilies so that these farmers experience and know various changes in natural conditions (weather) that occur from season to season. The stages were carried out starting from preparation process, data collection, data analysis and report preparation. Figure 1 shows Map of Reseach Location.

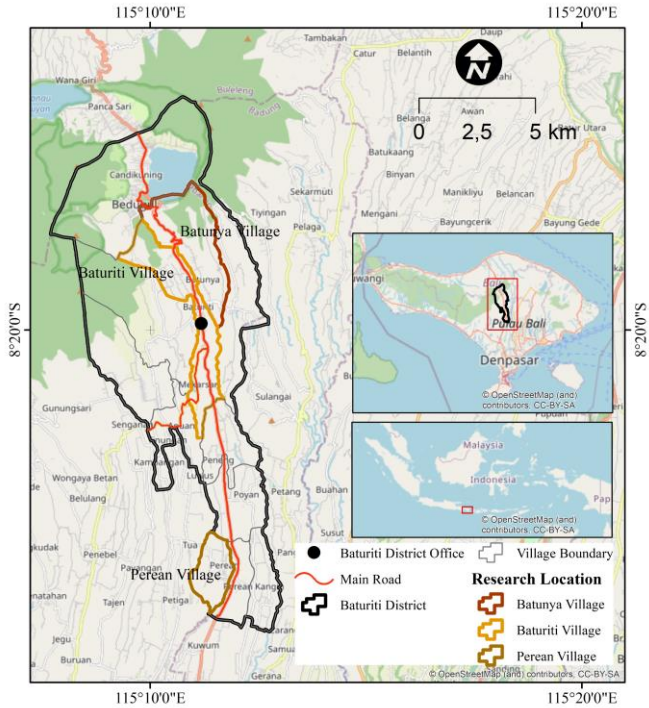

Figure 1. Research location

3.2 Data collection technique

Data collection was carried out using structured interviews using a questionnaire (list of questions) that had been prepared previously. Interviews were conducted to obtain information regarding farmers' behavior in cultivating chili plants due to climate change and their adaptation efforts. Apart from that, observations were carried out by recording and observing directly in the field to obtain accurate data about chili farming practices and farmers' adaptation to climate change. Recording and observations were carried out directly in the respondents' chili farming gardens. The questionnaire presented in Appendix 1.

The population in this study were farmers who planted chilies in the three research location villages. Because the types of vegetable crops grown by farmers in the research location are very diverse and there are no exact records of the number of farmers who grow chilies from season to season, the farmers who were used as samples or respondents in this study were determined using a non-probable sampling

technique, namely snowballing sampling [62]. This sampling method involves the primary data source nominating other potential data sources that can participate in the research study. The snowball method is based on referrals to new samples that can help answer the research question. This sampling technique can continue, like a snowball that gets bigger in this case the sample size until the researcher has enough data to analyze, to make the right decision [63].

The number of respondents taken in this research was 30 chili farmers with the assumption that this number could represent the nature and characteristics of the population and from statistical analysis it was considered valid in terms of data normality [64].

This research focuses on the impacts felt by farmers due to climate change and the adaptations made by farmers. Information regarding the impact of climate change is studied from the aspects of chili cultivation, production and farmer income based on farmers' memories from the latest two planting seasons. The information regarding farmers' adaptation to climate change that is studied is farmers' efforts to adapt chili cultivation in an effort to minimize risks.

3.3 Data analysis

Data processing steps, namely, checking (editing) the filling in of each data collection instrument, recapitulating the data, assigning a code or score to each data collected in each instrument. The next step is tabulation of the data presented in a frequency distribution table. After the data processing process is complete, data analysis is then carried out. The data analysis techniques used in this research are qualitative and descriptive analysis techniques. Qualitative analysis techniques are in the form of descriptive analysis, namely processing data and verbal information about all symptoms found at the research location [65].

Descriptive analysis is used to accurately describe or explain facts and their relationship to phenomena in the research area [66]. This descriptive research aims to know the impact of climate change on chili plants and the mitigation and adaptation efforts carried out by chili farmers. Descriptive analysis is also used to make it easier for researchers to explain data obtained from interviews with questionnaires and to describe the characteristics of respondents and demographics of the research location.

4. RESULT AND DISCUSSIONS

4.1 Impact of climate change on chili cultivation

The impact of climate change on chili plants in Baturiti District has had a negative impact on plant growth and production. Initially, local residents felt that cultivating chilies was not that difficult, but since climate change occurred, farmers have begun to experience difficulties in cultivation and the risks they face have also become greater. All farmers (100%) stated that the uncertain season, both the timing and length of the season, really confuses farmers in planning their farming business. Farmers in Baturiti District are aware of changes in the microclimate which are felt to have an impact on reducing the quality and quantity of harvests, and even experiencing crop failures, causing losses. The current issue of climate change is that farmers state that they get this information from television, radio and also from fellow farmers.

Referring to respondents' opinions, it indicates that chili farmers have felt the impact of climate change, especially changes in weather and temperature. The impact of climate change has resulted in crop failure, decreased production, decreased production quality, and climate change has resulted in increased pest and disease attacks.

4.1.1 Crop failure

The results of interviews with respondents stated that red chili plants can be harvested for the first time at 70-75 days after planting with harvest intervals every 3-7 days or a maximum of one week and can be harvested when the fruit is red. To keep plants fertile and fruitful, proper fertilization is required. The fertilizer that can be used for chili plants is NPK 15-15-15, which is good for stimulating the vegetative and generative growth of plants, especially the growth of fruit and leaves.

Climate change in Baturiti District has resulted in a decrease in chili production due to crop failure. This crop failure was caused by many plants withering, poor growth and decreased harvest area. Based on the results of interviews, it is known that 82.56% of respondents felt that harvest failure occurred in chili cultivation and the remaining 17.44% felt that harvest failure was due to climate change, especially changes in rainfall. Harvest failure causes production to fall so that supply to the market decreases. The results of this research are strengthened by the respondent's confession who said that the price spike that occurred for chili fruit was because many chili plants at the farmer level experienced crop failure due to high humidity so that production decreased. High humidity conditions also increase the level of disease attacks, especially anthrax which can kill chili plants.

4.1.2 Decrease in crop quality production

Harvest failure will result in a decrease in production or quantity obtained. Based on the interim results, it is known that 82.61% of respondents strongly felt that there was a decrease in chili production, 13.04% of respondents felt it and the remaining 4.35% of respondents said they felt it quite well. The decline in the quantity of chilies due to climate change is supported by BPS data from Bali Province which states that the average productivity of red chilies was 8.36 tons/ha in 2011, which has decreased to 7.57 tons/ha in 2021.

Chili cultivation in Baturiti District has good prospects for cultivation. This is based on several considerations, namely: a) chilies are really needed by the community for various needs related to food, b) marketing chilies are easy to do and is absorbed by the market, and c) can make money in a short time because chili plants can be harvested several times. Climate change has had an impact on reducing the quality of the chilies produced. Chili farmers in Baturiti District have experienced problems related to a decrease in quality, such as the fruit produced being small and rotting quickly. Based on the results of the interviews, it was found that 82.30% of respondents felt that there was a decline in the quality of the chili produced, 10.20% of respondents felt it quite well and the remaining 8.50% of respondents said they felt it very much.

Climate change results in a decrease in the weight of the chili fruit produced and the fruit rots easily [67]. Chili harvest and post-harvest processes such as transportation and storage are also greatly influenced by air temperature [68, 69]. The process of harvesting and storing in inappropriate conditions can speed up the chili rotting process. In certain cases, it can

damage the nutritional content of the chili. The chili rotting process can occur because changes in air temperature are more severe in wet tropical areas such as Indonesia [70].

4.1.3 Attacks by plant pests

Based on the results of interviews, it was found that 76.40% of respondents felt that the emergence of plant diseases was increasing. The chili production in Baturiti District is mostly green and red chilies. In recent months, this type of chili has experienced a price spike, both at the farmer level and at the trader level. This is because many farmers' chili plants during the recent rainy season have been attacked by plant diseases, made worse by bad weather conditions characterized by high rainfall intensity. This pest attack and bad weather resulted in the level of chili production at the farmer level decreasing from normal months, so that this condition triggered a spike in the selling price of chilies which was quite expensive.

One respondent stated that the anthrax pest attack caused 10 acres of his chili production area to experience crop failure, even though the Galungan and Kuningan holidays which fall this month have been targeted as moments to seek more profit from increasing market demand and increasing selling prices. Efforts have also been made to protect production from anthrax pest attacks by spraying pesticides, but these efforts have not been successful. It was further stated that from a 10-acre chili planting area, losses reached IDR 20 million. These losses cover costs for cultivating the land, purchasing seeds, and purchasing medicines (pesticides). Changes in temperature, season, humidity and wind speed as a form of climate change have an impact on the emergence of plant diseases.

4.1.4 Chili farming income

The amount of income received by chili farmer respondents in Baturiti District depends on the amount of production produced. Production costs are costs incurred during the production process. Fixed costs are costing whose use is not exhausted within one production period. Costs that are included in fixed costs in this research are land rental and depreciation costs for agricultural equipment. Variable costs are non-fixed costs whose use is exhausted within one production cycle, such as the costs of production facilities which include the costs of seeds, fertilizer, medicines/pesticides, labor and others.

The costs included in variable costs are the costs of production facilities, namely seed costs, fertilizer costs and pesticide costs and labor costs. The implementation of a farming activity cannot be separated from the existence of the required production facilities. Farmers have to pay money to buy or obtain these production facilities. Cost components included in the total cost calculation are seed costs, labor costs, fertilizers and pesticides. The production produced greatly influences the income that farmers will receive because the higher the production, the more income they will receive. Production results are influenced by the amount of production produced and the area of land used.

The risk of erratic weather is difficult to mitigate because it is related to natural factors, but farmers can minimize failure due to uncertain climate and weather by correctly calculating when is the best time to start planting chilies. When losses occur due to climatic factors and unpredictable weather that are difficult to mitigate, farmers will bear the losses themselves. Therefore, chili farmers in Baturiti District can minimize the risk of high rainfall by making adaptation efforts by using mulch on the land so that the plants do not become waterlogged so that the risk of crop failure can be reduced and the percentage of success of the chili can be achieved optimally. Mulch can help protect plants from direct exposure of the soil to rain and excess moisture so that the chilies do not turn yellow or wilt. Apart from that, risk reduction is carried out by making planting pattern schedules because the planting patterns carried out by farmers are still not intensive because they are still only based on habit.

From the results of the analysis of chili farming income for two growing seasons, it was found that the impact of climate change has resulted in a decrease in farmers' income by an average of 31.79%, which is equivalent to IDR 6,613,043.48/ha.

4.2 Mitigating climate change for chili farmers

Climate change is something that cannot be avoided due to global warming and is believed to have a broad impact on various aspects of life, including the agricultural sector. Climate change mitigation is an effort to reduce the risk of increasing greenhouse gas emissions. Changes in rainfall patterns, an increase in the frequency of extreme climate events, and an increase in air temperatures are serious impacts of climate change that Indonesia is facing. At the global level, the agricultural sector contributes around 14% of total emissions, while at the national level the contribution of emissions is 12% (51.20 million tons of CO_2e) out of total emissions of 436.90 million tons of CO_2e. In the 2020-2024 RPJMN, the Ministry of National Development Planning (BAPPENAS) has committed to reducing emissions from the land sector (agriculture included) by 58.3% (by 2024). In 2020-2045, it is projected that there will be an increase in rice production due to climate change in all provinces in Indonesia. A decline in rice production from high levels to very high levels occurred in several provinces in the north-east. Emission reduction also takes into consideration the development of the agricultural sector with the main target being food production to maintain food security.

Even though the contribution of emissions from the agricultural sector is relatively small compared to other sectors such as the energy, waste and IPPU sectors, the impact felt by this sector is very large. The warming climate in Indonesia will also be accompanied by monsoons, South Sumatra, Java, Madura, Bali, West Nusa Tenggara and East Nusa Tenggara have had a significant impact on crop failure for various agricultural commodities. Changes in rainfall patterns and rising air temperatures have caused agricultural production to decrease significantly. Extreme climatic events in the form of floods and droughts cause more and more plants to suffer from puso.

Mitigation aims to reduce greenhouse gas emissions from activities on agricultural land. Mitigation efforts targeted by the agricultural sector in Presidential Decree 61/2011 are land optimization, application of plant cultivation technology, use of organic fertilizers and biopesticides, development of plantation areas (palm oil, rubber, cocoa) on non-forested land/abandoned/degraded land, utilization of livestock manure/urine and agricultural waste for biogas [71]. Mitigation efforts that farmers can take to play a role in mitigation in the agricultural sector, especially chili farmers, are by doing small things that can reduce house gas emissions, such as agricultural cultivation using organic fertilizer and reducing the use of chemical fertilizers. However, this effort

has not been carried out by many local farmers because based on their experience in using organic fertilizer, the production they obtain is not as much as when they use chemical fertilizer. Obtaining lower production when using organic fertilizer means they are not interested in using this fertilizer so they continue to use chemical fertilizer. Likewise, when selecting the chili varieties to plant, they do not understand whether the varieties planted are low-carbon varieties or not. In selecting chili varieties, farmers are only guided by the plant's resilience in the face of climate change that occurs and the amount of production obtained.

4.3 Adaptation of chili farmers to global warming

The challenges for adaption in climate change that there are not many efforts made by farmers in Baturiti District in dealing with climate change. The use of organic fertilizers is still very limited as well as in the selection of low-emission varieties.

Farmers who have knowledge about climate change will act reactively and anticipate the impacts that occur as a result of climate change. Adaptation to climate change can be planned or carried out spontaneously. Spontaneous actions are taken to predict climate change based on experience and conditions that have occurred. Based on the interview results, it can be seen that the average adaptation of farmers to climate change related to chili cultivation in Baturiti District is 4.68, which is categorized as good.

Previous studies have shown that increasing temperatures cause changes in plant morphology. Increased air temperature causes potato plants to grow more upright, stems to elongate, leaf size to shrink, and tuber surfaces to become irregular [72]. Increased air temperature also affects the sugar content, organic acids, and antioxidant levels of chili [73]. Several studies have shown that changes in rainfall significantly increase pest attacks on chili plants. High rainfall increases disease attacks such as fusarium wilt, bacterial wilt, and chili anthracnose. When rainfall is low, pest attacks increase, including onion caterpillars, yellow viruses, chili thrips, and whiteflies [74, 75].

Water availability determines the success of chili cultivation. The impact of climate change, in this case rainfall, showed that changes in rainfall had a significant effect on the production and income of chili farmers [76]. The climate change often causes crop failure with an increasing risk of losses and has a direct impact on the sustainability of farming businesses, increased attacks of plant pests and the emergence of new pests [77]. The results of previous studies also support the results obtained in this study. The farmers are advised to improve current practice by changing chili plant varieties, reducing the planting area, changing planting patterns, changing planting times, controlling plant pest organisms, using mulch, fertilizing and handling weeds.

4.3.1 Varieties replacement

One of the most important adaptation steps in climate change adaptation is the use and development of varieties that are adaptive and tolerant to environmental stress and resistant to plant pests and diseases. Variety development takes a long time. If an area is projected to experience a decrease in rainfall, then the variety that will be developed is a drought-tolerant variety and vice versa. There are various types of red chili varieties that are traded and cultivated by farmers previously, such as Arimbi, Columbus, Imperial, Gada, Panex, Baja, Napoli and others. The type of chili variety that is currently widely planted by farmers in an effort to adapt to climate change is the PILAR F1 variety. PILAR F1 is a superior large chili that is recommended for planting in medium to high plains. Upright growth type, potential yield between 1-1.5kg per plant. In one kilogram of chili, there are 50-60 fruits with a length of 18cm and a diameter of 1.8-2cm. Pilar chili is very resistant to bacterial wilt and stem rot diseases. Bacterial wilt is caused by the bacteria Pseudomonas solanacearum, this virus attacks the roots so that they rot. In addition, it is resistant to stem rot when it rains.

4.3.2 Reduction of planting area

Adaptation efforts made by farmers to reduce the risk of crop failure due to unpredictable weather are carried out by reducing the area of planting. There was an average reduction in the area of planting by 13.74% from the previous planting area. The reduction in the area of planting was carried out by replacing the cultivation of chili plants with other types of vegetable commodities that are predicted to have better market value. Vegetable plants such as lettuce, cabbage, mustard greens are widely cultivated by farmers as a substitute for chili because these commodities have a relatively non-fluctuating selling value.

4.3.3 Changes in cropping patterns

Changes in cropping patterns are based on the desire to avoid and reduce the risk of failure in chili planting which is usually planted during the rainy season. Lettuce, cabbage and green beans are often chosen because these plants are considered quite resistant to water stress. In addition, planting intensity can also be increased because the age of the plant is relatively short. Planting intensity is more aimed at utilizing rainfall, rainy days and rainy periods during the rainy season with commodities that are suitable for planting. Increasing planting intensity is one strategy for adapting to climate. From the aspect of planting patterns, farmers make efforts to diversify the types of commodities planted as an effort to reduce the risk of crop failure and also the decline in the price of chili commodities.

4.3.4 Shifting planting times

Vegetable farmers in Baturiti District predict the planting season based on their local wisdom. All farmers (100%) predict that the rainy season will start every October to May and then the dry season from June to September. However, the local wisdom that is the basic knowledge of local farmers in determining the season or planting time is no longer accurate and does not match the predictions of what is happening. Farmers no longer depend on the season in cultivating their land, this is different from rice/secondary crops farmers who depend on the season. Thus, local knowledge and general climate knowledge that farmers currently hold are considered by farmers to be unusable because in reality, seasonal shifts sometimes occur extremely. In addition, according to farmers, they also lack information from government institutions in obtaining information about changes in weather and temperature (climate) which makes it difficult to predict the beginning or end of the rainy season or dry season.

Shifting seasons and increased air rainfall have an impact on increasing the risk of crop failure, damage to crops and also increasing pest attacks. Therefore, farmers are more selective in determining the types of plants to be planted to reduce risk. Likewise, the planting time for chili plants is also adjusted

according to the estimated rainfall. Previously, farmers tended to plant chili plants in March-April and now they have shifted to June-July. Farmers who shift planting times are adjusted to signs that the rainy season will come. Farmers who shift planting times state that they do not want to experience losses like the experience during the long dry season during the El Nino event in 20016.

4.3.5 Pest/disease control

Pests or diseases that attack chili plants can result in decreased production and even cause plant death. Pests and diseases can attack young chili plants as well as mature plants. Therefore, pest or disease attacks must always be watched out for and prevented as early as possible. Based on the interview results, it is known that the natural enemies of chili plants that are often found are aphids, mealybugs, and fruit rot caused by fungi. Control of plant pests is carried out by means of land sanitation, fruit attacked by pests is picked and then destroyed, maintenance pruning, spraying fungicides/insecticides from the planting stage to harvest. This is because in chili cultivation, farmers only spray fungicides/insecticides until the plants bear fruit, after that farmers carry out garden sanitation, pruning, and fruit picking.

4.3.6 Improving water management

Water is an important factor that greatly influences plant growth and production. Based on the interview results, it is known that chili farmers use irrigation carried out during the dry season using a direct watering system or with drip irrigation using tubes and drippers to deliver water at low pressure directly to the roots of the plant. This is to prevent plants from being flooded, the drip irrigation water supply will flow drop by drop at a very slow speed and maintain the air soil needed by plant roots for healthy growth. The application of the drip irrigation system makes it easier for farmers to carry out maintenance because farmers do not need to water each plant one by one. Farmers simply turn on the main water tap so that all the water is channeled to each hose.

4.3.7 Use of mulch

The use of black silver plastic mulch as a ground cover for chili plants can provide better results compared to not using mulch. The use of black silver plastic as mulch is more practical than using leaf mulch. This is because black silver plastic mulch is easy to obtain, easy to use and can be used more than once so that it saves costs on subsequent plantings and is not easily burned. The correct installation of mulch is to place the silver color on the top and the black color is placed on the bottom. The silver surface functions to reflect ultraviolet sunlight which can change the microclimate around the plant. The reflection of sunlight will also perfect the process of plant photosynthesis so that plant growth can be more perfect which can ultimately increase yields. The black surface of the mulch functions to suppress the growth of weeds and fungi in the soil.

4.3.8 Partnership

Partnerships with surrounding farmers who cultivate chilies in order to cover the existing demand and partnerships in the supply of superior seeds and quality organic fertilizers also need to be implemented. This will have implications for the production results obtained where if the supply of quality seeds can produce good products but by paying attention to the ongoing production activities. Mitigation for inappropriate pesticide use is to implement integrated control practices such as using organic materials. Based on field results, recently some farmers have started to switch to organic farming by using more organic fertilizers than inorganic fertilizers because they realize the importance of maintaining the land environment and reducing pesticide use.

The production risks faced by farmers are influenced by weather factors, pests and diseases in plants. Therefore, farmers need to carry out good production risk management so that the existing risks can be minimized. Production planning greatly influences the determination of the planting pattern to be carried out. Planning the time for planting chilies should be done when the weather is not rainy because it will maximize existing production. If planting is done when it rains, the seeds will be damaged and rotten so that the results will not be maximized. Intensive care is also very important, especially when the weather is not supportive. Plant care is done by maximizing control of pests and plant diseases. In addition, farmers need to protect plants, especially chili plants which are very sensitive to bad weather.

Partnerships are also important to deal with rising and falling prices. Partnerships with buyers or wholesalers who can provide certainty in product sales even though there are fluctuations in market demand. Product quality can also increase demand for products. Farmers are required to provide quality products and have added value with good and reliable quality. Product quality is one of the factors that consumers consider before buying a product, in addition, quality can also be an important marketing tool [78]. This opportunity can be a strategy to gain a wider market share. To gain a wide market share, partnerships can be established with distributors, agents, and retailers. Expanding market share can have an impact on product demand which will increase because the products marketed are spread to other areas. This partnership strategy can also help producers and distributors, agents or retailers to be able to work together with mutual need and benefit. Partnership cooperation can create mutually beneficial relationships, mutual need and mutual strengthening between the two parties. Expanding a wide market share can be an advantage because it can plan and forecast more demand. To support demand planning that 86 requires good input planning by establishing partnerships with cooperatives and suppliers to make it easier to obtain the materials to be used. Therefore, all of these strategies are interrelated to maintain product quality so that it can be accepted by consumers.

5. CONCLUSIONS

Farmers are aware of climate change that is felt through changes in rainfall and temperature. The impact of climate change results in crop failure, increased attacks by plant pests, decreased production and quality of chili production.

The impact of climate change causes an average decrease in chili production of 1601.09kg/ha or around 43.68% of previous production. The decrease in production is due to crop failure and increased attacks by plant pests. In terms of income, climate change has an impact on decreasing farmers' income by 31.79%, which is equivalent to IDR 6,613,043.48/ha. This decrease in income occurs due to decreased income due to decreased production and increased costs of purchasing production facilities such as fertilizers, water and pest control drugs.

Chili farmers' adaptation to climate change is carried out by

replacing more resistant chili plant varieties, reducing planting area, changing planting patterns, changing planting times, controlling plant pests, using mulch, fertilizing, maintaining and handling weeds more intensively. In an effort to minimize the risks faced by chili farmers in facing climate change, assistance from extension workers is very necessary. The assistance in question is determining the planting time, planting pattern and type of commodity planted according to the expected rainfall and temperature that occur. Continuous and sustainable efforts are needed to socialize the use of organic fertilizers and the selection of low-carbon varieties for chili farmers in particular and agriculture in general in an effort to reduce emissions through climate change mitigation efforts. As a result of climate change, the price of chili on the market fluctuates sharply. When production is abundant, the price of chili is very low and vice versa when chili production fails due to climate change (rainfall and temperature) production decreases so that prices increase sharply. For this reason, partnerships between chili farmers and traders need to be built to protect farmers as producers and the community as consumers.

Further research can be in the form of adaptation efforts that farmers can make to minimize the impact of climate change, especially related to manipulating the climate according to plant growth requirements. Climate manipulation activities include designing greenhouses according to the microclimate needed by plants. In the long term, the impact of climate change can help improve the land by increasing productivity and soil fertility so that the land does not change, farmers pay more attention to what types of commodities will be planted and adjust them to the season.

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APPENDIX

Appendix 1. List of Questions

Name:
Age (yrs):
Education (yrs):
Farming experience (yrs):
Address:

Additional information from respondents/field observation results:

1. Do you feel any changes in the current climate compared to the past?
a. Yes
b. No
2. In your opinion, what are the current seasonal conditions?
a. Longer rainy season
b. Longer dry season
c. No change
3. In your opinion, what are the current rainy season conditions?
a. High rainfall and rainfall intensity
b. High rainfall and low rainfall intensity
c. Low rainfall and rainfall intensity
4. In your opinion, what are the current air temperature conditions?
a. Hotter
b. Colder
c. No change
5. In your opinion, when did the climate/seasonal changes start to occur/be felt?
a. Last 3-4 years
b. Last 6-7 years
c. Over the last ten years
6. Have there been any incidents in Baturiti that occurred due to extreme climate?
a. Yes
b. Never
7. If the previous answer is yes, what type of incident occurred?
a. Drought, in the month….year….
b. Flood, in the month…..year……
c. Landslide, in the month……year…..
d. Whirlwind, in the month…….year…..
8. Do the climate/seasonal changes that you have heard/felt affect agricultural activities?
a. Yes
b. No
9. If yes, how do these climate/seasonal changes affect your agricultural activities?
a. Crop failure
b. Decrease in quality
c. Decrease in quantity
10. Do you always consider weather factors in your agricultural activities?
a. Yes
b. No
11. If yes, what agricultural activities take the weather forecast into account?
a. Planting time, explain
b. Types of seeds/plants, explain
c. Application of fertilizers and medicines, explain
d. Harvest time, explain
e. How to cultivate the land, explain
f. Others, ……
12. Do current climate conditions affect the availability of water for agriculture?
a. Yes
b. No
13. If the previous answer is yes, how does climate change affect the availability of water for agriculture?
14. Do current climate conditions affect the types and levels

of plant pest and disease attacks?

a. Yes

b. No

15. If the answer to the previous question is yes, how does climate change affect the types and levels of pest and disease attacks?

Adaptation to Climate Change

1. What efforts have you made to overcome the impacts of climate change?

a. Changing varieties

b. Changing planting times

c. Changing planting patterns

d. Improving irrigation and drainage techniques

e. Changing soil cultivation techniques

f. Changing pest control techniques

2. If you have not made efforts to overcome the impacts of climate change on agricultural production, what is the reason?

3. Are you currently changing planting times compared to when you first started farming?

a. Yes

b. No

4. If the answer to the previous question is yes, what is the form of the change in planting time?

5. Are you currently changing your planting pattern compared to when you first started farming?

a. Yes

b. No

6. If the answer to the previous question is yes, what is the form of the change in the type/variety of seedlings/seedlings/plants?

7. Are you currently changing irrigation and drainage techniques on agricultural land compared to when you first started farming?

a. Yes

b. No

8. If the answer to the previous question is yes, what is the form of the change in water management for agriculture?

9. Are you currently changing the way you manage your land compared to when you first started farming?

a. Yes

b. No

10. If the answer to the previous question is yes, what is the form of the change in land management?

11. Are you currently changing your soil processing techniques?

a. Yes

b. No

12. If the answer to the previous question is yes, what is the form of the change in fertilizer types?

13. Are you currently changing your pest and disease control techniques?

a. Yes

b. No

14. If the answer to the previous question is yes, what is the form of the change in the type of fertilizer?