Risk Analysis of Dry Land Rice Production on the Impact of Climate Change and Weather

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Abstract. Food crops are highly dependent on climatic conditions, because food crops, especially annual crops, are closely related to excess or lack of water. Demanding district is included in dryland agriculture where the availability of water depends on rain and pumps from the nearest river. The study aims a) to analyze the sources of dryland farming risk, b) to analyze the probability and impact of production risk in dryland farming, and c) to analyze alternative production risk strategies in dryland rice farming. The results showed that the risk sources that could reduce rice productivity were plant-disturbing organisms and weather factors. The highest risk sources from plant-disturbing organisms are blast disease and leaf blights, leafhoppers, and a combination of leafhoppers and leaf spot disease. Sources of risk due to weather factors are drought and strong winds. The probability of production risk in dryland rice farming is highest due to disease. The lowest risk productivities are caused by a combination of pest and disease attacks. The impact of highest production risk on dryland rice farming is the weather factor because it is a factor that is difficult to predict and overcome. The risk map for rice production is located in quadrant two, which shows a high probability of production risk and a high risk of loss impact. Strategies that are carried out to handle production risks are preventive strategies and mitigation strategies.

Keywords: Production Risks · Dry Land Rice

1 Introduction

Food crops are highly dependent on climatic conditions, because food crops, especially seasonal crops, are closely related to excess or lack of water. The availability of information and innovative technology for land, water, and climate resources is the basis for optimal food production. Water and climate greatly determine the production of food crops, so the technology for using water effectively and efficiently, as well as efforts to harvest rainwater for use in the dry season, is a technology that must be conveyed to farmers [1]. Global climate change has an impact on regional climatic conditions in Indonesia, marked by changes in surface climatic parameters, namely: air temperature

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and rainfall. Changes in climate parameters are often indicated by analysis of trends in temporal changes in air temperature and rainfall [2].

Tuban Regency, East Java is referred to as one of the drylands, namely: 1) influenced by the El Nino phenomenon (climate anomaly in the South Pacific) which causes long droughts and droughts, 2) Tuban's geographical conditions are dominated by limestone mountain structures, 3) entering the area water basin map with red shading. This means that the dominance of underground water with water discharge at its point is minimal [3]. According to The Agriculture Office, Province of East Java, the agricultural land affected by the drought in East Java in 2019 was 24,633 hectares and a puso area of 983 hectares, of which Tuban Regency was 2,768 hectares. The drought area is divided into several categories: a light category covering an area of 1453.1 hectares, a medium category covering an area of 783.2 hectares, a heavy category of 512 hectares, and puso or crop failure covering an area of 65 hectares. Drought areas are spread across several districts, where the worst affected conditions are Senori District covering an area of 1450 hectares, Singgahan District covering an area of 432 hectares, and Soko District covering an area of 339.3 hectares.

Tuban Regency is one of the dry areas in dryland agriculture, not many types of plants grow in this environment because of the lack of water and nutrients owned by the soil. According to [4], dryland or upland has characteristics of low productivity with high risk. These risks are in the form of climate, drought, pests, diseases, and so on, resulting in crop failure or less-than-optimal harvests. Tuban Regency's rice production in 2020 is 671,975 tons including field rice production of 5,915 tons [5].

Semanding district is included in dryland agriculture where the availability of water depends on rain and pumps from the nearest river, and if the agricultural land is far from water sources, the land cannot be processed optimally it affecting productivity and production results that will obtained by farmers. One of the causes of the decline in production yields plants rice in the rainy season so that the intensity of pest and disease attacks is higher than in the dry season. In addition, the weather factor is a source of risk that causes a decrease in production yields. Low rainfall causes rice fields to not get enough water supply. One of the impacts of risks faced by rice farmers in the production results experiencing crop failure. Risk is something that must be faced by anyone, action to avoid risk is quite difficult to do so the easiest thing is how to manage risk properly. [6] states that decision-making on certain events, decision-making on risky events, decision-making on uncertain events, decision-making on events that arise due to conflict with other circumstances.

Production risk is the variation of output due to factors that are difficult to predict such as weather factors, pests, and diseases that commonly attack rice plants (rats, stem borer, brown planthoppers, bugs, tungro disease, and leaf blight). The study aims a) to analyze the sources of dryland farming risk, b) to analyze the probability and impact of production risk in dryland farming, and c) to analyze alternative production risk strategies on dryland rice farming.

2 Research Methodology

The This research was conducted in Semanding district, Tuban Regency, East Java. The villages that are used as sample villages in the Semanding district are the villages that have the highest production, namely Genaharjo village, Sambongrejo village, Ngino village, and Penambangan village. The selection of sample villages was based on a) having the area with the largest rice income, b) having the largest dryland area, c) mostly highlands, and d) geographical conditions being dominated by limestone mountain structures which caused very minimal water reserves in the soil and the absence of an irrigation system during the dry season.

The population is a generalization area consisting of objects and subjects that have certain qualities and characteristics set by researchers to be studied and then drawn conclusions [7]. The population in this study were rice farmers who were members of the Tani Makmur, Sambong Makmur, Wilis, and Sumber Makmur farmer groups with 68 members. The total number of samples was calculated based on the Slovin formula. Calculation of the sample using the Slovin sampling method of 40 farmers.

The method of data analysis of sources of risk of rice farming production uses descriptive analysis. This analysis is used to analyze the sources that cause production risk to see the effectiveness of the risk management that has been applied. [8], risk can be associated with the possibility of unwanted or unexpected bad results/losses. Likelihood indicates the existence of uncertainty which is a condition that causes the risk to grow. According to [9] Risk is defined as the potential for an event, both predictable and unpredictable, to have an impact on the achievement of objectives.

[10] states that risk measurement consists of measuring the possibility of the impact of the consequences caused and knowing the status and risk map. An event is identified if it has a chance of occurrence or level of probability and causes a loss. The method used to measure this level of mobility is the standard Z-score method. The Z-score method is a method that uses a number (Z-score) which indicates how far a value deviates from its average in a normal distribution. Z-score can be known as the magnitude of the possibility of a size or a different value greater or less than the average. According to [10], the steps taken to calculate the probability of risk occurrence are as follows:

Calculate the Average Risk Event with the Formula

$$\overline{x} = \frac{\sum_{i=1}^{n} Xi}{n}$$

$$\overline{x} = \frac{\sum_{i=1}^{n} Zi - Yi}{n}$$

Information:
$\overline{x}$ = average value of risky events.
Xi = risk event data.
n = number of respondents.
Zi = potential productivity data.
Yi = actual productivity data.

The average referred to in this formula is the average occurrence of risks that are considered detrimental to farmers. This data is obtained from the difference between actual productivity and potential productivity (farmers).

Calculating the Value of the Standard Deviation of the Risk Event

$$S = \sqrt{\frac{\sum_{i=1}^{n} xi - \overline{x}^2}{n - 1}}$$

Information:
$\overline{x}$ = average value of risky events.
Xi = risk event data.
n = number of respondents.
S = standard deviation of the risk event.

Calculating Z-Score

$$Z = \frac{X - \overline{X}}{S}$$

Information:
$\overline{x}$ = average value of risky events.
X = risk limit which is considered to be within the normal level.
S = standard deviation of the risk event.
Z = Z-score value of the risk source.

If the score obtained is negative, then the value is to the left of the average value on the normal distribution curve, and vice versa if the Z score is positive, then the value is to the right of the normal Z distribution curve.

The Probability Value of the Occurrence of Production Risk
The Z-score value obtained is then searched for the possibility or probability of the occurrence of production risk obtained from the Z distribution table (normal) so that it is known the percent possibility of a situation where production causes losses.

Risk Impact Analysis
According to [11] the measurement of risk consists of determining the national amount, sensitivity, volatility, and bottom deviation. Bottom deviation has two meanings, namely a negative impact of not achieving the expected return and a Value at Risk (VaR) which measures the maximum loss that can occur with a certain level of confidence. The most effective method used in measuring the impact of risk is Value at Risk (VaR). VaR is the largest loss that may occur in a certain time range which is predicted with a certain level of confidence.

The data needed in this processing is the receipt or sale of the harvest. Events that are considered detrimental in the form of a decrease in production as a result of the occurrence of sources of risk. VaR method can be calculated by the following formula [10].

$$VaR = \overline{X} + z\frac{S}{\sqrt{n}}$$

Information:
VaR = Impact of losses caused by sources of risk.
$\bar{x}$ = Average value of the following events.
Z = z value taken from the normal distribution table.
S = Standard deviation of risk event.
N = Number of respondents.

3 Result and Discussion

3.1 Identify Sources of Risk

Plant-Disturbing Organisms
Rice farming is inseparable from the attack of plant-disturbing organisms which vary according to regional conditions. Plant-disturbing organisms are animals or plants both micro and macro in size that interfere, inhibit, and even kill cultivated plants. [12] explained that some of the risks from fluctuations in agricultural production can be caused by uncontrolled events, such as rainfall, weather, and pest and disease attacks. Plant-disturbing organisms of rice in Semanding district consist of brown planthoppers, stem borers, urets, bugs, rats, and birds. Types of diseases that attack rice plants are leaf blight, or blast, and spot (Table 1).

Table 1 shows the highest disease attack was blast and leaf blight, the highest pest attack was leafhopper, and the highest pest and disease attack was leafhopper and leaf spot. The results of this study are in line with [13, 14] which showed various types of pests, diseases and weeds were pests of rats, brown Planthoppers, and stem borers, as well as bacterial leaf blight, tungro, and blast disease. The impacts felt by farmers due to climate change are a decrease in crop yields, an increase in pest attacks, an increased risk of crop failure, and a decrease in farmers' income [15]. [16] showed that ratoon rice cultivation can be utilized to anticipate the impacts of climate change such as increasingly limited water availability, namely by modifying ratoon rice cultivation technology, optimizing the performance of agricultural extension workers and farmer groups, and establishing ratoon rice cultivation areas.

Weather Factor
Natural conditions such as weather and climate are part of the risks that must be faced by farmers. The weather factor is one of the external factors in rice farming. Weather changes are increasingly difficult to predict because the weather cycle is not under its normal cycle. Temperature changes cause a decrease in yield quality and an increase in pest and disease attacks. Meanwhile, the sea-level surface causes a decrease in the rice field area and a decrease in productivity [17]. Strong winds usually only affect certain growing seasons, namely from January to April. Weather attacks can be seen in Table 2.

Table 1. Losses due to Diseases and Pests

No.	Causative factor	Number of respondents (person)	Harvest Impact (%)
1.	**Disease Attack**		
a.	Blast and leaf spot	2	60,50
b.	Blast	2	66.00
c.	Blast and leaf blight	1	64.00
d.	Leaf blight	1	59,00
2.	**Pest Attack**		
a.	Planthoppers	6	65.83
b.	Planthoppers and bugs	2	65,50
c.	Planthoppers and mice	2	58.00
d.	Planthoppers and uret	1	50.00
e.	Planthoppers and stem borers	2	60,50
f.	Rats	1	57,00
g.	Stem borers	1	64.00
3.	**Pest and Disease Attack**		
a.	Leafhoppers and Blast	4	58.75
b.	Leafhoppers and leaf spots	1	61.00
c.	Leafhoppers and leaf blight	2	50.00
d.	Stem and blast borers	1	50.00
e.	Uret, bugs, and blast	1	57,00
f.	Bugs and blast	1	50.00

Source: Primary data processed (2022)

Table 2. Losses Due to Weather Factors

No.	Causative factor	Number of respondents	Harvest Impact (%)
1.	Drought	4	41.75
2.	Strong winds	5	44.40

Source: Primary data processed (2022)

Table 2 shows the biggest losses due to weather factors are drought and strong winds. Semanding District is an area with dryland and rainfed rice fields. Rainfed rice field irrigation systems rely on rainwater as the main source for irrigating their land. Low rainfall will affect the rice crop and make the plants lack water which is planted in an average of one planting, namely December to April. Strong winds usually only affect certain growing seasons, namely from January to April. [18] stated that the risks faced by farmers were caused by pests and floods. The probability of risk due to pest

Table 3. Risk Probability Analysis

No.	Description	Mark
1.	Average	40.65%
2.	Standard Deviation	7.31
3.	X	40%
4.	Z	-0.09
5.	Values in Table Z	0.464
6.	Risk Probability	46.40%

Source: Primary data processed (2022)

attack and climate is 18.41% and 0.60%, respectively. Indonesia has a high-risk level of decreasing rice production with an average of 1.37% per year and has the potential to cause a decrease in national food production [19]. [20] also explained that the level of dryness of rice fields varied temporally and spatially from very vulnerable to safe. The dry and drought-prone level of rice peaks in September and October with the widest area coverage.

Labor

The availability of skilled labor greatly affects the success of a production. The availability of sufficient farmers and farm laborers in farming and post-harvest activities will run better so that the risk of failure can be avoided. The labor required to plant rice ranges from 10 to 30 people according to the land owned, and 10 to 15 people for harvesting and processing the land usually, two people are in charge of slowing down. [21] stated that labor shortages are very visible in the harvest season, almost all of the labor for harvesting is labor from outside.

3.2 Analysis of Risk Probability and Impact

Probability analysis is carried out to determine the magnitude of the possibility of the occurrence of existing production risks. The probability value of the risk value of rice production that can be measured is data on the productivity of rice farmers caused by loss of production. The data taken is the difference from normal productivity when there is no risk of production or potential productivity with productivity obtained by farmers or actual productivity. Risk probability analysis can be seen in Table 3.

Table 3 shows the average risk of rice production in the Semanding district of 40.65% from a normal harvest with a probability level of rice production risk of 46.40%. The level of risk probability is determined by the normal production value of the farmer, or at harvest time, the farmer does not experience a loss even though the harvest does not reach the normal yield of 40%. According to farmers, the yield of 40% of the normal per season is not detrimental, although it is certain that there is almost no profit from rice cultivation due to costs during cultivation activities such as the cost of maintaining drugs and fertilizers.

Table 4. Risk Impact Analysis

No.	Description	Mark
1.	Average	IDR 10 814 750
2.	Standard Deviation	IDR 2 055 244
3.	Z	1,645
4.	VaR	IDR 11 349 699

Source: Primary data processed (2022)

Table 5. Risk Probability Analysis Based on Causative Factors and Risk Sources

No.	Description	Factors Causing Source of Risk			
		Pest	Disease	Pests and Diseases	Weather Factor
1.	Average (%)	37.73	37.33	44.70	43.22
2.	Standard Deviation (%)	7.68	7.97	5.08	6.08
3.	X	40	40	40	40
4.	Z	0.29	0.33	-0.93	-0.53
5.	Values in Table Z	0.385	0.333	0.178	0.298
6.	Probability Risk (%)	61.40	62.90	17.80	29.80

Source: Primary data processed (2022)

The opportunity for the rice production risk is 0.464 with a z value of 0.09 which has a negative sign, where the number 46.4% indicates the possibility of a production risk that causes rice farmers to lose production or suffer losses caused by sources of pests and diseases and weather factors by 46.4%.

Losses experienced by farmers will be measured based on the selling price of each farmer to middlemen of IDR 3,500 to IDR 4,000 per kilo of wet grain. The magnitude of the adverse impact on not achieving the production target can be determined using the Value at Risk (VaR) method. Calculation of value risk impact analysis is in Table 4.

Table 4. Shows the average level of losses due to risk sources reaching IDR 10,814,750 per hectare per harvest. Analysis of the impact of production risk is determined with an error rate of 5%, the Z value is 1,645, and the Value at risk is IDR 11,349,699 per hectare per harvest. This is in line with [18] which states that the impact of rice production risk is determined by a 95% confidence level and the remaining 5% error is obtained the Z value is 1.645.

The calculation of the probability and impact of this risk is a calculation with the assumption of multiple perils, namely the probability and impact of the risk of crop failure is calculated based on the total loss with all possible causes of risk such as pest attacks and weather factors. Based on the source of risk coverage, the probability of production risk can be seen in Table 5.

Table 6. Impact of Production Risk Based on Causative Factors and Risk Sources

No.	Description	Total Loss (IDR)			
		Pest	Disease	Pests and Diseases	Weather Factor
1.	Average	10,028,666	10,170,000	11.750.000	11,515,555
2.	Standard Deviation	2,115,094	2,412,757	1,428,091	1,927,246
3.	Z	1,645	1,645	1,645	1,645
4.	Value at Risk	10,927,717	11,789.993	12,493,420	12,572,328

Source: Primary data processed (2022)

Table 5 shows the probability of the highest production risk occurring in each growing season of 62.9% caused by disease. The lowest risk productivity is 17.8% due to a combination of pest and disease attacks. The intensity of disease attacks has the highest probability of occurring in the rainy season, due to high rainfall and humid air conditions.

The impact of losses caused by sources of production risk can be calculated and assessed in IDR so that losses can be estimated. The value of the estimated loss is not always the same as the previous condition, if the production risk occurs then a determination of the amount of loss is carried out with a level of confidence. Losses due to risk sources can be seen in Table 6.

Table 6 shows that weather factors have the highest impact on losses because natural factors (weather) are factors that are difficult to predict and overcome. Production risks caused by weather factors such as drought and strong winds are difficult to overcome, in contrast to production risks caused by pests and diseases, they can still be handled by spraying pesticides. The impact of losses caused by weather factors is greater than the source of risk caused by pests and diseases. This is different from the research by [18] which states that the biggest risk impact from the source of production risk due to pest attacks is IDR 3,764,495 while the impact of climate change is IDR 1,256,036.

Production Risk Mapping

Production risk mapping as a risk measuring tool, which includes risk status and risk maps. Risk status is a measure that shows the level of risk from various sources of production risk that have been previously identified. The value of the risk status is obtained by multiplying the probability with the impact of each source of production risk. The risk status of production risk sources can be seen in Table 7.

Table 7 shows that the source of the highest production risk is diseases, followed by pests and weather factors. Diseases attacks have the highest loss impact of IDR 11,789.993 with the highest probability of 62.9%. The source of the risk of disease is the most crucial source of risk because the majority of farmers cultivate in dryland in the rainy season.

Farming in the rainy season causes the intensity of disease and pest attacks to be higher than in the dry season. This is because high rainfall and humidity make pests and diseases easy to breed and the intensity of their attacks on rice plants is getting higher. In addition, the rainfed irrigation system in this area relies on rainwater as the main source of irrigation.

Table 7. Risk Status from Production Risk Sources

No.	Source of Risk	Probability (%)	Impact (IDR)	Risk Status (IDR)
1.	Pest	61.40	10,927,717	6,709,618.23
2.	Diseases	62.90	11,789.993	7,415,905.59
3.	Pests and Diseases	17.80	12,493,420	2,223,828.76
4.	Weather Factor	29.80	12,572,328	3,746,553.74
	Average	42.98	11,945,864	5,023.976.58

Source: Primary data processed (2022)

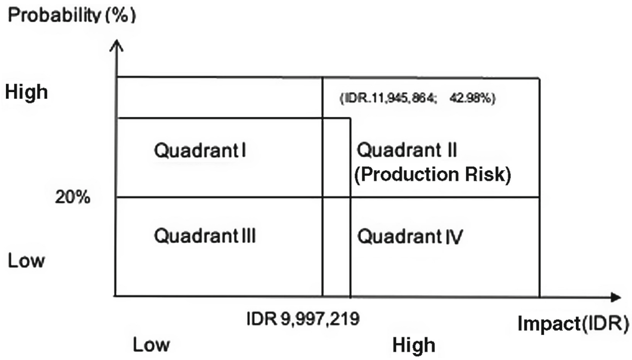

Fig. 1. Rice Production Risk Map in Semanding District

According to [10] the risk map is divided into two parts, namely probability and risk impact. Large and small probability limits for the occurrence of risk are determined by management, but researchers take a probability limit greater than 20 percent is considered high probability. A probability below 20 percent is considered a low probability. The determination of large and small impact limits is determined based on the production risk tolerance limit of the average revenue (IDR 15,855,250) minus the break-even point (IDR 5,858.031) so that the average value of the risk impact limit is IDR 9,997,219. Mapping the risk of rice production can be seen in Fig. 1.

Figure 1 shows a risk map of rice production which describes the adverse events with the high impact and mobility. The average risk probability on the yield of rice production can be seen from the calculation of 42.98% with the impact of the risk of production loss of Rp. 11,945,864. Through this mapping, it can be seen the position of rice production risk caused by pests, diseases, and weather factors. The risk map for rice production is located in Quadrant II, which shows a high probability of production risk and a high risk of loss impact. This result is different from the research by [18] which shows that the risk of rice production in Panca Arga Village, Rawang Panca Arga District is in Quadrant III which means that risk management can be done by transferring the risk to the insurance company.

Production Risk Management Strategy

[10] explains that the processing cycle of a company can be done by identifying the risks faced by the company. The decision use a strategy in dealing with risk by first mapping the sources of risk into a risk map. The risk map is a description of the risk position from two sources, namely the vertical axis which describes the probability, and the horizontal axis which describes the impact. The function of the risk map is to know where the source of the risk is, so it can be seen which source of risk has the greatest probability and impact. The strategies taken to deal with production risk in Semanding District are in Quadrants I and II can be handled with a preventive strategy, while the risks that are in Quadrants II and IV are carried out with a mitigation strategy.

Preventive Strategy

Several preventive strategies that can control pest attacks include intercropping planting of beans and corn. Manual cleaning of weeds every day and planting rice simultaneously. The preventive strategy in dealing with weather factors is planting according to the rainy season, which is carried out from December to April. Planting rice that is too fast or has not yet entered the rainy season, the possibility of drought is higher, causing crop failure.

Mitigation Strategy

Several mitigation strategies that can control pest attacks include the use of drugs, such as spraying pesticides and fungicides. A mitigation strategy in dealing with weather factors is to carry out agricultural insurance. Insurance has a goal so that assets owned by a large risk impact can be avoided from loss, if at one time something unwanted happens then the loss can be borne by the insurer under the agreed contract agreement.

4 Conclusion

Sources of risk that cause risk are plant-disturbing organisms and weather factors. Plant-disturbing organisms consist of brown planthopper, stem borer, bugs, rats, and birds as well as leaf blight, and fungus/leaf spot. The probability of an outcome risk using the Z-score in Semanding district is 46.4%. The biggest loss impact is caused by production risk using the Value at risk method of IDR. 11,349,699. Based on the production risk map caused by sources of pests and diseases and weather factors is located in quadrant II, which can be handled using preventive and mitigation strategies.

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