Climate Change and Rice Production: A Study in Central Java

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Abstract. Rice is a staple food of the Indonesian people, especially people in the regency or city of Central Java. Food needs such as rice are the primary basic needs of the community that must be met compared to other needs. The decline in harvest and rice production impacts the emergence of food shortages, especially rice. This study aims to determine the effect of harvest area, agricultural sector labor, regional minimum wage, and rainfall on district or city rice production in the province of Central Java from 2017 to 2021. The regression analysis method used is the regression analysis of panel data in 35 regencies or cities of Central Java Province for a five-year research period starting from 2017 to 2021. The results showed that the area of harvest positively affected rice production. The work of farmers has a positive effect on rice production. Rainfall has a negative and insignificant effect on rice production. Export has a positive effect on rice production. Export has a positive effect on rice production.

Keywords: Rice production · labor · harvest area · rainfall · Export

1 Introduction

The farming sector in Indonesia is one of the essential things in Indonesia's economic development. Many Indonesians generally make a living as farmers. So that this is what makes the agricultural sector have an important role, namely a means used as a provider of food for all Indonesian people, as raw materials for industry, a provider of opportunities to do business, and also one of the sources of livelihood for farmers. An agricultural commodity that many people in Indonesia need is the rice plant. This is because rice is one of the staples used for rice, as it is known if the Indonesian people consume rice as a food ingredient. Rice is one of the essential commodities to maintain food security, so the rice farming business is one part of people's lives. Indonesia can undoubtedly help create large jobs, and with the contribution of rice, a business can make household income very large [1].

Central Java is an area for developing various food crops, one of which is the rice commodity cultivated by farmers in Central Java. According to [2] farming business, the primary inputs are the workers. In agriculture, labor is classified into several types: human labor, labor sourced from livestock, and mechanical or machine labor.

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The development of agriculture in the province of Central Java has a vital role. Namely, until now, Central Java is still a province with food at the national level, so rice productivity must be more racing to produce better products every year [3]. Based on data from the Center for Statistics in the last five years (2017–2021), the labor force of the agricultural sector in Central Java continues to increase every year. In 2017 people who worked in the agricultural sector by as much as 92.27%, decreased in 2018 by as much as 91.64%. However, in 2019–2021 the workforce increased by 93.76%.

The increase in the workforce is hoped to help increase rice production. So that the agricultural sector can later be used as a superior sector in meeting the food needs of the Indonesian people, which are constantly increasing. Rice production over the past four years has fluctuated but tends to increase.

In 2017, the rice harvest area in Central Java Province is 8674678.00 ha, with a total rice production of 7865437.00 tons. In this case, it can be said that from 2017–2021 the lowest rice production was in 2017. In 20 18, rice production in Central Java increased by 55507.96 tons from the initial 7865437.00 in 2017, 8499588.00 in 2018 to 9655654.00 tons in 2019. This makes Central Java hold the title of the highest rice production per province in Indonesia in 2019. However, in 2020 it experienced a decrease of 9489165.00 tons and again experienced an increase in 2021 of 9618657.00. The agricultural sector labor did not influence the low rice production in Central Java because in 2020, towards 2021, the agricultural sector workforce increased while rice production decreased. Another factor is the problem of micro-water management (irrigation) and using superior varieties that are still few in Central Java.

According to [4] expressing, farmers and agricultural industry organizations often emphasize the importance of the agricultural sector in the economy of South Africa. The agricultural sector has supported less than 3% of the economy since 2005. The results showed that the agricultural sector has been unable to meet the demand for the leading food consumed domestically since 2000. However, this did not result in a rapid increase in foodstuffs and general inflation. Secondly, Agricultural exports play a minor role in growth, but rather a balancing role in economic development. Third, the agricultural sector has released labor throughout the economy since 1962, thus fulfilling the economic development literature. Fourth, the agricultural sector has been making net capital transfers throughout the economy since the mid-2000s. Finally, the agricultural sector has the most vital linkages representing about 7% of the economy in 2010.

From the existing background, Central Java Province has various potentials and problems related to food security, especially rice production, where the level of rice production fluctuates yearly, as it is known that food needs continue to increase yearly. This is due to several factors, one of which is the increase in labor in the agricultural sector, which will cause an increase in the amount of rice production in Central Java. The influence of inputs (area of harvest, labor, rainfall, and exports) can affect the level of rice production in Central Java. This study aims to determine the influence of variables in harvest, labor, rainfall, and exports on Central Java regency/city rice production during 2017–2021.

2 Literature Review

2.1 Production Theory

According to [5] there is a relationship between the production factors used to produce and the production process results. [6] stated that production theory describes the attachment between production factors and the production level produced. The agriculture production factor is known as the input, while the factor, the amount of production, is known as the output.

In farming activities, production factors are needed to be divided into three components, namely (1) land, (2) capital, and (3) labor, as has been explained in various literature if each factor of production has a different function that works. If one factor does not perform its function, the other factors will not work.

Soil (land) production factors are divided into several factors, namely water, temperature, air, sunlight, and so on. The existence of factors from the soil can not only be seen in terms of area and narrowness but can be seen from other aspects, such as the type of soil used, various lands used, topography, high low, and so on. Apart from the factor of land production, the agricultural sector, of course, also comes from the capital factor. If the capital used in a business is getting higher, the business is called a solid capital business. Similar to land and capital, in the agricultural sector, labor plays an essential role in agricultural production, as has been explained in economics. If labor work is a form of physical force, just like the brain humans cannot be separated from humans, it is also inseparable labor in a production venture.

2.2 Rice Production

Rice is one of the sources of food for the people of Indonesia, where rice is generally cultivated in rice fields. As is known, if rice is planted on narrow paddy fields, it can decrease the quality of rice growth. The most significant decline can be in the form of fewer saplings, shorter rice length, and reduced grain production from the rice when compared with rice planted on wide-spaced land [7].

The efficiency and production of rice farming can be influenced by several factors, such as the area of land used to grow pads, seeds used, fertilizers, and workforce. Work. So that the high or low rice production produced by rice farmers is greatly influenced by the following facts, such as technology, handling carried out pre and post-harvest, human resources, land used, and types of fertilizers used to fertilize rice, and so on [8].

Research from [9] using survey research methods involving farmers (farmer groups) as members of the Village Community Food Barn (LPMD). The rapid rural appraisal technique is selected as quantitative and qualitative analysis—a preliminary survey in the Baturetno and Wonogiri regions in 2010. The results showed that the active role of stakeholders (A-B-G-C) is significant in supporting farmer institutions (food barns). Economic and social aspects have also been essential in increasing the empowerment of farming communities. This model is a social engine for rural communities and local institutions, especially to achieve regional food security.

2.3 Harvest Area

According to [10], the harvested area is the area of the crop that is collected after the plant is old enough. Harvest Area is one factor determining commodity in the agricultural sector. We often see if a large area of land produces more products. Each area usually has its unit, which is used to measure the land area. The units used to calculate land area are divided into several types, namely internationally generally using ha/hectare, while nationally using HA/M^2, in provinces usually used shoulders, chains, or spears to measure land area. While locally usually use goods [11].

In Central Java, the harvest area continues to increase, although the area of paddy fields in the entire Central Java region generally tends to decrease or become narrower. This can be determined because the harvest area is the result of multiplication between the land area and the intensity of the crop. That is, if the paddy field is getting wider, of course, the yield will also increase, so this shows that there is a more dominant crop intensity in the development of the area of harvest [12, 13].

[14, 15] An Ordinary Least Square (OLS) multiple regression analysis conducted found that land area affected rice production in Sangi Village, Palanga District, South Konawé Regency. This results in regression coefficients of 0.466 and empirical sign fictions (ρ) t 0.020 (<0 > 0.10) and 0.682 (>0.10).

2.4 Labor

According to [16], the workforce comprises people who are 15 years of age or older who are employed or temporarily out of work. Meanwhile, someone who has no job or is looking for a job can also be referred to as working. While the labor force working in agriculture is categorized as working alone, generally, the farmers are assisted by workers who have odd jobs, usually coming from family members or can also come from outside family members.

According to [2], labor is part of the most important input in the farming business. In agriculture, labor is divided into several types, namely human labor, labor that comes from livestock, mechanics, and can come from machines as well. Usually, labor is obtained from family members; however, sometimes, it is also obtained from non-families. The labor force is divided according to gender, namely male and female. Then there is also a labor force of children, namely those 14 years old and below.

Based on previous Research, including [17] conducted using the Ordinary Least Squares (OLS) multiple regression analysis methods, between November 2015 and May 2016, land area and labor force significantly influenced rice production and 0.194, each and empirical significance (ρ) t each 0.046 (<0.10) and 0.007 (< 0.10). Meanwhile, education has no influence on rice productivity results with an empirical significance value (ρ) t of 0.692 (> 0.10).

Research [18] by Sragen Regency in 2008, using the ADF (Augmented Dicky-Fuller) test found that labor has a positive influence on production with a coefficient level of 0.371. The use of organic fertilizers (PPK) harms organic rice production with a coefficient level of 0.246. The cost of irrigation (AIR) has a positive influence on rice production with a coefficient level of 0.232. The result that education does not influence rice production is the same as the Research conducted by [19] in 2021. The Research

[20] Sukoharjo Regency in 2008, using descriptive analysis, found that the performance of food production, namely in grain and rice, has increased significantly every year. However, the increase that has occurred has not been able to fully offset the growth of rice consumption which continues to grow beyond the growth of rice. Of course, this can be seen in food availability, and food security in the area is still relatively low. This is due to the inability to provide food for all communities in the research area.

2.5 Rainfall

Rainfall is one of the factors for the risk of crop failure due to increasing flood events and droughts. So in the past few years, the Indonesian people have felt the variability of rainfall whose impact is felt by the Indonesian people [21]. Rainfall is an essential factor in various aspects of life, rain that dates erratically certainly influences the agricultural sector, especially in rice production [22].

Indonesia has a tropical climate, so rainfall in Indonesia is very high, and the impact is very significant. The climatic characteristics of the area can be seen from the variation in the rain in the area. Rain in tropical regions is particularly vulnerable due to land, ocean, and atmosphere interactions [23].

During the period 2000–2019 in West Kalimantan Province [24] the analysis of variability equations for annual rainfall that occurred in Mempawah and Kubu Raya can be categorized as areas with low rainfall. Based on the value of monthly variability, it is shown that there is a range that varies from low to extreme in each location. El Niño can hurt rainfall from June-August through September, October, and November (SON), while La Nina positively impacts the rainfall of June, July, and August. Rainfall, which occurs in December-February and March-May, makes El Niño have an impact on increasing rainfall. Dipole Mode has a positive impact on rainfall reduction. So based on this rainfall, there is a significant relationship between annual rainfall and rice crop productivity. It can be concluded that rainfall generally does not significantly affect rice yields in the study area. According to [25], rainfall and land area influence the production of organic rice yields. This is in line with the results of the regression coefficients of 50,500 and 9,796, respectively.

2.6 Export Activities

According to [26], Export is a process carried out to move goods or trade commodities originating from various countries, usually carried out legally. In the process, exports also require cooperation between the customs of the country that sends (exports) and the country that receives (imports).

The size of exports given by exporters to entrepreneurs or farmers will affect the high or low level of products produced. The production will increase when someone has enough of the wages they get. It is categorized as sufficient wages if the wages they receive are sufficient to be used to meet their daily needs. Of course, if the income is sufficient, it can lead to the results of increasing production [27].

According to [28] results of his Research conducted using the Vector Auto Regression (VAR) analysis method, it was found that the existence of exports, imports, and investment in agriculture influenced GDP growth in agriculture. Based on the impulse

response analysis results, it is shown that the investment response to the shock of GDP growth is greater than the response from the number of imports and imports.

Following the variance decomposition analysis, it shows that the contribution from exports can increase GDP growth can be greater than the contribution of imports and investment. So it can be concluded, according to [25], that the absolute size of exports, imports, and agricultural investment does not influence the growing GDP in the agricultural sector. However, the growth in GDP in the agricultural sector influences the size of exports, imports, and agricultural investment in Indonesia.

3 Methods

The data obtained in this study are secondary or indirect data and come from the literature studies' results. The Central Statistics Agency (BPS) provides the data collected in this survey. When processing data to be more complete, title information can be taken from literature and articles from google scholar. These secondary forms of data are time series and cross-sections. Time series data is data whose collection is carried out based on time. That is done using hours, days, weeks, months to years. Time series data for this study was collected from 2017 to 2021. Then cross-section data was taken from 35 yang districts in Central Java province.

This study uses panel data regression analysis during the 2017–2021 period in 35 districts/cities of Central Java, with the following econometric model:

$$RP_{it} = \beta_0 + \beta_1 HA_{it} + \beta_2 L_{it} + \beta_3 R_{it} + \beta_4 EA_{it} + \varepsilon_{it}$$

Description: RP = Rice Production, HA = Harvest Area, L = Labor, R = Rainfall, EA = Export Activities, β_0 = Constant, $\beta_0 \ldots \beta_4$ = Coefficient, ε_t = Confounding Variable, i = Regency or City i, t = Year t.

4 Analysis

The purpose of the hypothesis test aims to find out the results obtained from the corresponding regression. Then the results of the Panel Data Regression Estimation were carried out using a PLS (pooled ordinary least square) approach, then FEM (fixed effect model), and using REM (random effect model).

4.1 Estimated Model Selection Test

The chow test and the Hausman test are used to serve as better-estimated model selectors than PLS (pooled least square), then FEM (fixed effect model) is carried out if it is going to test the chow. Then a Hausman test will be carried out to select REM (random effect model), so that additional tests must be carried out, namely the LM (Lagrange multiplier) test used in choosing a model with a reasonable estimate, namely using PLS (pooled least square) or can be done by using REM (random effect model).

Table 1. Econometric Model Estimation Results of Panel Data Regression –Cross section.

Variable	Regression Coefficient		
	Pls	Fem	Rem
C	194406.4	1436857	795125.5
Lp	3.661877	3.879385	3.951637
Scene	33420.81	9990.311	21258.05
Ch	−2090.615	−523.0691	−1318.07
Eb	16512.86	25404.82	21477.29
R^2	0.470895	0.790439	0.258144
Adjusted R^2	0.458445	0.731885	0.240688
Statistics F	37.82427	13.499380	14.788730
Prob. Statistics F	0.000000	0.000000	0.000000
Model Selection Test Chow Cross-Section F (34.136) = 6.099320; Prob. F (34.136) = 0.0000 Hausman Cross-Section random χ^2 (4) = 11.957102; Prob. χ^2 = 0.0177			

4.2 Chow Test

The Chow test is used to find PLS or *FEM estimates*. The estimated model $H_{0:}$ for the Chow test is *PLS*, and the estimated model $H_{A:}$ is *FEM*. H_0 is accepted if it is p (*p-value*), probability, or significant with empirical statistics $F \leq \alpha$. H_0 can be rejected if *the p-value*, probability, or empirical statistical significance of $F \leq \alpha$. The results of the Chow test are shown in Table 1.

From Table 1, the *p-value*, probability, or statistical, empirical significance of *F* is 0.000 0 (< 0.01), so H0 is rejected, and the estimated model is *FEM*.

4.3 Hausman Test

The Hausman test is usually performed to allow a choice between *FEM* or *REM* models. Hausmann *Test* H_0: The Estimation Model is a form of *REM* and its $H_{A:}$ Estimation Model i.e. *FEM*. H_0 is acceptable if the p (p-value) value, probability, or statistically significant $\chi^2 < \alpha$. Hausmann test results are shown in Table 2. From Table 2 it is seen that the *p-value*, probability, or statistical significance χ^2 is 0.0177 (< 0.05), so H0 is rejected so that the estimated model is *FEM*. Hausmann test results are shown in Table 2.

4.4 FEM Estimated Model Existence Test

Models exist when all independents simultaneously influence dependent variables. This study uses two independent variables, so the formulation of the test hypothesis is: the entire regression coefficient is zero, so that the variables of harvest area, agricultural sector labor, rainfall, and rice exports do not affect rice production. Meanwhile, which

Table 2. Fixed Effect Model (FEM) Estimation Model

$PP_{it} = 1436857 + 3,8794LP_{it} + 990,311TKP_{it} - 523,0691CH_{it} + 25404,82EB_{it} + \varepsilon_{it}$ (0,0197)** (0,0675)*** (0,6938) (0,0112)**
$R^2 = 0.79044$; DW = 1.62870; F statistic = 13.4994; Prob. F = 0.000 00

Description**:** *Significant at $\alpha = 0.01$; **Significant at $\alpha = 0.05$; ***Significant at $\alpha = 0.10$; The number in parentheses is the probability of the statistical value t.

means that there is at least one regression coefficient that is not worth zero, so together, the variables of harvest area, agricultural sector labor, rainfall, and rice exports affect rice production. Not rejected if the probability of $F > \alpha$; and rejected if the probability of $F \leq \alpha$.

Based on Table 2, it is seen that the probability of a static F in an estimated model is 0.0000, which means less than 0.01, so it was rejected, so together, the variables of harvest area, agricultural sector labor, rainfall, and rice exports affected rice production.

4.5 Interpretation of the Coefficient of Determination (R2)

The coefficient of determination (R^2) is used to know the estimated model. Based on the results of the estimates in Table 2, it is known that the efficiency of determination (R^2) is 0.790439, meaning that 79.04% of the variation in rice production variables can be explained by the variables of harvest area, agricultural sector labor, regional minimum wage, and rainfall. The rest, at 20.96%, is explained by other variables not included in the model.

4.6 Test of the Validity of the Effect of Independent Variables of FEM Estimated Models

The validity test significantly impacts independent variables both individually and partially. The influence validity test uses the t-test. The t-test states that the independent variable to "i" has no significant influence; declaring an independent variable to "i" has a significant influence. Accepted when the statistical t probability value is $> \alpha$; and rejected if the statistical t probability value is $\leq \alpha$. The results of the influence validity test can be seen in Table 3.

Table 3. Independent Variable Influence Validity Test Results.

Variable	t	Sig. t	Conclusion
Lp	2.3596	0,0197	Effect on $\alpha = 0.05$
Kindergarten	1.8428	0,0675	Effect on $\alpha = 0.01$
Ch	−0.3946	0,6938	No effect on $\alpha = 0.10$
Eb	2.5711	0,0112	Effect on $\alpha = 0.05$

5 Discussion

5.1 Effect of Harvest Area on Rice Production

The results of the study showed that harvest area had a positive effect on rice production with a regression coefficient of 3.8794 and empirical signification (ρ) t is 0.0197 ($<$ 0.05) with a linear-linear relationship pattern. If the harvest area increases by 1 ha, rice production decreases by 3.8794 tons. This is because the land is one of the factors of production, which is the factory of agricultural products that have a considerable contribution to food availability so that the area of harvest is greater, the greater the amount of rice production that will be obtained.

This Research is in line with Research conducted by [29] from 2005 to 2013. It has an impact on Riau rice production. A different study by [15] found that the harvest area increased rice production in Aceh from 2021 to 2025.

The study's results differed from the initial hypothesis, which stated that the harvest area would increase rice production. The negative effect of the harvest area on rice production is due to the increasing conversion of productive land functions to non-agricultural use and improving food security in Central Java Province. Land conversion is frequently felt with development dynamics characterized by the transformation of economic and demographic structures. Thus, the availability of productive land used to grow rice is decreasing. On the other hand, the land cultivated per farmer is getting narrower, and the quality of the land is also falling. Overexploitation of land has an impact on declining rice production in Central Java.

5.2 Effect of Agricultural Labor on Rice Production

The results showed that farmer labor positively affects rice production with a regression coefficient of 990.311 and empirical signification (ρ) t of 0.0675 ($>$ 0.05) with a linear-linear relationship pattern. This means that if labor increases by 1 percent, then rice production increases by 990,311 tons. The increase in the number of workers can increase the yield of rice production in Central Java in 2017–2021 because every rice production process requires more workforce, starting from cultivating land, and caring for crops to harvesting production results. This is inconsistent with the original hypothesis that labor does not affect rice production, meaning that if labor goes up or down, it will not affect rice production. This is inconsistent with the initial hypothesis that the influence of rainfall is one of the main factors behind the decline in rice productivity.

These results are the following Research conducted by [30] found that Manpower in Panyarang Village, Chikong District, Tasikmalaya Regency, has no impact on glutinous rice production in 2021 [31]. It was found that labor influenced rice production in Khoya Subdistrict, South Todaro District, in 2017.

5.3 Effect of Rainfall on Rice Production

The results showed that rainfall had a negative and insignificant effect on rice production with empirical signification (ρ) t of 0.6938 ($>$0.10). The coefficient value shows that every ρ millimeter increase results in decreased rice production in Central Java Province

in 2017–2021 by 523.0691 mm if the variable harvest, labor, and export area is considered zero. This means that the higher the rainfall, the lower the rice production. In high rainfall, much-flooded rice will be damaged because it will reduce the supply of oxygen and carbon dioxide. In this case, it will interfere with the process of photosynthesis and respiration and potentially cause the rice to rot, causing rice production in Central Java in 2017–2021 to be low. The results of this study do not match what was found by [32] that rain is currently a factor triggering the productivity of rice crops in Lambo-lemma Village to be up and down.

The results of this study follow the initial hypothesis of the impact caused by rainfall showing that rainfall can reduce rice productivity. So, agriculture is starting to develop rapidly and become more advanced because it uses a modern agricultural system, and the government is also paying attention.

5.4 Effect of Exports on Rice Production

The results showed that Export had a positive effect on production p adi with a regression co-efficiency of 25404.82 and empirical signification (ρ) t of ρ 0.0112 (<0.05). This means that if rice exports increase by 1%, then rice production increases by 25404.82 tons. Exports generate foreign currency and are used to finance imports and the development of economic sectors. Theoretically, increasing exports will also increase the economic growth of rice production, and a decrease in exports will also reduce rice production growth. All other variables are constant. However, the results of this study show that exports do not affect rice production. This is because increasing imports influence the dynamics of Central Java's export growth, in general, compared to the commodity mix and competitiveness.

These results follow Research conducted by [33] which found that the variable of Export positively affected rice production in Indonesia during the period 2000–2019.

6 Conclusion

The results of the research and discussion show that harvested area, agricultural sector labor, and exports have a positive and significant effect on rice production, while rainfall does not affect rice production in districts/cities in Central Java during the 2017–2021 period.

Limited data is one of the obstacles in the observation considering the data used in the form of secondary data. However, this study presents something new from previous research, namely the use of variables related to the agricultural sector through rice production.

To grow agriculture and foster self-reliance, it is necessary to cooperate with the government and the community. The government must be able to increase the existing potential through established programs, especially in the agricultural sector. One strategy to increase rice production is through increasing human resource standards and providing adequate agricultural infrastructure. Communities with their level of expertise must be able to increase rice production by carrying out agricultural innovations.

It is hoped that further research can develop this research model by using additional variables and alternative approaches to model estimation, to produce more diverse results.

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Authors' Contributions. Identify the elements that affect rice production as a measure of food security with the independent variables of labor, land area, rainfall, and exports. Usually, the independent variable city income is not used in previous studies.

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