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The Impact of Climate Change, Economic Growth, and Population Growth on Food Security in Central Java Indonesia

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ABSTRACT

As climate change continues to cause more frequent weather shocks such as droughts and floods and increasingly erratic rainfall, people in developing regions are threatened by crop failures and hunger. In this study, the researchers describe how climate change influences food security in Central Java, seen from the frequency of floods, rainfall, and rainy days. This study also added another variable, i.e., economic growth, reviewed through GRDP and the amount of rice production. Using the Common effect model, the study results revealed that rainy days and population were the variables significantly influencing food security in cities/regencies in Central Java Province. Meanwhile, two other variables, i.e., rainfall and GRDP, had no significant effect on food security in cities/regencies in Central Java Province.

INTRODUCTION

In its latest report on food insecurity, the Global Hunger Index indicates that in 2019, 8.4% of the world's population was undernourished; in 2020, we reached 9.9% (Grebmer et al. 2021). About a third of the world's population (2.37 billion) lacked year-round access to adequate food in 2020, an increase of 320 million in one year; between 2019 and 2020, this indicator increased as much as in the previous five years combined (FAO 1983). Alt hough it is still too early to attribute these phenomena to anthropogenic climate change, significant changes in temperature and precipitation due to the increase in the concentration of greenhouse gases could seriously disrupt agricultural production systems and jeopardize global food security.

The FAO (1983) focused on access to food to define food security as ensuring that people have physical and economic access to the food they need. The increased frequency and number of extreme events such as drought or floods would seriously threaten this stability, whether the effects are felt at the national level or through the global food market. Aiming for food security makes it possible to: improve the health and well-being of citizens and progress toward collective well-being (Clapp et al. 2022 and Ani et al. 2021).

The Indonesian government has made the issue of food security one of its development priorities by including it in the Medium-Term Development Plan (RPJM). However, accomplishing good food security is still challenging for Indonesia. It can be seen from the calculation results of the Global Food Security Index (GFSI), which reported that Indonesia in 2020 had a score of 59.5, down 3.1 points compared to the previous year. The decline in Indonesia's GFSI number caused Indonesia 2020 to be ranked 65th out of 113 countries after being ranked 62 in 2019. Indonesia's position was below Thailand, Vietnam, the Philippines, and Singapore compared to other countries in ASEAN.

Despite impressive economic growth and poverty reduction, Indonesia's food security still faces significant challenges. According to (Rozaki 2021 and Suryanto Kumalasari et al. 2021), Indonesia is one of the countries with food security most vulnerable to climate change in Southeast Asia. It is caused by climate change, which significantly affects the agricultural sector, one of the crucial sectors

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in Indonesia as an agricultural country. Climate change, especially rainfall, can influence the productivity of the agricultural sector. Lobell et al. (2008) argued that climate change would affect systems related to production, storage, access, to food price stability, which will impact the condition of food security.

Another factor that also affects food security is economic growth. The Food and Agriculture Organization (FAO) states that economic growth is needed for sustainable solutions to food security. High economic growth will impact increasing the income and welfare of the poor. This condition will increase people's access to food and reduce their vulnerability to economic pressures. In line with the opinion of Manap & Ismail 2019),efficient economic growth will reduce poverty, hunger, and malnutrition to achieve food security, especially in developing countries such as Indonesia.

In addition, Rozaki (2021) also asserts that food security has three aspects: availability, affordability, and utilization. The aspect of food availability is related to the availability of food commodities to meet the community's food needs. In this case, Indonesia has its indicators to assess the condition of food security nationally and regionally. The indicator is the Food Security Index (IKP) based on three aspects of food security.

On the other side, the need for food will always increase along with the increase in population. This statement is consistent with the opinion of Thomas Malthus (1798) in (Pham et al. 2020) and (Montano & García-López 2020) that population growth will increase exponentially while the growth of food availability will increase arithmetically. The theory can be interpreted that along with the increasing population, the problem of food availability will also be more complex.

Indonesia is one of the countries with the largest population in the world. Based on data from the Central Statistics Agency (2018), the population in Indonesia reached 267 million people. The large population impacts other problems, including the increasing conversion of agricultural land amid growing food needs.

Specifically, Central Java is one of the provinces in Indonesia as a national food buffer. The level of rice production in Central Java itself still fluctuates every year. Based on data from the Central Statistics Agency (2021), rice production in Central Java in 2018 was 10,499,588.23 tons and continued to decline in 2019 and 2020, 9,655,653.98 tons and 9,489,164.62 tons, respectively.

The decline in rice production in Central Java is influenced by the condition of the rice harvest area, which is increasingly threatened due to natural disasters that often occur in Central Java, especially floods because of climate change. From 2018 to 2020, there were 254 flood events in Central Java. Based on data from the flood event recap of the Water Resources and Spatial Planning Public Works Agency (2020), flood events in Central Java throughout 2020 damaged rice fields up to 3,465 ha.

Research by Oskorouchi & Sousa-Poza, 2021) described the impact of climate change on food security in Afghanistan. Using the 2SLS analysis method, they found that the flood disaster significantly impacted food security long-term, related to decreasing calorie consumption and fulfilling community nutrition. Kinda & Badolo (2019)) al so elucidated the impact of climate change in terms of rainfall on food security in developing countries from 1960 to 2016. The Fixed Effect analysis results uncovered that rainfall had caused a decrease in food security in developing countries.

Further, limited literature has examined the impact of climate change on food security. It mainly used the HCVI (Hunger and Climate Vulnerability Index) indicator as a new measure developed to assess an area's food security level by combining related information to climate events (Krishnamurthy et al. 2014, Rosalia et al. 2021, Suryanto et al. 2021) .

Because of the lack of literature related to the topic of the effect of climate change on food security using HCVI as a new measure of food security, this study added an economic growth variable, measured through Gross Regional Domestic Product (GRDP) and the population in Central Java as a national food buffer area, which prone to disasters due to climate change.

MATERIALS AND METHODS

Research Methods

Empirical model: This study aimed to analyze the effect of climate change in terms of rainfall and rainy days, economic growth from GDP, and population on food security in Central Java. Employing the panel data regression analysis method, this study used data from 22 cities/regencies in Central Java from 2018 to 2020. The following equation is utilized in this study:

$$Foodsecurity\_it=\beta 0 + \beta 1\ rain\_fall\_it + \beta 2\ rainy\_days\_it + \beta 3\ loggrdp\_it + \beta 4\ log\_population\_it + e\_it$$

rain_fall is the rainfall variable (log) in city/regency i at period t; rainy_days is the rainy-day variable (log) in city/regency i at period t; lpdrb is the GRDP variable (log) in city/regency i at period t; lpend is a variable of the population (log) in city/regency i at period t

Three estimators were used: ordinary least squares (OLS), fixed effects (FE), and random effects (RE). However, the OLS estimator is biased since it does not consider the heterogeneity of entities (cities/regencies) that simultaneously affect the variables. Therefore, the FE or RE estimators were the ones employed.

Variable Description

Food security: According to the FAO (2012), food security is a condition in which all people at all times, both physically and economically, have access to sufficient, safe, and nutritious food to meet their daily nutritional needs. The food security indicator in this study used the HCVI (Hunger and Climate Vulnerability Index), which is a measure to assess the food security level by combining information related to climate events and relevant measures of sensitivity and adaptive capacity of food security (Krishnamurthy et al. 2014).

Climate change: Based on the IPCC (2014), climate change is defined as human intervention to reduce or increase the absorption of greenhouse gases. This change refers to an identifiable change in climatic conditions, such as using statistical tests with an average change and/or variability of its properties and persisting over a prolonged period. Climate change in this study employed the variables of flood frequency, rainfall, and rainy days.

Rainfall is the height of rainwater influenced by climatic conditions, topography, rotation, and the confluence of air currents that collect in a flat place, do not evaporate, do not seep, and do not flow in millimeters (mm) (Badan Pusat Statistik, 2018 or Central Statistics Agency of Semarang Regency 2018). Meanwhile, rainy days are the number of rainy days with an average intensity above 1, 20, 50, and 100 mm/day in a year. Climate change data in this study were obtained from the publications of the Central Statistics Agency per city/regency in Central Java.

Economic growth: Economic growth in this study used annual Gross Regional Domestic Product (GRDP) data based on constant prices in 2010 to determine how much production increased without calculating the amount of inflation. GRDP also can provide an overview of the ability of a region to create added value in a specific period. GRDP data in this study were obtained from the publications of the Central Statistics Agency per city/regency in Central Java.

Total Population

The population is all people who occupy a specific area within six months or more or all who occupy a particular area for less than six months but intend to settle there (Badan Pusat Statistik 2019). The population data in this study was obtained from the publication of the Central Statistics Agency per city/regency in Central Java.

RESULTS

Based on the test results for selecting the best model, the Hausman, and the Chow tests, it was found that the common effect of the best model to be used in this study, with each prob>chi2 of 0.28 more than 0.05 and prob>F of 0.15 more than 0.05. Thus, this study used the common effect model (CEM).

From the classical assumption test in this study, it was uncovered that the model used was free from multicollinearity problems, with a value of VIF 1.21 < 10, and heteroscedasticity and autocorrelation problems, with prob> chi2 of 0.33 and 0.16 more than 0.05, respectively. Hence, the model in this study was BLUE (Best Linear Unbiased Estimator).

Following are the regression results with the common effect model:

Table 1 presents the estimation of results using the common effect model. We found that two variables had a significant effect on food security in cities/regencies in Central Java Province, with a significance level of 0.005 and 0.003, respectively. The two variables were rainy days and population. Meanwhile, two other variables, i.e., rainfall and GRDP, had no significant effect on food security in cities/regencies in Central Java Province.

The coefficient of the rainy_days variable of 0.19 indicates that the frequency of rainy days significantly positively affected food security in cities/regencies. It means an increase in the number of rainy days pretends to farmers to cultivate their land

But, the impact of rainy days differs from rainfall in Central Province. Although the impact of rainfall is not

Table 1: Common effect model.

rain_fall	-0.12 (0.722)
rainy_days	0.19 (0.005)
log_gdrp	0.064 (0.114)
log_population	-0.1 (0.003)
Cons	-0.24 (0.805)
R-sq	0.52
Prob > F	0.000

Source: processing data

significant on food security, the signs of this variable are negative. The volume of rain may increase the risk of flood. It aligns with research by (Oskorouchi & Sousa-Poza 2021), describing that floods significantly and negatively affected food security in Afghanistan.

It suggests that the flood events that hit cities/regencies in Central Java caused food insecurity. This considerable influence can be caused by floods that often afflict Central Java Province. There were 254 flood events reported in Central Java from 2018 to 2020, in which the flood damaged 3,465 ha of rice fields.

Thobei et al. (2014) stated that climate variability has little effect on crop production. According to the National Disaster Management Authority of Indonesia, the average rainfall in cities/ regencies in Central Java Province was 2378 mm, with an average of 122 rainy days, which is still within the limits of the expected average rainfall ranging from 2000 to 3000 mm per year and the expected average rainy day of 144 per year.

Moreover, the economic growth variable using the GRDP indicator revealed a significant positive effect with a coefficient of 8.53, so an increase in GRDP in the cities/regencies in Central Java Province would lead to an increase in food security. Following research conducted by Manap & Ismail (2019) using the Generalized Method of Moments (GMM) method, it was found that economic growth positively affected food security. This positive effect is because a higher economic growth level will reduce the poverty rate, increase life expectancy, and increase the number of workers.

Higher economic income leads to the other macroeconomic indicators that make up the food security level, thus affecting the increase in food security. To reduce poverty and hunger, it is essential that growth reaches the poor and can meet the increased needs for income to create demand for the assets controlled by these populations. Poor households should be able to use the additional economic assets to improve their diets in quantity and quality.

DISCUSSION

Concerning food and nutritional security, the impacts of climate change will be reductions in food availability following declines in agricultural and animal production, increases in the prices of agricultural products, and malnutrition (Godde et al. 2021). For many Africans, the ability to access sufficient, nutritious, and safe food capable of meeting their dietary needs has been increased by a succession of natural disasters and epidemics (Ahmed 2020).

Many studies have demonstrated that changing climate variability directly affects food security systems. Using semi-structured interviews and special reports from International Non-governmental organizations, Ani et al. (2021) revealed that climate change has negatively affected food security in Nigeria. Moreover, the significant negative effect of floods on food security has been described by (Oskorouchi & Sousa-Poza 2021) in their research related to the impact of climate change, particularly floods, on food security in Afghanistan. Using the 2SLS analysis method, the results showed that the flood disaster significantly impacted food security in the long term, related to decreasing calorie consumption and fulfilling community nutrition. These results are supported by the research results by (Akukwe et al. 2020) with the regression method, revealing that flood disasters had a negative and significant effect on food security in Southeast Nigeria by increasing the number of households vulnerable to food security by 92.8% (Abia et al. n.d; Ani et al. 2021). In Asian continent also showed the impact of climate change harms humanity. Based on the research of Abdelfattah & Abdelfattah (2021) found that climate change has impacted water availability. The scarcity of water would affect crop production and the daily consumption of the population.

Kinda & Badolo (2019) have also elucidated the impact of climate change concerning rainfall on food security in developing countries from 1960 to 2016. The results of the fixed effect analysis method demonstrated that rainfall had caused a decrease in food security in developing countries. In addition, a study by (Gladys 2017) using the Pearson correlation method explained consistent results, where climate change, especially rainfall and rainfall frequency, negatively affected food production, affecting food security conditions in Kitui, Kenya. Besides, some researchers, such as Case et al. (2007) and Nugroho et al. (2022), noted that recurring environmental disasters in parts of Indonesia have worsened food availability.

Economic growth is also one factor that can affect a region's food security condition. The relationship between the level of economic growth and the state of food security demonstrated by Świetlik (2018) showed a significant territorial difference between GDP and food security levels. Research by Manap & Ismail (2019) using the Generalized Method of Moments (GMM) method found that economic growth positively affected food security.

Meanwhile, a study on the effect of rice production on food security was conducted (Martadona & Elhakim 2020) with confirmatory factor analysis techniques and exposed that the amount of agricultural production had a significant positive effect on food security.

The growth of the world population and the rise in living standards are challenges for tomorrow's food security (van Dijk et al. 2021), (Nepal et al. 2021), (Abdelfattah & Abdelfattah 2021). With no land area expansion, population growth will threaten food production in developing countries. Studies have confirmed that population growth affects household food security (Hall et al. 2017). In his study using the VAR approach, Ceesay & Ben Omar Ndiaye (2022) showed that population significantly affects food security in the short run and is insignificant in the long run.

CONCLUSION

Based on the data analysis results using the common effect method in this study, rainy days and population variables have significantly affected food security in cities/regencies in Central Java Province. Meanwhile, two other variables, i.e., rainfall and GRDP, had no significant effect on food security in cities/regencies in Central Java Province.

From the results of statistical testing, we noticed that rainfall harms food security, although it is not significant. The implication for the government to anticipate is to control the variability of climate change. Managing climate change, including rainfall variations, requires several mitigation policies.

The government has implemented several policies to overcome the food security problem. In this case, intervention from the government is needed to reduce the risk of climate change. The government can implement effective climate change mitigation strategies. Investments related to agricultural research should also be increased, accompanied by extending methods to farmers in mitigating climate change risks. Investments in mitigation, i.e., clean energy technologies and land-use changes, particularly the switch to bioenergy production, will prevent or reduce agricultural production losses caused by climate change.

In addition, the government is expected to increase social protection for the community to stabilize economic growth and minimize the impact of the economic crisis on food security. Besides that, the government should still be concerned about managing the population's growth to decrease the demand for food.

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