The impact of climate change and natural disasters on food security in Indonesia: lessons learned on preserving forests sustainability

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Abstract. Food security is one of the main goals in achieving the Sustainable Development Goal’s (SDG’s). Food security, natural disasters, and climate change are thought to be interrelated. Climate change contributes to natural disasters such as floods, landslides, drought, land and forest fires, resulting in reduced food production, increased food prices, and disrupted access to food distribution. Ultimately, the impacts of climate change and natural disasters are one of the main causes of hunger and affect all dimensions of food security. This study aimed to analyze the impact of climate change, natural disasters, and other determinants on food security in Indonesia using the Tobit regression. The data used was from 33 provinces in 2010-2018. Climate change was proxied by rainfall, while natural disasters were proxied by the frequency of natural disasters and facility damage due to disasters. The results showed that food crop production, GRDP per capita, and the average years of schooling had a significant effect on increasing food security. Meanwhile, rainfall and deforestation had a significant effect on reducing food security. On the other hand, although not significant, the frequency and damage to facilities due to natural disasters harms food security. The results of this study confirmed the importance of preserving forest biodiversity as an effort to achieve food security as seen from the negative effects of rainfall and deforestation on food security. In this case, deforestation was one of the contributors to climate change which in turn had an impact on the intensity of natural disasters. To achieve food security for the achievement of the SDGs, policies to reduce deforestation or forest conversion need attention as one of the efforts to mitigate the impacts of climate change and natural disasters.

1. Introduction

Food security is one of the main goals in achieving the Sustainable Development Goals (SDG’s). The SDG’s are a global action plan agreed by world leaders, including Indonesia, intending to end poverty, reduce inequality, and protect the environment. Food security is the second goal in the SDG’s, namely ending hunger, meeting nutritional needs, and achieving food security to encourage and support sustainable agriculture. Based on UU Number 18 of 2012, food security is a condition of fulfilling food for the state to individuals, which is reflected in the availability of sufficient food, both in quantity and quality, safe, diverse, nutritious, evenly distributed and affordable and does not conflict...
with religion, belief, and culture of the community to live a healthy, active, and productive life sustainably. In line with this definition, FAO stated that food security is a condition when everyone at all times, both physically and economically, has access to sufficient, safe, and nutritious food to meet their dietary nutritional needs according to their preferences [1].

The concept of food security can be used to describe the situation of food fulfillment at various levels, namely global, national, regional, household, and individual levels. This shows that the concept of food security is very broad and complex. According to FAO, there are 4 indicators of food security, namely food availability, food access, food utilization, and food stability [1]. Meanwhile, according to [2], food security refers to 3 main pillars, namely food availability, food access, and food utilization. Food security can be achieved if food availability is accompanied by access to adequate food so that food utilization can take place properly. The facts show that many regions in Indonesia have sufficient food availability and even surpluses but are not accompanied by adequate food access. This causes food utilization to be not optimal so that many regions have not been able to achieve food security even though food crops production is surplus.

The dynamics of food security analysis show that food availability and access to food are two important factors that determine household food security [3]. Arianin in 2005 added that although food availability is an important prerequisite for sustainable consumption, in the context of food security it is considered “necessary but not sufficient” because there are still many influential variables to achieve food security at the regional and household levels [4]. Other factors such as natural disasters [5,6] are both temporary and long term. As one of the most disaster prone countries in the world, natural disasters are a major factor in food insecurity in Indonesia [7]. Unpredictable natural disasters such as floods, landslides, volcanic eruptions, forest and land fires, droughts, and earthquakes cause damage to productive agricultural land and disrupt access to food distribution which will affect the availability, access, and use of food.

Natural disasters are closely related to climate change and subsequently affect food security [8,9]. Climate change contributes to natural disasters such as landslides, forest and land fires, floods, and droughts that lead to reduced food crops production, increased food prices, and disrupted access to food distribution [6]. One form of climate change, namely the variability of rainfall can cause crop failure and an increase in plant disturbing organisms (OPT), especially in food crops, which are highly dependent on water availability and seasons. Furthermore, climate change is related to the rate of deforestation. In this case, deforestation is one of the contributors to climate change which in turn has an impact on the intensity of natural disasters. Indonesia is one of the owners of the largest tropical rainforest in the world, so its role is very important in stabilizing the global climate. In addition, the link between deforestation and food security can be seen from the high dependence of the community on the forest, especially the people living in and around the forest to fulfill the need for agricultural land and other sources of livelihood [2,10]. The conversion of forests to plantations and agriculture, illegal logging, and peat conversion will contribute to increased carbon emissions and climate change which in turn increases the intensity of natural disasters, thereby reducing the level of food security.

Various empirical studies to know the determinants of food security have been carried out. [11] in their research in Kwara State, Nigeria found that farm size of the households, gross farm income, total non farm income and household size are significant factors affecting food security. [12] found that the factors that influence food security in Eastern Indonesia are the percentage of poor people, GRDP per capita, female illiteracy rate, and average years of schooling. [13] found that the factors that affect household food security in Indonesia are the sanitation aspect, the use of the main fuel for cooking, the location of the household, age, marital status, education level, and the livelihood of the head of the household. However, research analyzing the relationship between food security and natural disasters, climate change, and deforestation in Indonesia is still relatively limited. Food security, natural disasters, and climate change are thought to be interrelated. The impact of climate change and natural disasters is one of the main causes of hunger and affects all dimensions of food security. Therefore, the purpose of this study is to analyze the impact of climate change, natural disasters, and other determinants of food security in Indonesia. Indonesia was chosen because of its position as one of the
countries most prone to natural disasters in the world. The results of this study are expected to provide additional important information as a consideration in establishing a more comprehensive food security policy.

2. Methods

2.1. Type and data sources

This study used secondary data in the form of panel data, which was a combination of data time series and cross-sectional. The data involved 33 provinces in Indonesia. The data period was annual data from 2010-2018. While, the secondary used in this study came from various institutions, literature studies, and internet searches. The details of the data were presented in Table 1.

| No | Type of Data                                      | Source                                                                 |
|----|--------------------------------------------------|------------------------------------------------------------------------|
| 1  | Percentage of food security population           | Food Security Agency                                                   |
| 2  | Production of food crops                         | Central Bureau of Statistic of Republic of Indonesia                   |
| 3  | GRDP per capita                                  | Central Bureau of Statistic of Republic of Indonesia                   |
| 4  | Average years of schooling                       | Central Bureau of Statistic of Republic of Indonesia                   |
| 5  | Rainfall                                         | NASA Langley Research Centre                                           |
| 6  | Frequency of natural disaster                    | National Disaster Management Authority                                 |
| 7  | Facility damage due to natural disasters         | National Disaster Management Authority                                 |
| 8  | Deforestation                                    | Ministry of Environment and Forestry                                  |
| 9  | Population                                       | Central Bureau of Statistic of Republic of Indonesia                   |

The determinants of food security in this study are proxied from the pillars of food security according to the FAO and Dewan Ketahanan Pangan (DKP) concepts and modified from several previous studies such as [9,12,14,15]. In this study, the variables of natural disasters, climate change, and deforestation are included which are also thought to affect food security. Natural disasters are proxied by the frequency of natural disasters and facility damage due to disasters such as the study of [16–19]. Climate change is proxied through the intensity of rainfall such as the [20] study.

2.2 Data analysis

This study used descriptive analysis and Tobit regression. The purpose of this study was to analyze the factors that affect food security in 33 provinces in Indonesia. The dependent variable was the percentage of food security population in each province with the value in the range 0-1 (in percentage). Therefore, Tobit regression will be used to estimate the factors that affect food security. The Tobit model is a censored regression model with many bound variables clustered around zero so that it often causes heteroscedasticity problems. In estimating variables, the Tobit regression method uses maximum likelihood estimation (MLE), which is maximizing the value likelihood function by finding the regression parameters that give the highest value for the likelihood function [21]. According to [22], the Tobit method assumes that the independent variables are unlimited in value (non-censored) and all variables (independent and independent) are measured correctly so that there is no autocorrelation, no heteroscedasticity, and no perfect multicollinearity. The formulation of the panel data Tobit regression model used in this study is expressed in the following equation:

\[ \text{PTP}_{it} = \beta_0 + \beta_1 \text{LnPROD}_{it} + \beta_2 \text{LnPDRB}_{it} + \beta_3 \text{LnRLS}_{it} + \beta_4 \text{PBH}_{it} + \beta_5 \text{LnCH}_{it} + \beta_6 \text{LnKJDN}_{it} + \beta_7 \text{LnFAS}_{it} + \beta_8 \text{LnDEF}_{it} + \beta_9 \text{LnPOP}_{it} + \epsilon_{it} \]
Where:

| Abbreviation | Description |
|--------------|-------------|
| PTP          | Percentage of food security population in province i in the year t (%) |
| PROD         | Production of food crops in province i in the year t (tons) |
| GRDP         | GRDP per capita in province i in the year t (thousand rupiah) |
| RLS          | Average years of schooling in province i in the year t (years) |
| PBH          | Percentage of illiterate women in province i in the year t (%) |
| CH           | Rainfall intensity in province i in the year t (millimeters) |
| KJDN         | Frequency of natural disasters in province i in the year t (times) |
| FAS          | Facility damage due to disasters in province i in the year t (unit) |
| DEF          | Rate of deforestation in province i in the year t (Ha) |
| POP          | The population in province i in the year t (thousand persons) |
| Ln           | Logarithm natural |
| $\beta_0$    | Intercept |
| $\beta_1 - \beta_9$ | Parameters to be estimated |
| $\epsilon$  | Error term |

3. Result and discussion

Based on calculations by the Food Security Agency, the level of food security of the Indonesian population is divided into food security population, food insecurity population and very food insecurity population. The calculation was based on nutritional adequacy figures (AKG), namely calories and protein. Based on Table 2, it could be seen that the percentage of the food security population tended to increase every year. This was accompanied by a decrease in the percentage of the population that is very food insecurity and food insecurity. However, in 2011-2013 there was an increase in the percentage of the population that is very food insecurity and food insecurity. If we look further, the percentage of the population is very food insecurity and food insecurity is the most in the eastern Indonesia, especially Papua, Maluku, and East Nusa Tenggara. This is inline with [12] and Food Security and Vulnerable Atlas that were published by the Food Security Agency. Therefore, the eastern region of Indonesia needed to be prioritized in efforts to increase food security.

Table 2. Percentage of population based on food security status in Indonesia in 2010-2018.

| Years | Population with very food insecurity (<70% AKG) | Population with food insecurity (<70%-89% AKG) | Population with food security (≥ 90% AKG) |
|-------|---------------------------------|---------------------------------|---------------------------------|
| 2010  | 15.34                          | 31.12                          | 53.53                          |
| 2011  | 17.41                          | 32.48                          | 50.10                          |
| 2012  | 19.42                          | 33.50                          | 47.08                          |
| 2013  | 19.04                          | 33.87                          | 47.09                          |
| 2014  | 16.76                          | 33.36                          | 49.89                          |
| 2015  | 14.71                          | 27.99                          | 57.30                          |
| 2016  | 12.69                          | 27.16                          | 60.15                          |
| 2017  | 9.84                           | 22.12                          | 68.03                          |
| 2018  | 8.23                           | 22.42                          | 69.73                          |

Source: Food Security Agency (2019)

To increase food security, it was necessary to know the determinants or factors that affect food security. Tobit regression was used to analyze the factors that affect food security. The results of the analysis showed that the model built in this study had passed the test Likelihood Ratio with the value Likelihood Ratio greater than the 5% real level or there was at least one independent variable that affected the dependent variable. To determine the significance of each independent variable, it was
done by comparing the probability of each independent variable with a significance level of 1% and 5%. The factors that affect food security in Indonesia were presented in full in Table 3.

Table 3. Factors that affect food security in Indonesia

| Variable | Coeff  | Std. Error | P>|t| |
|----------|--------|------------|-----|
| PROD     | 2.936322 | 0.642999 | 0.0000* |
| GRDP     | 2.727021 | 1.591576 | 0.0866** |
| RLS      | 20.57792  | 7.880834 | 0.0090* |
| PBH      | -0.098401 | 0.135096 | 0.4664 |
| CH       | -5.635497 | 1.095990 | 0.0000* |
| KJDN     | -7.07E-05 | 0.007014 | 0.9920 |
| FAS      | -0.502050 | 0.365426 | 0.1695 |
| DEF      | -0.473603 | 0.180552 | 0.0087* |
| POP      | -0.542806 | 1.221558 | 0.6568 |
| C        | -1.989696 | 24.59848 | 0.95355 |

Note: * Significant at 1% level; ** Significant at 10% level

The factors that affected food security in this study were derived from the three pillars of food security, namely food availability, food accessibility, and food utilization. The food crops production variable as a proxy for food availability had a positive and significant effect on the percentage of food security population at a significant level of 10%. Food production in this study referred to the Central Bureau of Statistics of the Republic of Indonesia (BPS) which included commodities of rice, corn, soybean, cassava, sweet potato, mung bean, and peanut. This result was in line with [23] who found a positive effect of rice, corn, and soybean production on food security. One of the benefits of ensuring food production was the realization of food prices that were following the range of people's purchasing power. Hardono and Kariyasa (2006) in [24] stated that affordable prices will enable people to meet their food needs all the time. These results indicated that food production was quite influential on food availability so that people's needs for food can be met.

The positive effect of food crops production on the percentage of food security population indicated that the availability of food production was one of the factors that can increase food security. Various efforts had been made by the government to increase food production in Indonesia such as the PAJALE program, revitalization of dams and irrigation, opening of food estates, and many other policies. Regarding food commodities, [4] stated that rice was already a staple food in various regions in Indonesia, including areas that previously had non-rice staple food patterns such as corn, sago, and tubers so that in the future food verification policies need serious attention. Food crop production as a pillar of food availability is considered insufficient “necessary but not sufficient” in the context of food security because there are still many other variables that have an effect to achieve food security [4].

GRDP per capita had a positive and significant effect on the percentage of the food security population at a significant level of 1%. These results strengthen the research of [12] who also found a positive influence of per capita GRDP on food security in eastern Indonesia. GRDP per capita was a derivative variable from the pillar of food access. GRDP per capita was an indicator that describes the level of welfare of the population in an area. Increased welfare had an impact on increasing people's purchasing power of an item, including food commodities. On the other hand, with a better level of welfare, the community can meet their food and nutritional needs better as well. The positive influence of GRDP per capita on the percentage of food security population indicates that one of the efforts to increase food security can be done through increasing household income. Increased household income will provide flexibility for the community to choose diverse and nutritious food to meet their needs.

The positive influence of GRDP per capita is supported by data showing that provinces with a fairly high percentage of food security population also have a relatively higher average GRDP per capita than other provinces. Although GRDP per capita is positively related to food security, [25]
found an anomalous relationship of GRDP per capita with the share of food expenditure in several provinces in Indonesia. This information implies that it is not only GRDP per capita that determines food security. As explained earlier related to the pillars of food security, other factors such as food availability, nutritional knowledge and consumption patterns also determine the food security of an area.

The variable average years of schooling had a positive and significant effect on the percentage of the food security population at a significant level of 1%. These results were following the research of [12,13,24]. This variable was derived from the pillar of food utilization. The average years of school or level of education was closely related to the paradigm and insight a person has regarding food and nutrition management. The level of education also affected improving the quality of human resources so that it led to a more decent livelihood and access to food that was more easily affordable both in terms of purchasing power and the ease of infrastructure.

The positive effect of the average years of schooling on the percentage of the food security population indicates that increasing the average years of schooling or education can be one way to improve food security. This is also seen from data showing that provinces with higher average years of school tend to have a greater percentage of food security population than other provinces. [12] added that from the results of econometrics analysis, the variable of average years of school has the highest elasticity. This implies that education is the most important factor in improving food security. Government efforts related to the importance of education such as the Wajib Belajar 9 Tahun, Biaya Operasional Sekolah (BOS), Kartu Indonesia Pintar (KIP) and several other programs should be accompanied by improvements in educational infrastructure, teaching staff, and other supporting facilities.

The variable percentage of illiterate women as a proxy for the pillar of food utilization had a negative correlation but not significant effect on the percentage of food security population. These results were following the research of [12]. Women who can read and write (literate), especially mothers and child caretakers, have an important role in food processing and utilization. Women had an important role in choosing food to meet the nutritional needs of the household and other family members. [26] added that food security cannot be separated from the role of women farmers both in production activities, food crop management and the distribution process of food crops. In addition, the level of education and awareness of women, especially mothers, on food processing can explain the nutritional situation and condition of children in developing countries that can affect food security. The positive effect of the percentage of illiterate women on the percentage of food security population but not significant can be explained by the phenomenon of the increasingly massive use of information and communication technology. Currently, information about food processing and nutrition does not only come from print media but from various sources with very informative audiovisual displays so that even illiterate people can easily catch the information provided.

The population variable had a negative correlation of the percentage of food security population but is not significant. Based on the Malthusian theory, an increase in population that was not accompanied by an increase in food production will cause food insecurity. [9,14,27] also state that an increase in the number of household members has an impact on increasing food insecurity. The government continued to try to suppress the rate of population growth through the Keluarga Berencana (KB) program so that it was hoped that with a relatively smaller population per family, their level of food security could increase. It was also supported by the increasing public awareness to participate in government programs in suppressing the rate of population growth.

The rainfall variable as a proxy for climate change had a negative and significant effect on the percentage of the food security population at a significant level of 1%. These results are following the research of [9] which states that the level and variability of rainfall are important determinants of food insecurity. The Intergovernmental Panel on Climate Change (IPCC) projects that rainfall variability and extreme climates will adversely affect food production and security for some time to come. The adverse effects of extreme climates have a two-fold impact in the tropics compared to other regions,
thereby reducing the economic growth of countries in Africa and Asia Pacific, especially developing countries [28].

The variability of rainfall as a result of climate change can cause flooding, an increase in plant disturbing organisms (OPT), and drought, causing crop failure. [29] added that climate change phenomena such as El Nino Southern Oscillation (ENSO) had a greater influence on food crops because of their relatively short lifespan and the production process depends on water availability and seasonal conditions. Failure to harvest due to climate change causes a reduction in the supply of agricultural products, especially food crops, which can trigger an increase in food prices and inflation. [20] based on simulations in his research added that the combination of increasing temperatures and decreasing rainfall as a result of climate change is projected to cause a rice deficit of 90 million tons by 2050 in Indonesia.

The negative effect of climate change on the percentage of the food security population needs serious attention. [30] stated that climate change was one of the five challenges that must be faced by Indonesia in terms of food supply to achieve food security. Furthermore, [30] explained that extreme climate phenomena and their frequency are increasingly occurring. Some symptoms of climate change such as changes in rainfall patterns and intensity, increases in air temperature, floods, droughts, and the increasing intensity of pest and disease attacks have had an impact on decreasing food crop productivity. Several efforts that can be made to mitigate and adapt to climate change include the development and use of climate adaptive varieties, cropping time and pattern adjustment, improvement of irrigation or drainage systems on agricultural land, development of climate prediction systems, and dissemination of information on climate anomalies as well as the development of agricultural insurance.

Climate change contributes to natural disasters such as droughts, forest, and land fires, floods, and landslides. These natural disasters had an impact on loss of life, damage to productive agricultural land, damage to various public facilities and infrastructure, disruption of community economic activities, decreased community income, and disruption of access to food distribution so it had an impact on food security. Natural disasters which were proxied by the frequency of natural disaster and facility damage due to natural disasters had been shown to have a negative effect on the percentage of food security population, although not significantly. In line with the results of this study, [31] stated that natural disasters are one of the main threats to sustainable agricultural development because agricultural productivity growth was highly dependent on climatic and biophysical conditions. The loss of output and disruption of the agricultural supply chain due to natural disasters had an impact on the competitiveness of the sector. [32] added that natural disasters and climate change were major risks to agricultural production. Disruption of agricultural production due to natural disasters caused a reduction in the supply of agricultural products, especially food crops, thus triggering price increases. The higher intensity of natural disasters also affected the number of facilities and infrastructure that were damaged causing the disruption of food distribution. Concerning natural disasters, an emergency food barn was needed that can store food that is safe for consumption, easy to distribute, easy to consume, and has sufficient nutritional content in every disaster prone area.

Indonesia's position in a disaster prone area with an increasingly frequent occurrence of natural disasters must be a serious concern. Natural disaster phenomena such as floods, landslides, and droughts are closely related to deforestation that frequently happens. In early 2021, parts of Indonesia, such as Kalimantan, experienced floods. The Ministry of Environment and Forestry (MoEF) stated that the very large extreme rainfall cannot be accommodated by the Barito River Basin, which has lost around 62.84% forest cover in the last 29 years. Forests on the island of Kalimantan had undergone a lot of conversion into residential, agricultural, plantation, and mining lands, so that the high rainfall and extreme climates cause the land to be unable to absorb all rainwater due to drastically reduced forest cover. Ultimately, the impact of natural disasters due to climate change and deforestation was one of the main causes of hunger and affects all dimensions of food security. This fact was confirmed by the results of this study which found that deforestation had a negative and significant effect on the percentage of the food security population at a significant level of 1%. These results indicated that the
higher deforestation rates will reduce the percentage of the food security population. In addition to contributing to natural disasters, the link between deforestation rates and food security can be explained by the important role of forests in providing various food needs and livelihoods for people living in and around forests [10]. Furthermore, [10] stated that food security was negatively related to the reduction in forest area so that preserving forest can be one of the contributions to achieving sustainable food security.

Natural disasters, climate change, and deforestation were interrelated and have an impact on food security. Forests had direct benefits in the form of wood and non-timber producers as well as indirect benefits as microclimate regulators, regulators of water management and soil fertility, as well as germ plasm which was very important for human life. In addition, forests also play an important role in climate change, namely as carbon absorbers and carbon emitters. In this case, deforestation and forest degradation that occurred in Indonesia led to the development of significant carbon emissions and further contributed to climate change. Climate change such as the increase in air temperature and changes in rainfall patterns and variability ultimately had an impact on changes in cropping patterns and schedules, increased attacks by plant disturbing organisms (OPT), and the risk of crop failure. This caused a decrease in food supply and an increase in food prices so that it has an impact on food security. Deforestation also affects the food security of the rural poor living in or around forest areas who depend on biodiversity and natural habitats for their livelihoods because forests are the main source of fruits, medicinal plants, and edible plants. In the end, deforestation and climate change contribute to the increasing intensity of natural disasters that occur. Natural disasters due to deforestation and climate change such as floods, forest and land fires, droughts, and landslides cause loss of life, damage to public facilities and infrastructure, damage to productive agricultural land. This caused a decrease in the supply of food crop production and disruption of distribution access so that it has an impact on the availability, access, and use of food.

Efforts to improve food security should also take into account other factors such as climate change, natural disasters, and deforestation. Based on the results of this study, it was confirmed that there was a relationship between these three things on food security. Keeping forests sustainable means playing a role in mitigating the impacts of climate change and natural disasters. This indicated the importance of preserving forests as one of the efforts to achieve sustainable food security. Realizing the important role of forests in efforts to achieve food security, reducing the rate of deforestation and forest degradation needs serious attention.

4. Conclusion

Food security is a very broad and complex concept with three main pillars, namely food availability, food access, and food utilization. However, other factors are also thought to affect food security, such as climate change, natural disasters, and deforestation. Based on the results of this study, the factors that significantly increased the percentage of the food security population were food crop production, GRDP per capita, and the average years of schooling. Meanwhile, the factors that significantly reduced the percentage of the food security population were rainfall as a proxy for climate change and deforestation. Although the effect was not significant, natural disasters that are proxied by frequency and damage to facilities due to natural disasters had a negative effect on the percentage of population food insecurity. The high rate of deforestation contributes to climate change and in turn has an impact on the intensity of natural disasters so that it affects the availability, access, and use of food. The results of the study confirmed the importance of preserving forests to achieve sustainable food security.

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