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# THE PRODUCTION OF FOOD COMMODITIES IN INDONESIA: CLIMATE CHANGE AND OTHER DETERMINANTS

## *Produksi Komoditas Pangan di Indonesia: Perubahan Iklim dan Faktor Terkait Lainnya*

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### *ABSTRACT*

*One of the global problems that has a huge impact on the socio-economic conditions of the country, particulary on food security, is climate change. The El Nino Southern Oscillation (ENSO) is a climatic change phenomenon in Indonesia that has three phases: El Nino, La Nina, and Normal. Phenomenon has an impact on rainfall intensity, which bring another impact on the agricultural sector, food crops. This study examines the impact of climate change and other determinants on the production food commodities such as rice, corn, and soybean using the static panel data method. The cross section data focuses on the provinces on the island of Java which became the production center for rice, corn, and soybean, as well as four other provinces with the highest production for the three commodities mentioned. Time series data is used from 2009 to 2017. The results show that El Nino has a significant effect on decreasing rice and corn production and increasing soybean production. La Nina has a significant effect on increasing the production of the three commodities studied. Fertilizer subsidy has a significant effect on increasing the production of the three commodities studied meanwhile productivity significantly impact rice and corn productions.*

***Keyword: climate change, fertilizer subsidy, food crop production, panel data***

### *ABSTRAK*

Salah satu permasalahan global yang berdampak luas terhadap kondisi sosial ekonomi suatu negara khususnya ketahanan pangan adalah perubahan iklim. El Nino Southern Oscillation (ENSO) merupakan fenomena perubahan iklim yang terdiri dari tiga fase yaitu fase El Nino, La Nina, dan Normal. Fenomena tersebut berdampak pada intensitas hujan yang dapat memengaruhi sektor pertanian, khususnya subsektor tanaman pangan. Studi ini menggunakan metode panel statis untuk meneliti dampak dari perubahan iklim terhadap produksi komoditas pangan yaitu padi, jagung, dan kedelai yang berfokuskan pada Provinsi di pulau Jawa yang merupakan sentra produksi padi, jagung, dan kedelai dan empat provinsi lain yang memiliki produksi terbesar untuk masing-masing komoditas dari tahun 2009 sampai 2017. Hasil studi memperlihatkan bahwa ada pengaruh signifikan dari El Nino terhadap penurunan produksi padi dan jagung dan peningkatan pada produksi kedelai. Sedangkan La Nina berpengaruh signifikan terhadap peningkatan produksi ketiga komoditas yang diteliti. Faktor lain yaitu subsidi pupuk berpengaruh signifikan terhadap peningkatan produksi ketiga komoditas tersebut sedangkan produktivitas berpengaruh signifikan terhadap peningkatan produksi padi dan jagung.

***Kata Kunci: perubahan iklim, produksi tanaman pangan, subsidi pupuk, panel data***

## INTRODUCTION

Food security is the condition of the fulfillment of food for the state to individuals, which is reflected in the availability of sufficient food, both in quantity and quality, safe, diverse, nutritious, equitable and affordable and must not contradict with the community's faith, beliefs, or culture, in order to remain healthy, active, and productive in the long run (UU 2012). Increased production is one of the government's initiatives to promote food security, however these efforts are hampered by climate change. Climate change, according to GSC-WEF (2017), is the most significant problem facing the world now.

Climate change have critically important consequences for crop yields and markets, land use, and food security (Thompson et al., 2018). According to an FAO (2005), climatic variability and change influence 11.0 percent of agricultural land in developing countries, reducing food production and lowering GDP by up to 16.0 percent. One of the effects of climate change is the occurrence of El Nino and La Nina climatic anomalies. These two events are often followed by a drop in rainfall and an increase in rainfall above average. This climate anomaly is unfavorable for agricultural output since El Nino's precipitation decreases dramatically, causing crop failure due to dryness, while La Nina's precipitation increases, causing flooding and increasing disturbance of plant-disturbing organisms (Irawan, 2006).

Indonesia is one of the regions most affected by climate change in the world because of its lengthy coastline, high population density, high economic activity in coastal areas and its high reliance on agriculture, fishing, forestry and other natural resources. As a result, Indonesia faces many climate-related disasters such as floods, droughts, storms, landslides and forest fires (Syaukat, 2011). Agriculture, in addition to the industrial and trade sectors, is a major contributor to economic growth. Agriculture, particularly the food crops sub-sector, is highly dependent on the environment, which can alter productivity due to variations in temperature and water availability.

The primary food crops of Indonesia are rice, corn, and soybean. Rice, as a rice-producing crop, is a vital commodity for Indonesia, since it is not only a source of basic food but also a major source of income for millions of farmers (Suwarno, 2010). Corn is utilized as animal feed in addition to being consumed by humans. Soybean is an essential food component in Indonesia since it is used to make tempe and soy sauce.

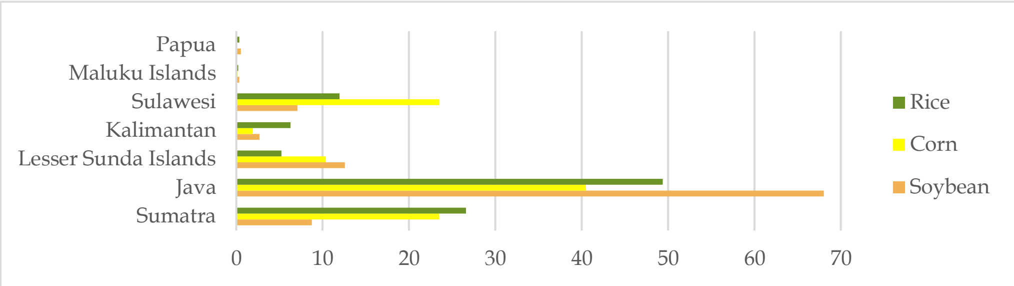


Figure 1.
Rice, Corn, and Soybean Production by Archipelago Year 2017

Figure 1 shows the percentage of rice, corn, and soybean production in each archipelago to the total production in Indonesia. Indonesia's rice, corn, and soybean production are mostly based on Java Island. East Java province is the province with the largest contribution to the production of rice, corn and soybean, accounting for 16.09%, 21.90% and 37.29% of Indonesia's total production respectively, followed by West Java rice production and Central Java for corn and soybean. This makes Java Island one of the centers of food crop production.

The Government, through Indonesia Climate Change Sectoral Roadmap (ICCSR), has created a roadmap that includes agricultural development directions and general policies for addressing climate change through adaptation and mitigation programs. Adaptation efforts are carried out through improved water management, including irrigation systems and networks, and the development of soil and plant management techniques to improve plant adaptability. Meanwhile, mitigation efforts are being made through the use of fertilizers and technology. In addition, Rencana Aksi Nasional Perubahan Iklim (RANPI) outlines climate change-related adaptation and mitigation policies, such as the construction of irrigation dams and changes in the use and use of fertilizers.

Climate change has an impact on agricultural output that affects food security in Indonesia, where the role of fertilizer subsidies, the size of irrigated paddy fields, and productivity are crucial impacts on rice, corn, and soybean production. Based on this, the aims of this study are split into two parts: (1) describe the phenomena of climate change and the development of other factors on rice, corn, and soybean production, and (2) analyze the impact of climate change and other factors on rice, corn, and soybean production.

## RESEARCH METHOD

The data used in this study is panel data, which is a combination of time series and cross-sectional data. The time series data used is annual data from 2009 to 2017. This study's cross-section data covers the provinces of Java Island and four additional provinces with the highest output for each commodity, with the provinces chosen based on the percentage contribution of island production to overall production in Indonesia. The data for this study comes from several sources, including NOAA (National Oceanic and Atmospheric Administration) and the Ministry of Agriculture.

Descriptive and quantitative analysis methods are used to answer the objectives of this study. Descriptive analysis method was used to present the data in the form of graphs and tables and to add citations from previous studies. The quantitative analysis method of this study uses an econometric approach, specifically the panel data method.

This study model includes three econometric models of panel data. Each model will demonstrate the impact of climate, fertilizer subsidies, irrigated paddy fields growth and productivity on the production of each commodity. The model refers to the study of Huang et al. (2006), Huang & Khanna (2012), Afzal et al. (2017), AlAmin et al. (2017), Suhartini (2018) and Xu (2019). Mathematically, the model used in this study is as follows:

$$lnprodP_{it} = \alpha + \beta_1 lnprdvP_{it} + \beta_2 lnppk_{it} + \beta_3 Girg_{it} + \beta_4 Dnino_{it} + \beta_5 Dnina_{it} + e_{it} \quad (1)$$

$$lnprodJ_{it} = \alpha + \beta_1 lnprdvJ_{it} + \beta_2 lnppk_{it} + \beta_3 Girg_{it} + \beta_4 Dnino_{it} + \beta_5 Dnina_{it} + e_{it} \quad (2)$$

$$lnprodK_{it} = \alpha + \beta_1 lnprdvK_{it} + \beta_2 lnppk_{it} + \beta_3 Girg_{it} + \beta_3 Dnino_{it} + \beta_4 Dnina_{it} + e_{it} \quad (3)$$

The first model of the variables $lnprodP_{it}$ and $lnprdvP_{it}$ is rice production and productivity. The second model of the variables $lnprodJ_{it}$ and $lnprdvJ_{it}$ is corn production and productivity. In the third model, the variables $lnprodK_{it}$ and $lnprdvK_{it}$ is soybean production and productivity. The variables Inppkit, Girgit, Dninoit and Dninait respectively are the distribution of fertilizer subsidies, the growth of irrigated paddy fields, El Nino dummy where D=1 is a

El Nino condition and D=0 is a normal condition and La Nina dummy where D=1 is a La Nina condition and D=0 is a normal condition.

## RESULT AND DISCUSSION

### Climate Change and the Development of Factors Affecting Food Crop Production

The climate change in this study examines the phenomena of the El Nino and La Nina climate anomalies that can disrupt the agricultural sector, especially the production of rice, corn, and soybean. One of these phenomena can be identified by Oceanic Nino Index (ONI) indicators based on sea surface temperature (SST) in the central and eastern tropical Pacific regions, and more commonly in the Nino 3.4 region. When the ONI value is +0.5 or more, it indicates the El Nino phenomenon, and when it is 0.5 or less, it indicates the La Nina phenomenon.

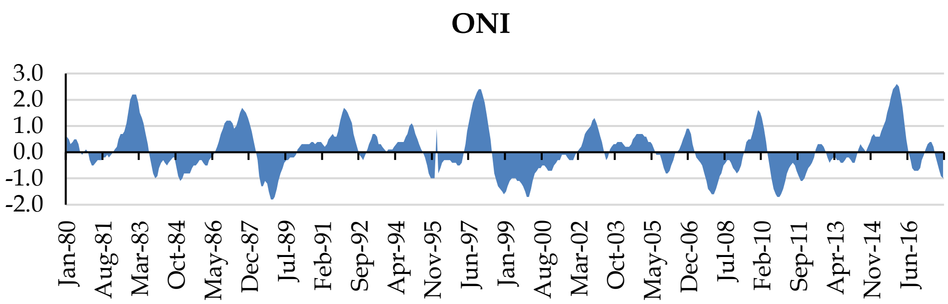


Figure 2.
Oceanic Nino Index Development Trends 1980-2017

Figure 2 shows trends in ONI development from 1980 to 2017. ONI values above 2 ° C indicate a very strong phenomenon. Very strong El nino phenomena occurred in 1982, 1997 and 2015, reducing rainfall in some areas and potentially disrupting agricultural production, especially food crops. It can be seen that the intensity of the ONI value increases in the year when the very strong El Nino phenomenon occurs. El Nino can cause changes in rain and drought patterns, which can affect the short-term decline in agricultural production that is vulnerable to it. Declining agricultural production leads to food shortages, followed by rising food prices and inflation (Ahmad et al., 2019). This is supported by Siregar et al. (2020) discovered that El Nino as a non-economic factor impedes production in the micro and small industrial sectors where the provinces studied mostly processed food crop production into the output of the micro and small industrial sector. This shows that climate change is an important issue as it can have a significant impact on the agricultural sector, especially on the production of food crops.

One of the factors that determine the production of food crops is the productivity of the food crops themselves. Productivity depends on the use of various inputs, in this case technology, used to produce the output. Figure 3 shows the growth in average productivity and changes in ONI values in the study area. In 2011 and 2015, climatic anomalies in El Nino and La Nina can lead to changes in precipitation intensity.

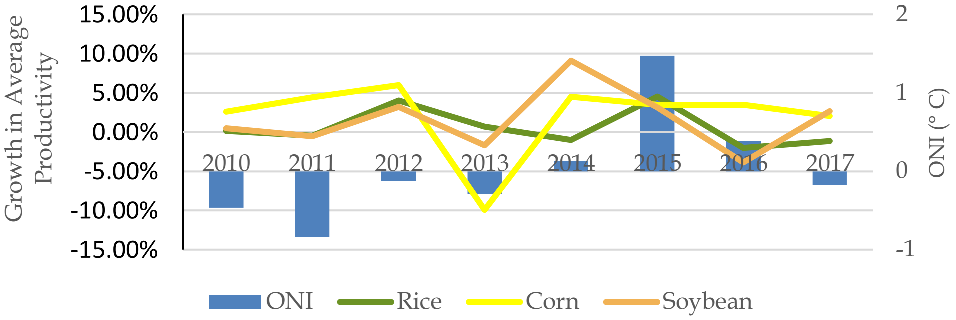


Figure 3.
Average Productivity Growth in Study Provinces and ONI Value Movement 2010-2017

The highest productivity of food crops in Java in the last 20 years (1996-2015) occurred in the 2011-2015 range for rice, corn, and soybean, respectively, reaching 5.73 tons per hectare, 5.04 tons per hectare, and 1.46 tons per hectare. This is driven by land expansion for the application of rice, corn, and soybean cultivation technology (Nadapdap, 2017). Based on Figure 3, there were climate anomalies in 2011 and 2015, as can be seen from the ONI values. Trends in food crop productivity in the study area are fluctuating. One of the reasons for the increase or decrease in productivity is the climate anomalies. Some foods commodities experienced productivity fluctuations in the year of the climatic anomaly. These fluctuations are caused by several causes, including land expansion for the application of technology, increased harvested area, high rainfall, and reduced land area due to competition from other commodities, etc.

An important part of determining the production of food crops is the distribution of fertilizer subsidies. Fertilizer is a nutrient source for plants, and the use of fertilizer is essential for agriculture to prevent plants from being attacked by nuisance organisms. Distribution of subsidized fertilizers is a means to increase agricultural production and promote food security.

Table 1. Distribution of Fertilizer Subsidies in Study Provinces (Tons)

| Province | Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
| DKI Jakarta | 250 | 24,409 | 85 | 1,029 | 130 | 324 | 95 | - | 4 |
| West Java | 1,128,803 | 939,807 | 1,087,425 | 1,069,623 | 1,090,448 | 1,095,868 | 1,054,374 | 1,179,267 | 1,108,414 |
| Central Java | 1,461,708 | 1,736,418 | 1,430,615 | 1,776,430 | 1,747,300 | 1,751,100 | 1,754,540 | 1,783,324 | 1,697,174 |
| DI Yogyakarta | 88,994 | 406,666 | 215,226 | 88,178 | 86,945 | 82,631 | 92,952 | 84,442 | 79,412 |
| East Java | 2,310,169 | 1,349,942 | 2,282,644 | 2,483,842 | 2,459,419 | 2,627,312 | 2,626,944 | 2,702,011 | 2,698,425 |
| Banten | 141,999 | 413,084 | 79,103 | 119,822 | 110,427 | 111,284 | 110,204 | 124,108 | 116,463 |
| North Sumatra | 376,652 | 368,345 | 437,045 | 422,639 | 412,499 | 386,171 | 385,194 | 398,849 | 400,477 |
| Lampung | 485,333 | 509,168 | 525,781 | 521,237 | 476,810 | 439,929 | 438,330 | 479,685 | 501,055 |
| South Sumatra | 291,473 | 354,864 | 375,614 | 365,755 | 311,988 | 280,088 | 262,638 | 285,296 | 304,741 |
| South Sulawesi | 408,920 | 346,847 | 394,441 | 481,278 | 483,989 | 500,804 | 458,745 | 530,758 | 573,112 |
| West Nusa Tenggara | 64,556 | 160,864 | 47,540 | 199,225 | 220,044 | 214,957 | 237,500 | 227,314 | 259,659 |
| Jambi | 72,761 | 94,143 | 85,425 | 106,420 | 98,194 | 97,652 | 110,204 | 107,857 | 121,281 |

Table 1 shows the distribution of fertilizer subsidies, most of which fluctuated from 2009 to 2017. The largest distribution of subsidized fertilizers is found in East Java, followed by Central Java and West Java. This is because the province is the center of rice, corn and soybean production. East Java saw the most growth of subsidized fertilizer in 2011, with 932,701 tons, Central Java saw a 335,815 ton increase in 2012, while DI Yogyakarta saw a 317,672 ton increase in 2010.

The allocation of subsidized fertilizers is calculated in accordance with the recommendation for location-specific balanced fertilization, taking into account the proposed needs submitted by the provincial government in the form of a recapitulation of the RDKK (Rencana Definitif Kebutuhan Kelompok Tani), as well as the fertilizer subsidy budget allocation. Subsidized fertilizer needs are primarily allocated to provinces on the island of Java, where the majority of rice producing hubs are located. Over the last ten years, the nominal value of the APBN (Anggaran dan Pendapatan Belanja Negara) has climbed by 12.9% each year, followed by budget allocations for fertilizer and food subsidies, which have increased by 13.3% per year (Suryana, et al., 2016)

Figure 4 shows the variable total area of irrigated paddy fields. East Java and Central Java have the largest areas of irrigated paddy fields. In 2012, land was converted to non-agricultural, resulting in a 3.41% reduction, or approximately 125,023 hectares. This reduced agricultural land and affected the country's food production and stability. This decline was also caused in 2015 and 2017 by the relocation of paddy fields to gardens in some areas that did not benefit the growth of the agricultural sector.

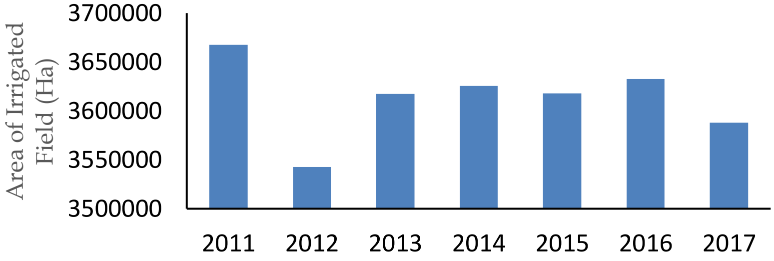


Figure 4.
Total Area of Irrigated Paddy Fields in the Study Province

The government has endeavored to adapt and mitigate climate change, including optimizing irrigated paddy fields and subsidizing fertilizers. However, many issues with fertilizer subsidy distribution indicate that this policy isn't always optimum, such as the distribution system that is not on target. Similarly, the ever-declining growth of irrigated paddy fields due to population growth, housing, public facilities and industrial needs will lead to a food crisis.

**Panel Data Regression Model Estimation**

Two tests need to be run to determine which model to use. The first test is the Chow test, which is used to select either the Pooled Least Squared (PLS) model or the Fixed Effect (FEM) model. The second test is the Houseman test used to select either a fixed effect (FEM) model or a random effects (REM) model.

Table 2. Chow Test and Hausman Test Results

| Best Model Test | Prob. *Chi-Square* | | |
|---|---|---|---|
| | Rice Comodity | Corn Comodity | Soybean Comodity |
| Chow Test | 0,0000* | 0,0000* | 0,0000* |
| Hausman Test | 0,0000* | 1,0000 | 1,0000 |
| Estimation Model | FEM | REM | REM |

Note: *) level of significance 1%

Based on table 2, the model chosen for the rice commodity is FEM because the *Chi-Square* probability value on the Chow Test and Hausman Test is smaller than the 1 percent level of significance. On the other hand, for corn and soybean commodities, REM is used because the *Chi-Square* probability value on the Hausman Test is greater than the 5 percent level of significance.

Classical assumption test so that the estimator meets the Best, Linear, and Unbiased Estimator (BLUE) criteria, including normality test, multicollinearity, heterogeneity test, and autocorrelation test need to do it. JarqueBerra probability values for all study models show values of 3,3203, 164,7060, and 2,8719, which are above the 5% significance level. This shows the error term of the normal distribution model. In addition, the correlation between the variables of the three models is less than 0.8, so no signs of multicollinearity are detected.

Heteroscedasticity test on rice comodity model for the probability values of all variables exceed the 5% significance level. This means that the model has free from heteroscedasticity. In the corn and soybean model, this test is not required because the model uses the REM model as the best model under the general least squares (GLS) approach. The GLS approach helps avoid the symptoms of heterogeneous. Because the model in this study uses the GLS (section weighting) weighting method, the autocorrelation problem can be overcome with an autocorrelation test and the model does not have an autocorrelation problem.

Table 3. Estimation Results

| | Rice Commodity (Coef.) | Corn Commodity (Coef.) | Soybean Commodity (Coef.) |
|---|---|---|---|
| Productivity | 2.315* | 2.887* | 0.594 |
| Fertilizer Subsidies | 0.074* | 0.159* | 0.447*** |
| Growth of Irrigated Paddy Fields | -0.00029 | -0.00018 | -0.001*** |
| El Nino Dummy | -0.038** | -0.053** | 0.186* |
| La Nina Dummy | 0.042*** | 0.309* | 0.138** |
| R-Squared | 0.996 | 0.47 | 0.277 |
| Adjusted R-squared | 0.996 | 0.44 | 0.229 |

Note: *) level of significance 1%, **) level of significance 5%, ***) level of significance 10%

The growth of irrigated paddy fields has no significant effect on the production of rice, corn and soybean because of the declining paddy fields, and strategic steps are needed to take advantage of the decreasing land area by using irrigation development technology to maintain and increase it. The growth of irrigated paddy fields has also decreased from 2009-2017 causing a decrease in the area of land to produce these food crops.

## Impact of Climate Change and Other Factors on Rice Production

One of the most sensitive food crops for water availability is rice. Rice plant growth and production are largely reliant on the availability of water. Rice plants require water during their growth period; the more the availability of water during this time, the better the rice growth and production. (Rusmawan, et al., 2018) Based on the estimation results of the panel data model, El Nino and La Nina have a great influence on rice production. Based on the estimation results in Table 3, El Nino has the effect of reducing rice production by 0.038%, and La Nina has the effect of increasing rice production by 0.042%.

The El Nino phase causes a decrease in rainfall, which leads to a decrease in the supply of irrigation water. The La Nina phenomenon, on the other hand, causes an increase in rainfall, which leads to an increase in the availability of water for production. This study is supported by a study by Selvaraju (2003) that during El Nino rice production decreased by 7% and La Nina rice production increased by 3% in India.

In addition to climate change, table 3 show other factors that have an effect on rice production, specifically productivity and fertilizer subsidies. Productivity, reflecting the use of technology to increase production, has the largest impact on rice production at 2,3%. The use of technology to support efficiency and improve productivity is carried out as an integral part of efforts to tackle climate change. Fertilizer subsidies have a positive impact of 0,07%. Fertilizer subsidies can have a positive effect on rice production, however this must be optimized in order to achieve efficiency in the use of fertilizer subsidies. This is in accordance with a study conducted by Hermawan (2014) where the policy of increasing fertilizer subsidies has a positive impact on the expansion of harvested area, production, and also rice productivity.

**Impact of Climate Change and Other Factors on Corn Production**

Corn is a crop that is usually planted in two growing seasons, the wet season and the dry season. This crop is also commonly grown in the dry season on dry land without irrigation. In the dry season, water supply is highly dependent on rainfall and is one of the food crops sensitive to water availability.

Based on the estimation results in table 3, El Nino and La Nina have an impact of -0.05 % and 0.39 % respectively on corn production. El Nino typically happens withinside the dry season. This is one of the reasons of the fantastically huge decline in production, consisting of corn. This is due to the limited water supply which increases. In the El Nino phase, this may have an effect on lowering rainfall and ensuing in limited supply of water needed by corn. This is in step with the observe of Iizumi, et al. (2014) which indicates that the average corn yield has a tendency to be beneath normal during El Nino phase.

The La Nina phase, on the other hand, tends to have a positive impact on corn production. This increase is usually greater for commodities grown on dry land without irrigation. This is due to the limited availability of water, especially in dry areas that rely on rainfall. Increased rainfall during the La Nina phase helps to anticipate water shortages for corn production. The results of this study are supported by a study by Irawan (2006), which found that La Nina had the greatest impact on corn yield compared to other commodities studied, at 3.92%.

Productivity, which measures how much technology was used to produce corn, has a 2.88% impact. The impact of the fertilizer subsidy on corn production is 0.15%. This is consistent with the study of Otieno et al. (2014), where fertilizer subsidy programs for agriculture can stimulate increases in corn yield.

**Impact of Climate Change and Other Factors on Soybean Production**

Soybean is a type of annual crop and is cultivated in paddy fields and dry land consisting of fields. This plant generally lives in tropical and subtropical climates. According to Prihatman (2000), optimum soybean production calls for rainfall among 100-200 mm/month. Based on table 3 above, the effect of El Nino and La Nina significantly impacts soybean production withinside the studied province. During El Nino and La Nina, soybean manufacturing has a tendency to increase through 0.186% and 0.138%, respectively.

Soybean grow on dry land and do not require much water. The water required for soybean growth will increase simplest for the duration of flowering and pod formation (Taufiq & Sundari, 2012). Soybean generally can grow and adapt to different types soil. During the El Nino phase, the conditions of reduced and drier rainfall maintain soil temperature to help proper soybean seed germination wherein the soil temperature have to be above 10 $^{o}$C and the ideal temperature stages from 24.2-32.8 $^{o}$C. In addition, soybean varieties have different resistance to the threat of drought.

Fertilizer subsidies have a positive impact on soybean production by 0.45%. This result is consistent with the study of Abubakari, F (2015) showing that the use of fertilizer subsidies will increase the average yield per hectare of soybean. However, this is followed by the need to increase the efficiency of fertilizer subsidies. From a productivity standpoint, the use of technology does not have a significant impact on soybean production, especially in Java. This reflects the fact that the utilization of technology for maximum soybean production has not yet been achieved and the dominant soybean production capacity is concentrated in Java.

## CONCLUSION AND SUGGESTION

### Conclusion

Climate change is a major problem as it has a greater impact on the agricultural sector, especially food crops. Governments have anticipated these impacts through adaptation and mitigation efforts, one of which is through irrigation and fertilizer subsidies discussed in this study. However, those efforts were ineffective, so there is a need to optimize fertilizer subsidies and use technology, consisting of irrigation technology.

Climate change affects rice, corn, and soybean production. El Nino tends to impede rice and corn production due to reduced rainfall, but soybean production tends to increase at this phase. La Nina phase in this study tends to drive increased food production as rainfall increases, which may help anticipate limited water supply. Distribution of fertilizer subsidies plays an important role in increasing production. However, distribution should be optimized to be effective. Productivity has the greatest impact on rice and corn production, but not soybean production. This indicates that the utilization and production capacity of soybean technology has not been maximized as it is still heavily concentrated on the island of Java. The growth of irrigated paddy fields does not affect the production of rice, corn, and soybean due to the reduction of land for production.

**Suggestion**

Adaptation and mitigation efforts need to be made to anticipate the effects of climate change. One possible adaptation strategy is to improve irrigation infrastructure and maintain the area of irrigated paddy fields while also creating new irrigated paddy fields that are not limited to the island of Java. Meanwhile, mitigation efforts can be carried out by maintaining the fertilizer subsidy policy and expanding its distribution to stimulate increased production in order to attain food security. However, policies need to be optimized, especially for the food sector, and oversight needs to be strengthened to make distribution systems more effective. Furthermore, productivity in this case is a proxy for technology that must be maintained in a variety of ways, one of which is access to information and communication technology (ICT).

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