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The Linkage of Rainfall Anomaly due to El Nino Southern Oscillation (ENSO) on Cassava Productivity in Central Java Province

Anugrah Jorgi Firmansyah[1,2 a)], and Emilya Nurjani[1]

[1]*Department of Environmental Geography, Faculty of Geography, Universitas Gadjah Mada, Indonesia*
[2]*Center for Natural Disaster Studies, Universitas Gadjah Mada, Indonesia*

[a)] Corresponding author: anugrahjorgi@mail.ugm.ac.id

Abstract. El Nino Southern Oscillation (ENSO) is a global climate phenomenon that affects the climate of a region and causing climate anomalies. ENSO can cause rainfall anomalies that have an impact on the agricultural sector. Cassava is one of the plants known as climate-resistant plants. Cassava has high productivity and is almost evenly distributed in Central Java Province. This study aims to determine the relationship between rainfall anomalies due to ENSO and cassava productivity in Central Java from 1990-2019 at each different ENSO phase. El Nino in weak, moderate, and strong phases triggers a decrease in annual rainfall intensity with an even distribution from the north and becomes softer towards the south of the province. When La Nina begins, the intensity of rainfall increases with a strong intensity starting from the south side and weakening towards the province's north. The increase in rainfall during the La Nina phase tends to increase cassava productivity and the El Nino phase tends to decrease cassava productivity, although there are case findings in certain areas.

1. Introduction

El Nino Southern Oscillation (ENSO) is one of the global climate phenomena that can affect the climate of a region or country so that it changes climate patterns and causes climate anomalies. ENSO is a non-periodic Global Climate System. This ENSO phenomenon affects marine conditions in Indonesia. During El Nino, Indonesian sea waters will be colder and when La Nina will be warmer [1]. The impact of El Nino in 1997/1998 caused the rainy season to be delayed by 2 - 3 months. This resulted in the delay in the 1998 dry season planting time. In the 1997/1998 period, rice production decreased by 6.5 percent and rice imports increased by 3 million tons [2]. This climate change also affects secondary crops such as cassava and corn, significantly affecting planting time and production yields [3].

The effect of ENSO on annual rainfall is 16.36% higher than the effect of El Nino (11.28%) and La Nina (12.80%). The effect of ENSO and El Nino on seasonal rainfall in Indonesia takes place in the middle of the year. La Nina does not have a significant effect on the rainfall of early dry season, peak dry season, early rainy season and peak rainy season in Indonesia [4]. El Nino events had more of an impact on secondary crops, the decline in productivity of secondary crops and tubers due to El Nino only occurred in 2002. On the other hand, El Nino in 2015 had a positive impact on several commodity productivities. La Nina in 2000, 2008, and 2010 caused a decrease in palawija productivity in several sub-districts, but did not affect the productivity of tubers [5].

Cassava is a multipurpose plant because the tubers, stems, and leaves are helpful [6]. Cassava is used as food (58%), industrial raw materials (28%), feed ingredients (2%), and exported in the form of cassava (8%). The marketing chain for cassava in Java is relatively simple. Generally, farmers sell to traders who then distribute to the cassava processing industry group. In Central Java Province alone, there are 36 cassava processing industrial companies, more than East Java (15 companies) and West Java (26 companies) [7]. Research on the relationship between climate elements and the productivity of cassava (Manihot esculenta Crantz) in Malang Regency shows that rainfall climate elements affect cassava production by 80% and the other 20% do not feel the effect [8].

Cassava is a climate-resistant crop with a growing period of 8 to 12 months. However, it turns out that cassava requires unique criteria for climatic conditions, especially rainfall for its growth [9][10]. The climatic conditions in Indonesia are undoubtedly inseparable from the impact of global climate phenomena both in Indonesian waters and waters in other parts of the world, one of which is ENSO. This is one of the exciting factors in studying whether ENSO has a relationship with cassava productivity in Central Java. The aim of this research is to identify the linkage of rainfall anomaly due to El Nino Southern Oscillation (ENSO) on cassava productivity in Central Java Province. The map of the research area can be seen in Figure 1.

Figure 1. Map of the research area in Central Java, Indonesia

2. Data and Methodology

We use monthly rainfall data CHIRPS (Climate Hazard Group Infrared Precipitation with Station Data), which is reanalyzed rainfall data from the combination of satellite data, models, and surface observations [11]. This CHIRPS was obtained from the Climate Hazard Center website of the University of California, Santa Barbara (https://data.chc.ucsb.edu/products/CHIRPS-2.0/). Central Java Province cassava productivity data for 1990-2019 was obtained from the Central Java Provincial Statistics Agency (https://jateng.bps.go.id/).

The relationship between rainfall anomalies caused by ENSO and cassava productivity in Central Java Province was carried out by comparing rainfall anomalies with cassava productivity anomalies.

The anomaly of cassava productivity was calculated using the moving average method. Moving average of order three is used to find the average value of the three years before the El Nino/La Nina event, which will calculate the productivity of cassava. The trend of moving average of order 3 is the most suitable model to estimate the variables of palawija production in Maluku Province [12].

$$\acute{Y}_t = \frac{(Y_{t-1} + Y_{t-2} + Y_{t-3})}{3} \quad \ldots. (1)$$

where:

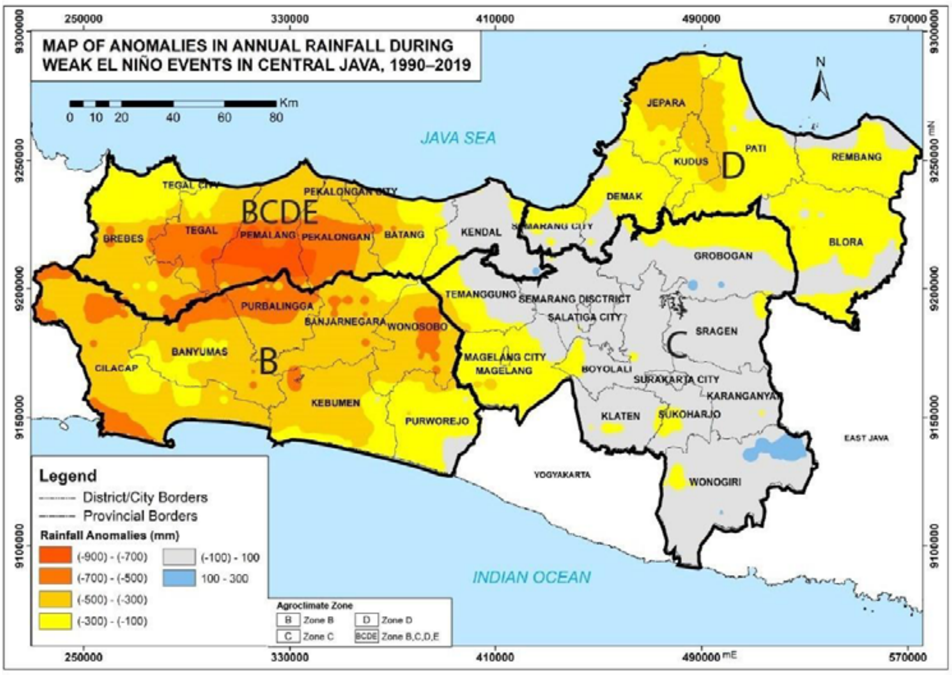
$\acute{Y}_t$ = Expected value in t-period

$Y_{t-1,dst.}$ = Productivity value (year)-1, and so on

This classification of productivity anomalies is classified as multiples of 50 quintal/ha in each class. The anomaly is neutral if the change in cassava productivity during the ENSO phase in that year is between -25 to 25 quintal/ha and it symbolized by a gray color. Negative anomalies are said when there is a decrease in productivity starting from -25 quintal/ha with multiples of -50 quintal/ha, symbolized by colors ranging from light yellow to dark orange. Positive anomalies are said if productivity increases starting from 25 quintal/ha with multiples of 50 quintal/ha, which is symbolized by light blue to dark blue.

3. RESULT AND DISCUSSION

The observations of rainfall anomalies with cassava productivity during a weak El Nino can be seen in Figure 2. In the area of climate type B, there is an anomaly of evenly distributed rainfall in the area. The decline in cassava productivity occurred only in a few districts such as Cilacap, Banjarnegara, and Purbalingga with low intensity. In regions with climate type C, decreased rainfall occurred in several districts/cities bordering climate types B and D, but cassava productivity decreased on the southern side of the area, namely in Magelang, Klaten, Boyolali, and Sukoharjo Regencies. Climate type D, which is in the northeast and mixed in the northwest of the province when El Nino is weak, gets a high decrease in rainfall. At the same time, the calculation of the anomaly in cassava productivity is normal, neither increases nor decreases, there is only one district that experienced a rise in productivity cassava at Pemalang Regency.



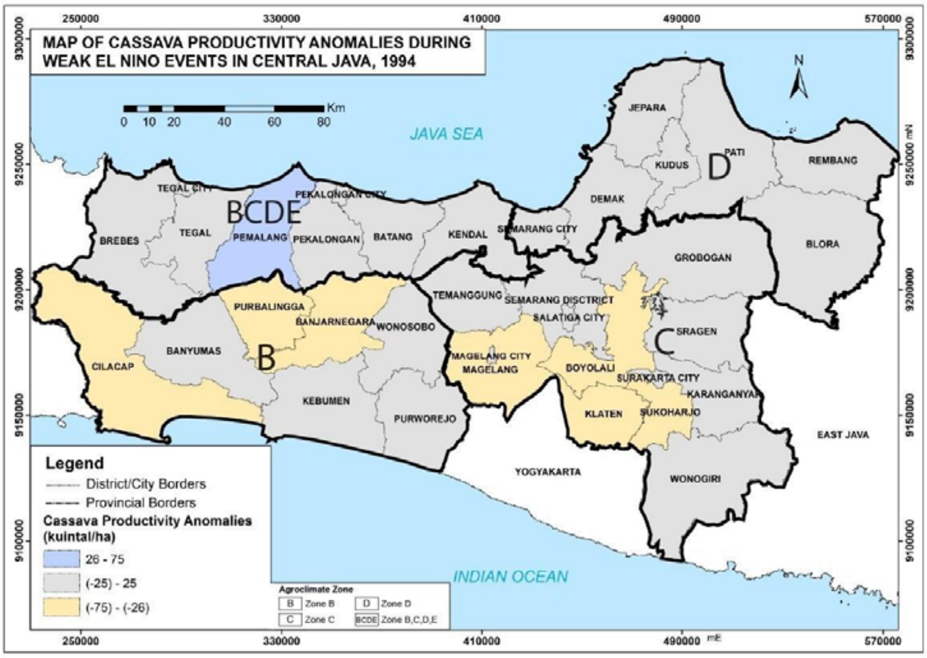


Figure 2. Comparative Map of Rainfall Anomaly and Cassava Productivity during the 1994 Weak El Nino in Central Java Province

The results from observations during a moderate El Nino can be seen in Figure 3. In areas with climate type B, the decrease in rainfall was uneven and only spread in the western part. However, the increase in cassava productivity occurred in Purbalingga and Kebumen Regencies, which experienced a relative decrease low in rainfall. In the climate type C area, most productivity decreases in the districts bordering climate type D with a reduction in light rainfall, but there is also an increase in productivity in the Klaten and Wonogiri districts followed by normal rainfall anomalies. The climate type D area experienced decreased cassava productivity on average during a moderate El Nino, except for Pati Regency, which increased to 95 quintal/ha. In the mixed climate type area (BCDE), the regencies/cities located on the east side did not experience anomalies, while the west side experienced a mild decrease in cassava productivity, namely in Brebes, Tegal, Pemalang, and Tegal Regencies.

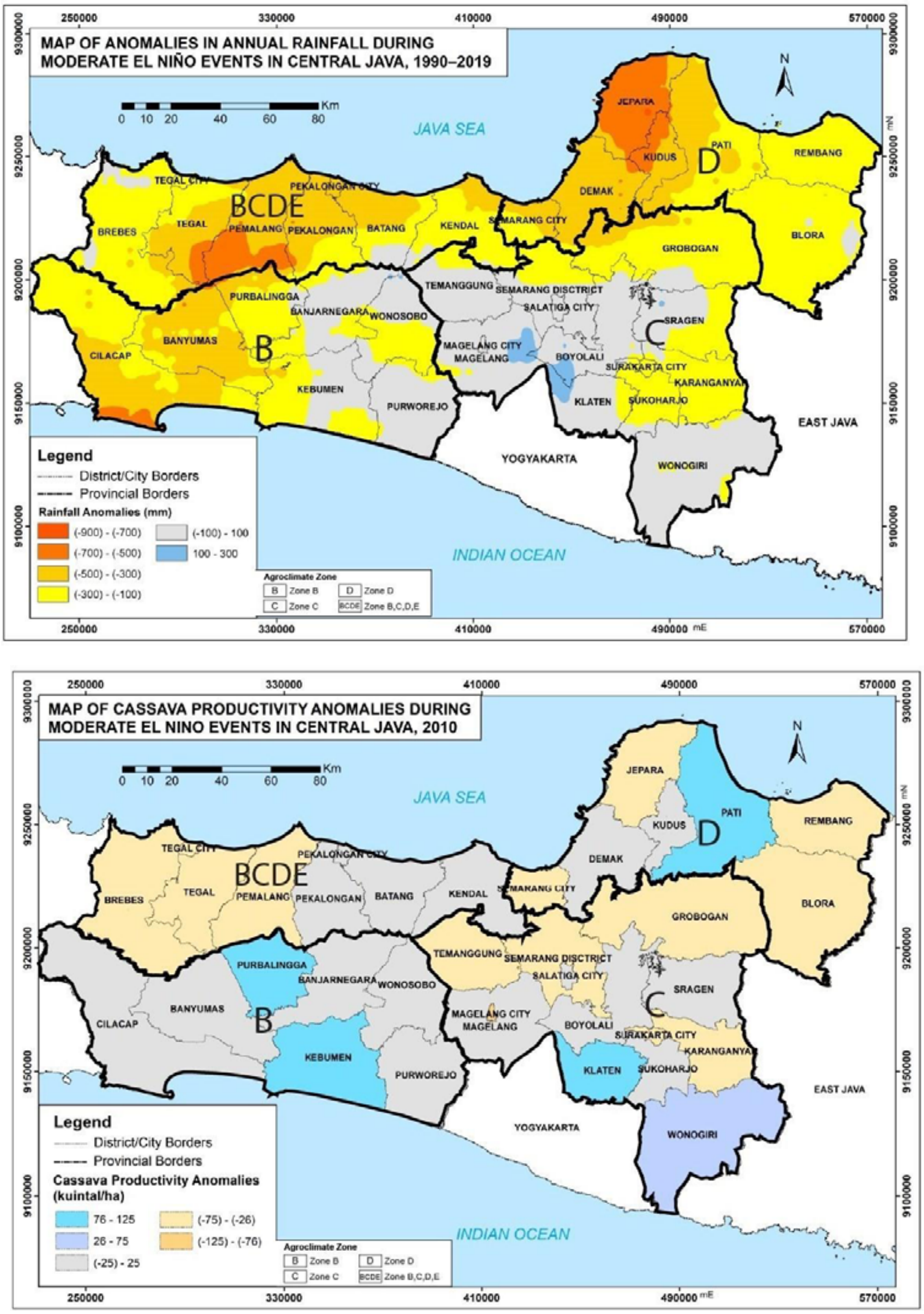
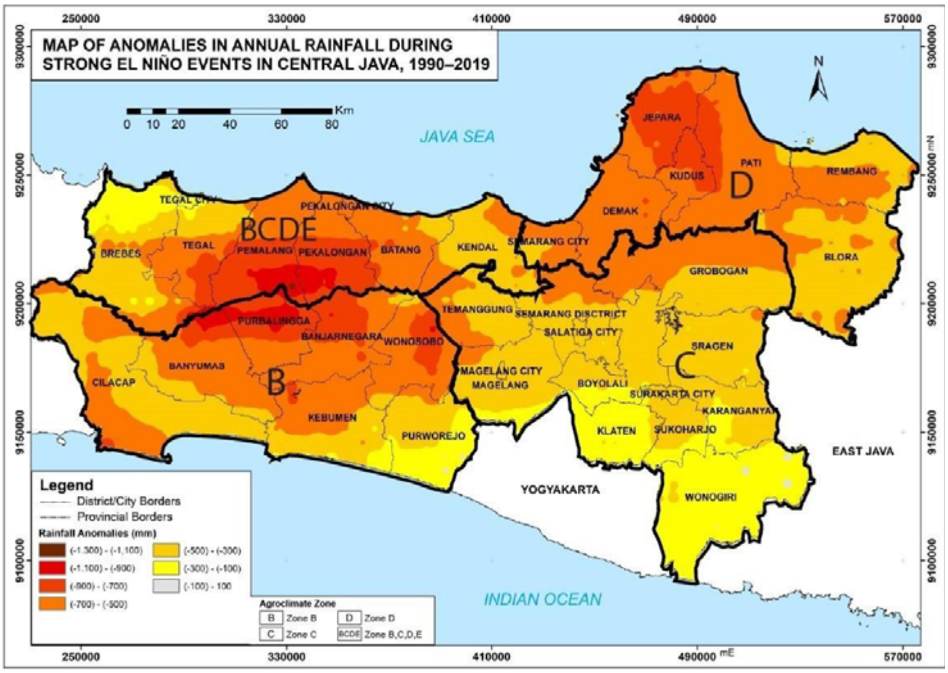


Figure 3. Comparative Map of Rainfall and Cassava Productivity during the 2010 Moderate El Nino in Central Java Province

The comparison of rainfall anomalies and cassava productivity in Central Java Province during a strong El Nino is shown in Figure 4. The decrease in annual rainfall intensity is evenly distributed when there is a strong El Nino in this province. In climate type B, two districts experienced a decline in cassava productivity, namely Cilacap Regency with -118 quintal/ha and Banyumas Regency with -32 quintal/ha. In climate type C, the anomaly of cassava productivity is heterogeneous. Three districts experienced a decline in productivity, namely Temanggung Regency (-32 quintal/ha), Magelang (-144 quintal/ha), and Wonogiri (-28 quintal/ha). Magelang Regency was affected by the most significant decline in productivity during a strong El Nino in 2015. This happened because in the three years before this strong El Nino event, Magelang Regency had always experienced an increase in cassava productivity which peaked in 2014 reaching 413 quintal/ha, and decreased rapidly in 2015. There are also districts/cities that experienced an increase in productivity when El Nino was strong in climate type C areas, namely Klaten (+93 quintal/ha), Boyolali (+44 quintal/ha), Karanganyar (+61 quintal/ha) /ha), and Salatiga City (+38 quintal/ha). The area of climate type D and mixed climate type (BCDE) experienced a decrease in annual rainfall when a strong El Nino occurred in Central Java Province in the last 30 years. The climate type D area, which experienced a reduction in cassava productivity was only in Rembang Regency with -107 quintal/ha, while other regencies/cities tended to be normal. In diverse climate type areas, most regencies/cities are normal and not affected by rainfall anomalies. Only Batang Regency experienced an increase in productivity of 55 quintal/ha during the strong El Nino in 2015.



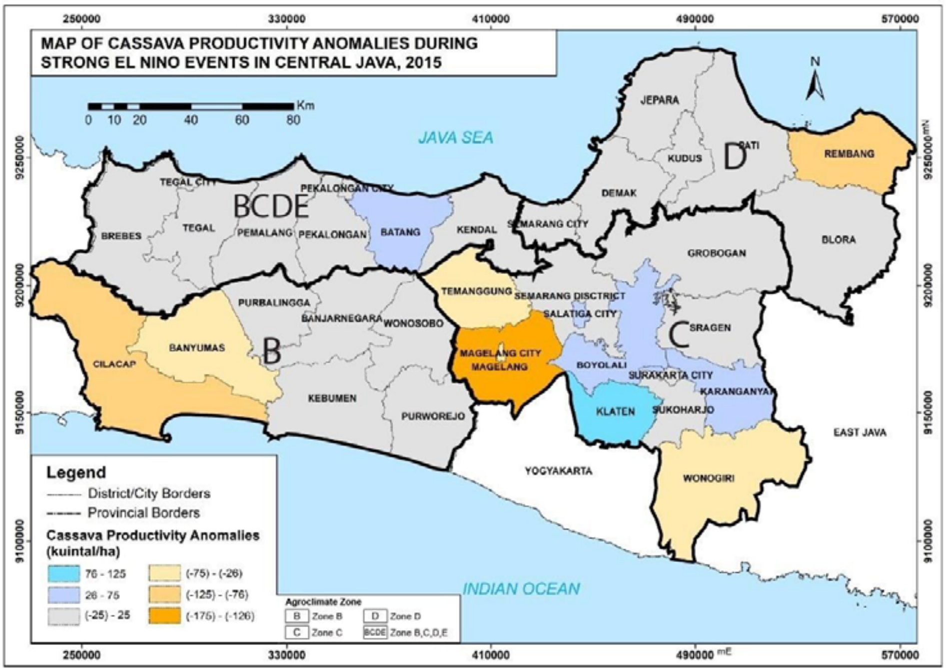


Figure 4. Comparison Map of Rainfall Anomaly and Cassava Productivity during Strong El Nino in 2015 in Central Java Province

The relationship between rainfall anomaly and cassava productivity anomaly when La Nina is weak in Central Java Province can be seen spatially in Figure 5. Areas with climate type B experience an increase in light rainfall and are spread unevenly when linked to a map of the cassava productivity anomaly during this phase. According to the ENSO, all districts/cities in climate type B tend to be normal and not affected by rainfall anomalies when La Nina is weak. In the climate type C area, productivity anomalies only occur in urban areas with a slight increase in productivity and other areas tend to be normal. Areas in climate type C that experienced an increase in productivity were Magelang City (+39 quintal/ha), Surakarta City (+44 quintal/ha), and Salatiga City (+57 quintal/ha). Areas with climate type D when a weak La Nina experienced a decrease in light rainfall in the northern areas around Jepara and Kudus regencies. However, this decrease in rainfall has no impact on the existing cassava productivity anomaly; it can be seen that all districts/cities in climate type D areas tend to be normal. Areas with a mixed climate type experienced an increase in rainfall on the southeast and southwest sides and a slight decrease in rainfall around Pekalongan City. The anomaly of cassava productivity tends to be normal in the districts in the region; however, there are two cities, namely Tegal City (-97 quintal/ha) and Pekalongan City (-82 quintal/ha), which experienced a decrease in cassava productivity. During the weak La Nina 1996, the two cities did not publish data on cassava productivity, resulting in a moderate decline compared to the previous three years.

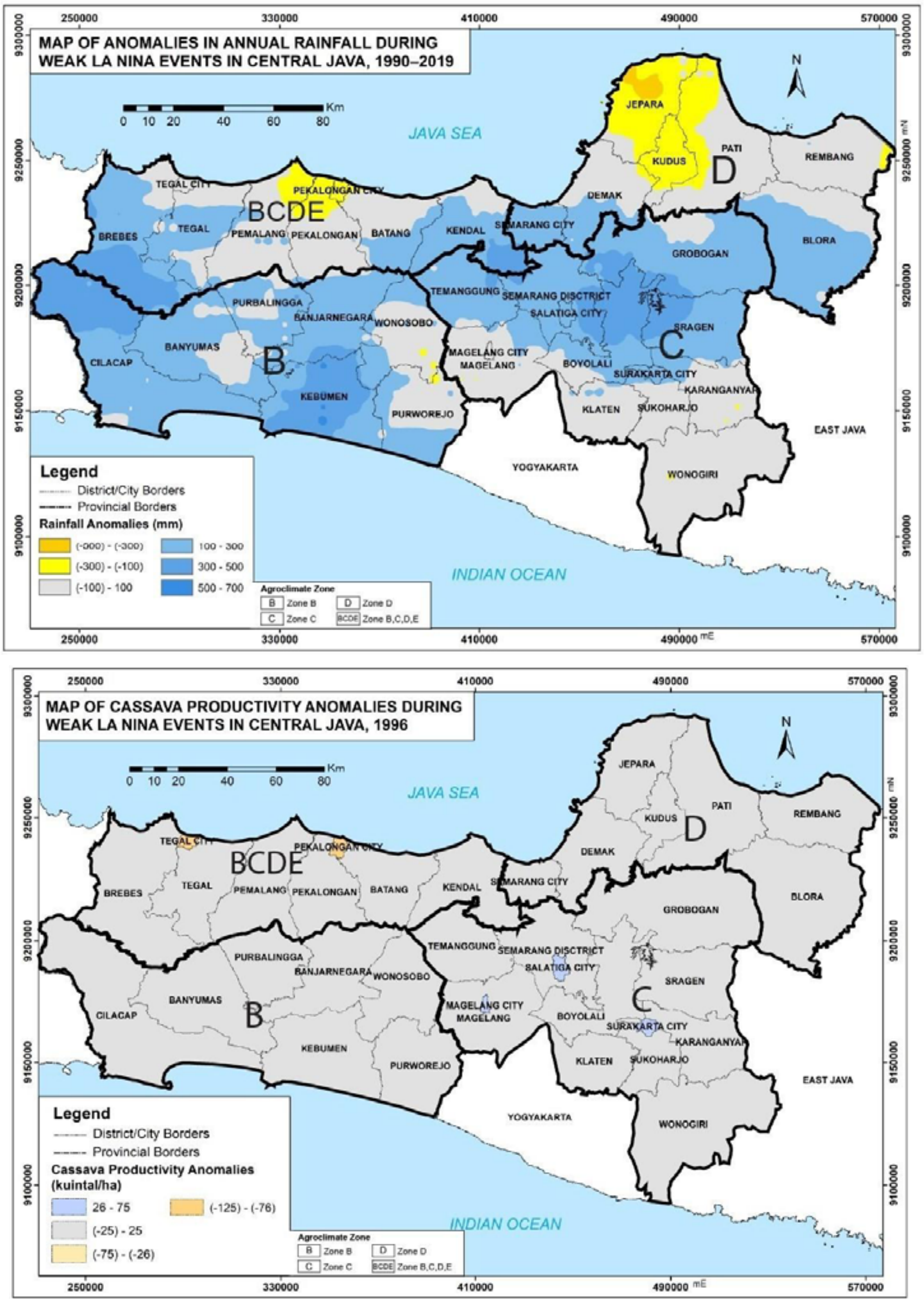


Figure 5. Comparison Map of Rainfall Anomaly and Cassava Productivity during Weak La Nina 1996 in Central Java Province

The comparison of rainfall anomaly with cassava productivity anomaly during moderate La Nina in Central Java Province spatially can be seen in Figure 6. In the climate type B area, the positive anomaly of rainfall is unevenly distributed and there is only an increase in light rainfall on the southeast and north sides bordering the mixed climate type area. The positive anomaly of cassava productivity occurs in almost all districts in climate type B. Only Cilacap and Banyumas Regencies are in normal condition. In the climate type C area, the rainfall anomaly is not much different from the climate type B, but some mild negative anomalies on the northeast side bordering the climate type D area. The productivity of cassava tends to increase slightly to moderately in Semarang Regency with an increase of 81 quintal/ha compared to the previous three years' average. Areas with climate type D experience a negative rainfall anomaly with a decrease in light rainfall during moderate La Nina for 30 years in Central Java Province.

However, when La Nina was in 2009, most districts/cities in the region continued to experience a slight increase. Only Kudus Regency did not experience growth and was included in normal conditions. In diverse climate-type areas, positive anomalies of cassava productivity occur in almost all districts/cities. The most significant increase was in the City of Tegal with +190 quintal/ha. Only Pekalongan City was included in normal conditions when La Nina was in 2009.

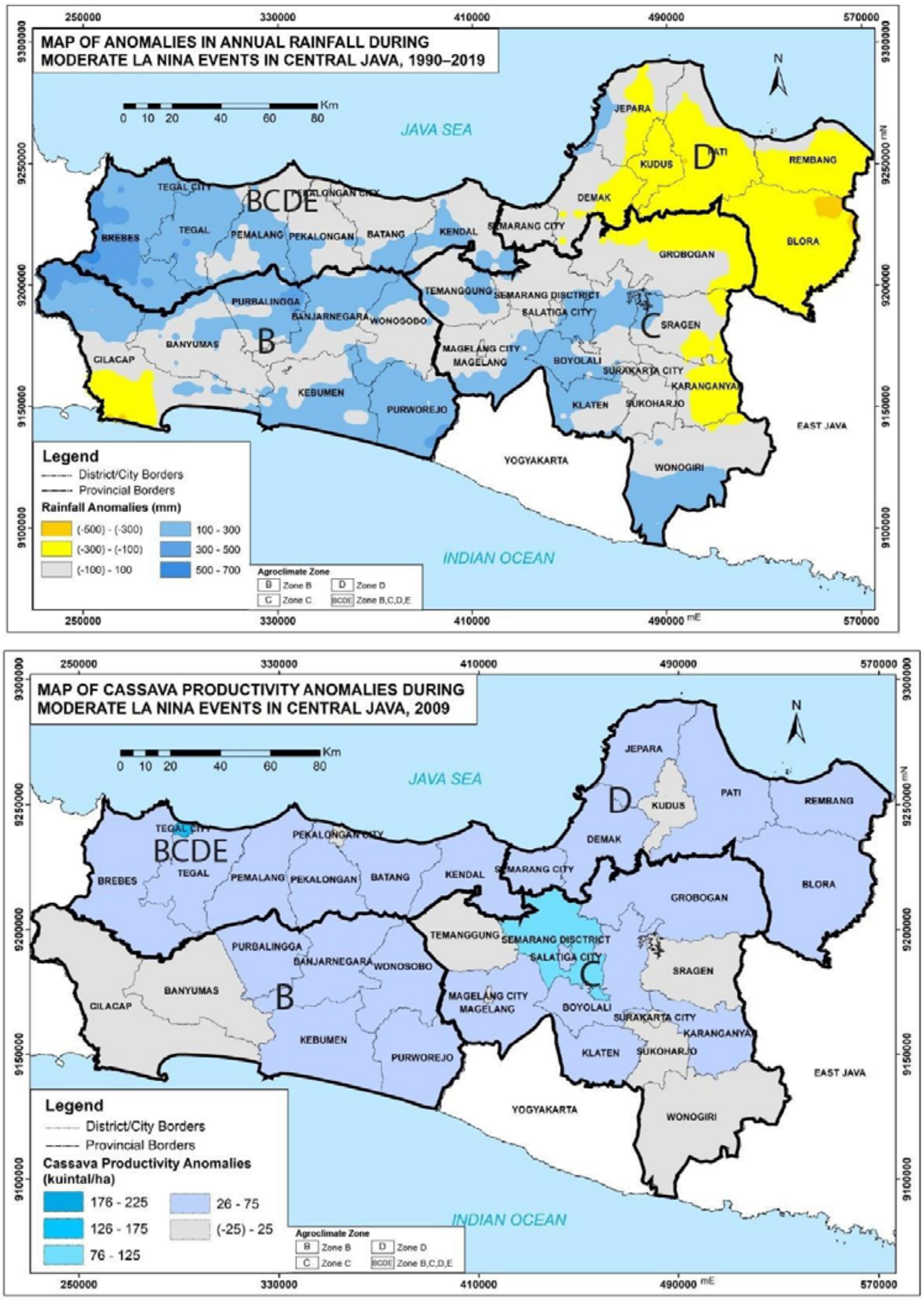


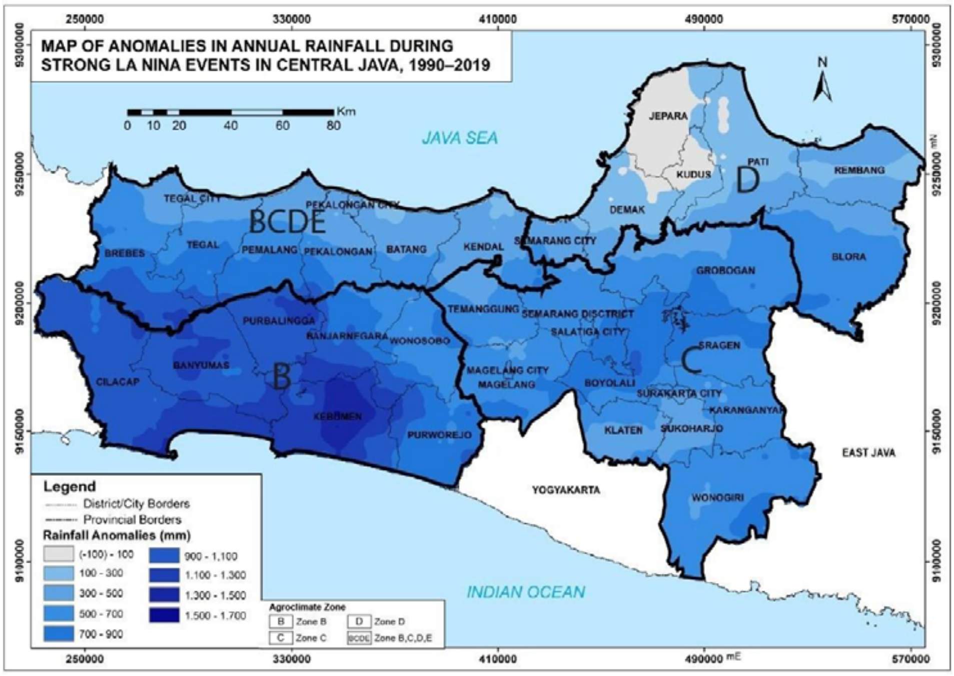
Figure 6. Comparison Map of Rainfall Anomaly and Cassava Productivity during Moderate La Nina 2009 in Central Java Province

The comparison of rainfall anomaly with cassava productivity anomaly when La Nina is strong in Central Java Province spatially can be seen in Figure 7. The increase in annual rainfall is evenly distributed in almost all areas of Central Java Province, only Jepara Regency which tends to be normal when La Nina has been strong in the last 30 years. Areas with climate type B experience positive rainfall anomalies evenly distributed when this strong La Nina occurs. However, in 2012 productivity, not all regions in climate type B experienced positive anomalies. Only Cilacap (+193 quintal/ha), Banyumas (+58 quintal/ha), and Wonosobo (+40 quintal/ha) districts experienced an increase in cassava productivity. There is a decline in productivity in the climate type B area, namely in Banjarnegara Regency with -27 quintal/ha.

Areas with climate type C experienced an increase in cassava productivity in the districts of Temanggung (+47 quintal/ha), Semarang (+44 quintal/ha), Klaten (+49 quintal/ha), and Grobogan (+30 quintal/ha). There was also a decline in productivity in Boyolali (-26 quintal/ha) and Sragen (-31 quintal/ha) districts. Other regencies/cities in climate type C areas have normal productivity.

The climate type D area does not experience an anomaly of positive rainfall that is flat when there is a strong La Nina. However, when La Nina was strong in 2012, the district that did not experience an increase in rainfall increased its productivity was Jepara Regency (+48 quintal/ha). Other regencies that experienced increased productivity in this climate type area were Pati (+96 quintal/ha) and Rembang (+94 quintal/ha). Meanwhile, other regencies/cities tend to have normal productivity anomalies.

Areas of mixed climate type where La Nina is strong experienced most declines in cassava productivity. This decrease occurred in Pemalang Regency (-47 quintal/ha), Batang (-39 quintal/ha), Kendal (-57 quintal/ha), and City of Tegal (-135 quintal/ha). Meanwhile, the other four regencies/cities, Brebes, Tegal, Pekalongan, and Pekalongan city, are in normal condition when La Nina is strong in this climate type area.



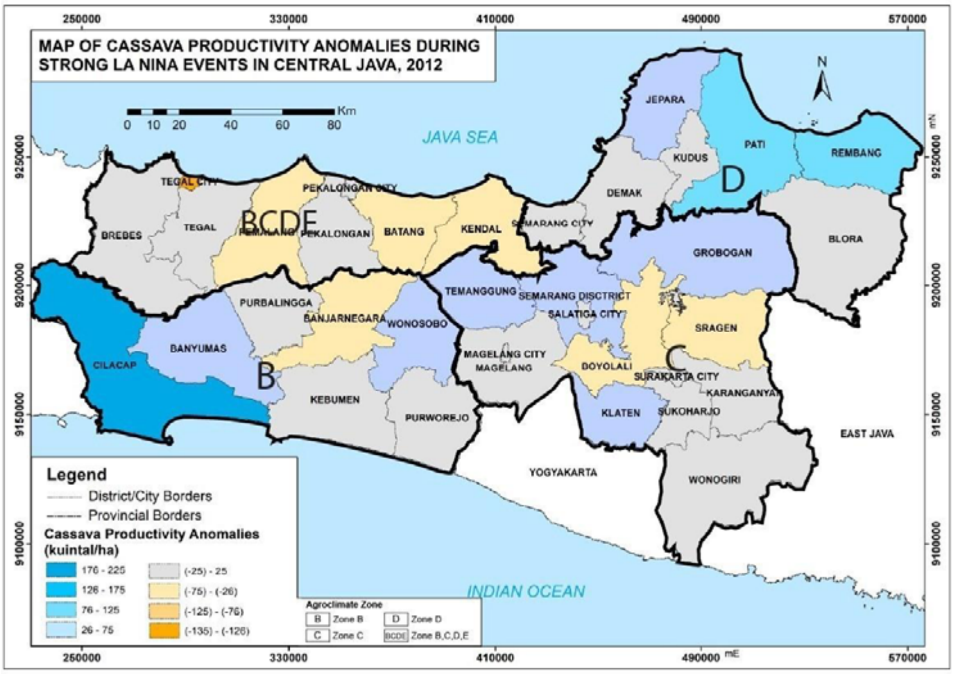


FIGURE 7. Comparison Map of Rainfall Anomaly and Cassava Productivity during Strong La Nina 2012 in Central Java Province

Cilacap, Banyumas, and Rembang Regencies during the 2015 El Nino experienced negative productivity anomalies, but during La Nina, it turned out to have positive anomalies. It can be concluded that cassava productivity in these three districts is affected by rainfall. During La Nina, the increase in rainfall in Cilacap and Banyumas regencies is quite high, reaching 1.000 mm/year, and in Rembang Regency, it is increasing up to 700 mm/year. The increase in rainfall during La Nina is one of the factors in increasing the productivity of cassava in the three districts, apart from other technical factors such as cropping patterns to the treatment of plants by farmers.

The effect of ENSO on rainfall anomalies in Central Java Province impacts some districts/cities that rely on rainfall as one of their main water sources. This can be seen when there is a strong El Nino or La Nina. It can affect the amount of agricultural productivity, especially cassava in the region. Most agriculture in developing countries still depends on climatic conditions, so phenomena such as ENSO, both El Nino and La Nina can affect agricultural productivity in these countries [13].

4. CONCLUSION

The relationship between rainfall anomalies due to ENSO and cassava productivity is evident, but the intensity is not always the same in every district/city. Judging from the pattern when El Nino is weak, moderate, or strong, several districts/cities in Central Java Province tend to experience a decline in cassava productivity. When La Nina was in 2009, the increase in cassava productivity was evenly distributed in Central Java Province. When La Nina is strong, some districts experience high productivity increases, but there is also a decline in productivity in some districts. This can be due to the treatment and changes in cropping patterns from farmers who adjust their respective climatic and geographical conditions to maintain agricultural conditions and maintain their economy.

Planting cassava during La Nina has a positive effect on farmers. However, when an El Nino occurs, it also does not have a negative impact as long as the water needs for plants are still fulfilled. Suggestions from the authors for the study of the effect of ENSO on cassava in Central Java Province, it is necessary to add more detailed climate parameters for each district/city to see whether other climate parameters affect cassava productivity. A detailed study of the effect of ENSO on cassava must also determine the treatment and cropping patterns of farmers in each district/city to suit the agricultural characteristics of the area.

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