Applied Environmental Research
- RESEARCH FOR SUSTAINABLE PLANET -

Research Article

El Nino Effects on Water Availability for Agriculture: Case Study of Magelang, Central Java, Indonesia

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Abstract

Climate change in Indonesia has resulted in a longer dry season. Furthermore, El Nino is one of the main factors causing drought in agricultural areas. The research aim is to study the water availability for agriculture in the Bompon sub-watershed, Magelang Regency, by identifying the El Nino Southern Oscillation (ENSO) impact related to climate variability and changes in extreme hydroclimatic events. Quantitative and qualitative research methods, including climate data analysis and interviews, were used. Quantitative methods were used based on the climate data analysis using R from the ERA5 climate model and water balance. Qualitative methods based on in-depth interviews were used to obtain climate conditions from farmers' perceptions. The results indicate Climate change influences the ENSO phenomenon and affects water availability for rice and cassava production. The extreme El Nino caused extended droughts and a lack of water for rice production. Farmers would find it hard to predict the cropping season due to increasing uncertainty regarding the transition between dry and rainy seasons. Climate adaptation was needed to increase farmers' capacity to have certainty for rice production twice a year.

ARTICLE HISTORY

Received: 23 Nov. 2023
Accepted: 8 Mar. 2024
Published: 23 May 2024

KEYWORDS

Climate change;
Drought;
El Nino;
ENSO;
Water availability

Introduction

One of the impacts of climate change on the water cycle is reduced water availability [1–2]. In the coming decades, water depletion will become water shortages [3–4]. Climate change has many impacts in Indonesia, such as prolonged droughts during the dry season and increased extreme precipitation during the wet season [5]. Interannual variability in rainfall in Indonesia cannot be separated from the existence of the El Nino Southern Oscillation (ENSO) [6–7]. ENSO is distinguished into two opposite extremes: El Nino in the warm phase and La Nina in the cold phase [8].

ENSO exists periodically in a four-year cycle [9]. The ENSO cycle is the simultaneous variation in sea surface temperatures (SSTs), surface air pressure, rainfall, and atmosphere circulation in the equatorial Pacific Ocean [8]. ENSO exacerbates droughts in the warm phase [9]. In Java, precipitation patterns are affected by ENSO [10]. Atmospheric and oceanic extremes associated with El Nino events lead to reduced precipitation, and water resource depletion results in crop failure [11].

Climate change in Indonesia also increases the length of the dry season. Droughts often occur throughout Indonesia due to El Nino [12–13]. During the El Nino years, there was a delay in the onset of the monsoon, which resulted in a delay in the first rice cropping season [14]. In Magelang Regency, Central Java, rice and cassava are the staple foods [15]. Agriculture in the Bompon Watershed is dominated by rainfed rice monoculture.

Meanwhile, cassava is sometimes intercropped with corn at the beginning of the cropping season. Rice needs about 120 days for one growing season, whereas cassava is planted for twelve months. Farmers find it difficult to produce those staple foods because of prolonged and frequent droughts [16–17]. Drought in agricultural areas continues to worsen, resulting in decreased agricultural productivity and crop failure in Magelang Regency.

The Bompon sub-watershed has poor infiltration, causing problems when there is frequent and intense rainfall [18]. Farmers are unable to use water optimally. This phenomenon could become more severe because farmers and the local society depend on agricultural production. The research shows the impact of ENSO in the Bompon sub-watershed. Furthermore, the research assists the farmers in improving rice and cassava production, providing information on agricultural adaptation to ENSO by identifying the ENSO impacts.

Furthermore, the Bompon River is the base of the surface hydrology in the Bompon sub-watershed. The discharge is low during the dry season, and groundwater resources are abundant. Nonetheless, the bedrock and groundwater layers are more than 100 m deep and are difficult to access. All agricultural products in the Bompon sub-watershed are rainfall-dependent. In the ENSO warm phase, drought in Indonesia is a common cause of reduced water availability [19]. This situation is a challenge for water management. Proper water resources management will prevent water scarcity and help farmers manage their agricultural land.

Material and methods

The Bompon sub-watershed around 295 ha. The area elevation is between 377 and 539 m above sea level. In the Bompon sub-watershed, the agricultural area is covered by rice fields of about 37 hectares and non-irrigated agricultural areas of about 15 hectares. The average precipitation from the wet season from November to April was around 275 mm per month. The most rainfall occurs during February and March [20]. The sub-watershed is in a hilly area with deep clay soils and cannot form a good aquifer despite high precipitation [21].

The research used both qualitative and quantitative data. Primary data were collected from in-depth interviews with the farmers. The secondary data was from the Climate Data Store and The European Centre for Medium-Range Weather Forecasts (ECMWF) from the Copernicus Climate Change Service (C3S). Climate data were extracted from the ECMWF Reanalysis 5 Generation Description (ERA5) open-source dataset.

ECMWF Reanalysis 5 Generation Description (ERA5) is a dataset with hourly estimates of atmospheric, land, and oceanic climate variables [22]. The ERA5-Land monthly averaged data from 1981 to 2020 was used in this research. The reanalysis dataset was used to analyse long-term historical climate conditions, calculate the precipitation, and calculate the water balance in the Bompon sub-watershed. ERA5 has a higher spatial and temporal resolution, variation in quality over space and time, improved troposphere simulation, tropical cyclone representation, better global balance, and better precipitation modeling over land in the deep tropics [23].

Climate data extraction in this research was carried out using R software as the programming language. R in environment software was usually used for statistical computing. Then, the data were calculated and processed in Microsoft Excel and displayed in some graphs and plots. The data were used to calculate the water balance in the Bompon sub-watershed. The water balance technique estimates rainwater distribution in micro-sub-watersheds [24]. The basic formula for water balance is mentioned below [25].

$$R = P - ET \pm \Delta S \qquad \text{(Eq. 1)}$$

Where; R = runoff (mm a^{-1}), P = precipitation (mm a^{-1}), ET = evaporation plus transpiration become evapotranspiration (mm a^{-1}) and ΔS = change in soil moisture storage (mm a^{-1})

Some data, such as runoff, precipitation, and evapotranspiration, were based on ERA5 data for the Bompon sub-watershed area [20]. Evapotranspiration data used the total evaporation and included a simplified representation of the transpiration from vegetation [23].

On the other hand, ENSO was identified in more detailed data each month using the Oceanic Nino Index (ONI). The ONI is one of the El Nico-Southern Oscillation measures to identify the incidence of above-average SST thresholds that persist for several months, including the first indications of the El Nino phase at the beginning and end [26]. The threshold is +/- 0.5°C. Periods below and above normal SSTs are colored in blue (La Nina) and red (El Nino) when the threshold has met a minimum of 5 consecutive overlapping seasons [27].

Moreover, interviews with local farmers were needed to collect primary data related to the local climatic conditions and rice and cassava cropping seasons. Water distribution for rice and cassava production was also asked about during the interviews. The sample size for the in-depth interviews was 30 farmers with rice fields for rice production and/or dry fields for cassava production. The range of interviewees includes sampling requirements for a small study area of around 300 ha.

Results

1) Climate condition

Climate conditions in Indonesia have changed over the last few decades. Temperature continuously increases by 0.2-0.3°C per decade. Meanwhile, annual precipitation in Indonesia has decreased by 2 to 3% per decade [28]. Precipitation patterns also changed with annual rainfall decline in the southern region, including Magelang Regency. The total temperature increase is estimated at 0.9-2.2°C by 2060s and 1.1-3.2°C by 2100 [29–30].

The increased global temperature averages 0.08°C per decade [31]. The temperature trend increased or decreased at the average rate over time. Asia had an annual average temperature of more than 2.0°C above the historical average in 2020.

Figure 1 shows the last 40 years of precipitation data, showing that the dry season runs from May until October. August became the driest month, with no more than 59 mm per month precipitation. The rainy season, on the other hand, runs from November until April. The peak of the rainy season happens in January and February, with precipitation around 274-328 mm per month.

Climate conditions in Indonesia, including increasing temperatures, affect the amount of precipitation. The precipitation data explain that the Bompon sub-watershed experiences high rainfall. However, most precipitation occurs during the rainy season. Meanwhile, in the dry months, rain is relatively low.

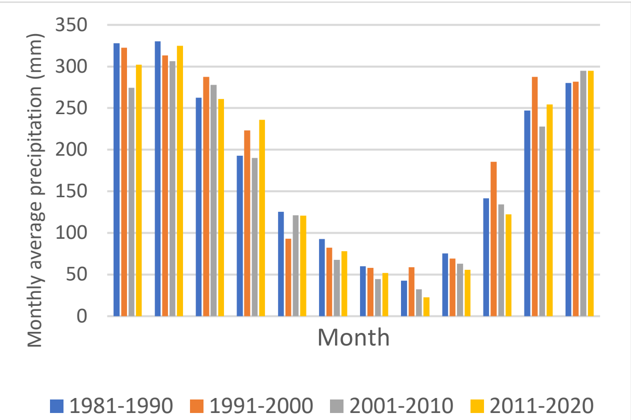

Figure 1 Monthly average precipitation in Magelang Regency.

2) ENSO phenomenon

Several factors affect rainfall intensity, such as climate change, seasonal changes, and the ENSO cycle. The ENSO phenomenon is the event that most affects precipitation and, thus, the water available in the Bompon sub-watershed. The global atmospheric oscillation, called the Southern Oscillation, is closely related to El Nino. Lower pressures generally start in the eastern tropical Pacific, and higher pressures start in Indonesia and northern Australia during El Nino. There is an east-to-west equatorial wind near the surface with a weak frequency. This warm phase characterizes the El Nino [32].

Moreover, rainfall and temperature anomalies have a relatively consistent pattern from one period to another. During the warm phase, Indonesia experiences a dry season because Indonesia is located in the tropics, with a shift in thunderstorm activity eastward from Indonesia to the central Pacific during the summer. The Pacific Ocean area is in the equator line.

Figure 2 shows some years with a strong El Nino and others with a strong La Nina. The ONI is used for monitoring and shows ENSO values that indicate the cycle's strength. The ONI shows the average three-month SST in the east-central tropical Pacific. El Nino occurs when the index is 0.5°C or higher and is shown in the red colors. La Nina occurs when the index is -0.5°C or lower and is shown in blue. The trend from 1981 to 2020 shows that extreme El Nino increased in 1982, 1997, and 2015. In contrast, the extreme La Nina has decreased in strength, as in 1988, 1999, 2007, and 2010.

Precipitation in the Bompon sub-watershed was affected by some ENSO phenomena. The ENSO in the blue line shows several years with strong El Nino and La Nina cycles (Figure 2). The precipitation graph in orange colour displays the precipitation fluctuation within the last forty years. Low precipitation indicates that the cycle was in the El Nino phase. On the other hand, heavy rainfall occurs during the La Nina phase. Some ENSO events are not in line with the precipitation. For example, some years in the red highlight boxes, 1992, 2007, 2008, 2015, and 2016, do not reflect this pattern, as shown in Figure 2.

The scatter plot in Figure 3 presents precipitation and ONI with a negative linear Trend line. The graph shows a negative correlation between rainfall and ONI. If the ONI is high during El Nino years, there often is below-average rainfall. On the other hand, with the low ONI during La Nina, rainfall is often above average. Typically, the ENSO cycle occurs between 3-5 years. Recently, ENSO occurred with increasing amplitudes and shorter cycles. It shows that El Nino and La Nina events are becoming more frequent. However, the scatter plot between precipitation and ONI shows an R^2 value of 0.1476, indicating no correlation.

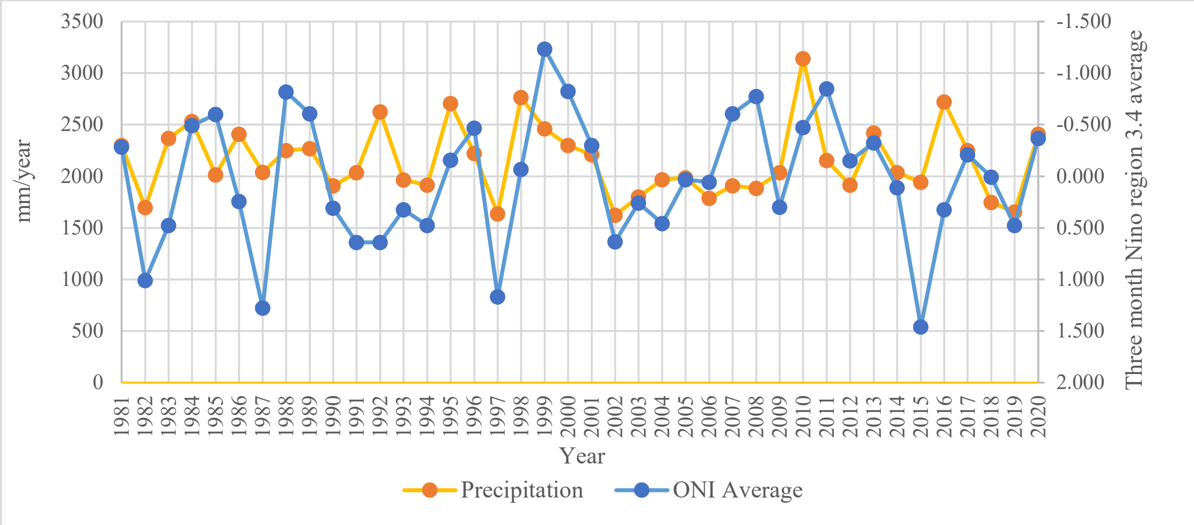

Figure 2 Precipitation and ONI graph with a red box indicating precipitation, not in line with ENSO.

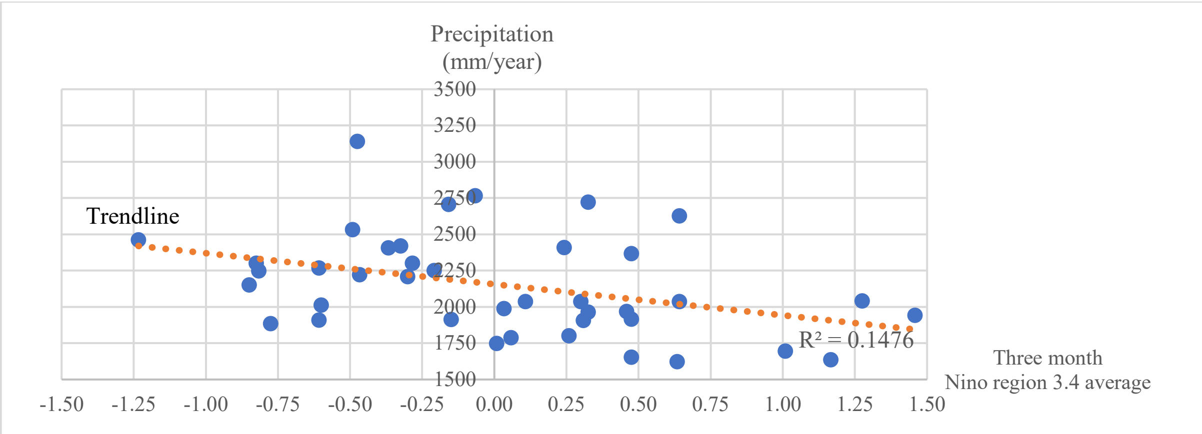

Figure 3 Precipitation vs Oceanic Nino Index (ONI) scatter plot.

3) Water availability

A simple water balance calculation indicates water availability in a small sub-watershed with poor infiltration conditions. Figure 4 presents the water availability results between 1981 and 2020, which include surplus and deficit. The most extreme water unavailability occurred in 1982 and followed other deficit years, such as 2002, 2006, 2015, and 2019. On the other hand, 2020 has the highest water availability, 108.26 mm per year. In 1983, 1998, and 2010, the available water balance was around 56.36-101.96 mm per year. In all observed years, the water balance surplus occurred in a year experiencing a cold phase during La Nina.

The surplus and deficit water balance trends correlate with the ENSO phenomenon, as shown in Figure 4. The ENSO phenomenon displayed with the ONI graph in grey colour presents the three-month Nino region 3.4 average. Not all water balance calculations correlate with ENSO. However, some years with extreme events show that ENSO correlates with the results of the water balance calculation. Some obvious correlations are the extreme El Nino events in red highlight circles (1982, 1987, 1997, 2002, 2015, and 2019).

Figure 5 shows a scatter plot between the water balance and ONI. The negative correlation means that the ONI decreases where the water balance increases in value. It is in line with the ENSO phenomenon in the Bompon sub-watershed. La Nina happens with a positive water balance and negative ONI. On the other hand, El Nino occurs with a negative water balance and positive ONI. However, some data points are broad from the best-fit trendline (R^2=0.0868), indicating non significant correlation.

The last forty years in Figure 6 show water deficit during the dry season, especially in July and August. However, on average, the beginning of the year from February has experienced a deficit in water balance. Within the observed years, the water balance surplus peaked around November because of the precipitation high intensity. Overall, the Bompon sub-watershed's water balance shows the dry season's deficit periods. In contrast, rainwater supply during the rainy season is very high and creates a surplus.

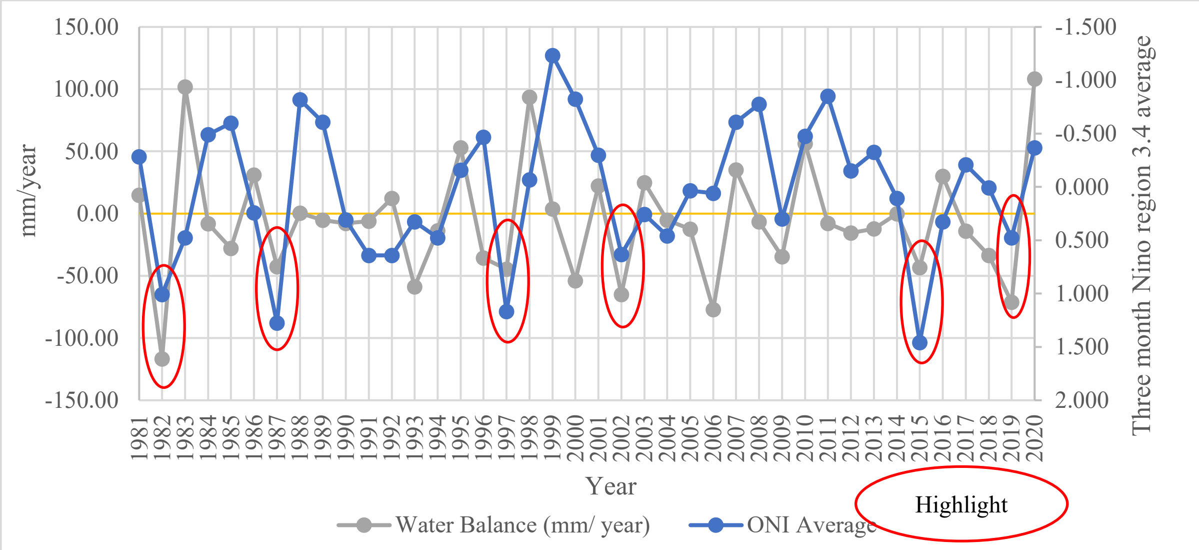

Figure 4 The water balance and ONI graph are in red circles, indicating an extreme EL Nino correlation with water balance.

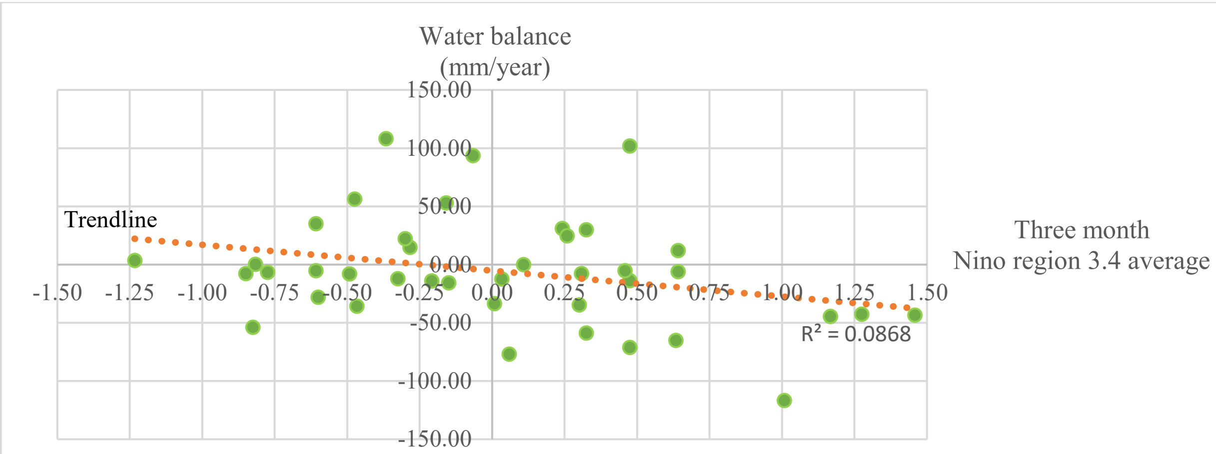

Figure 5 Water balance vs. ONI scatter plot.

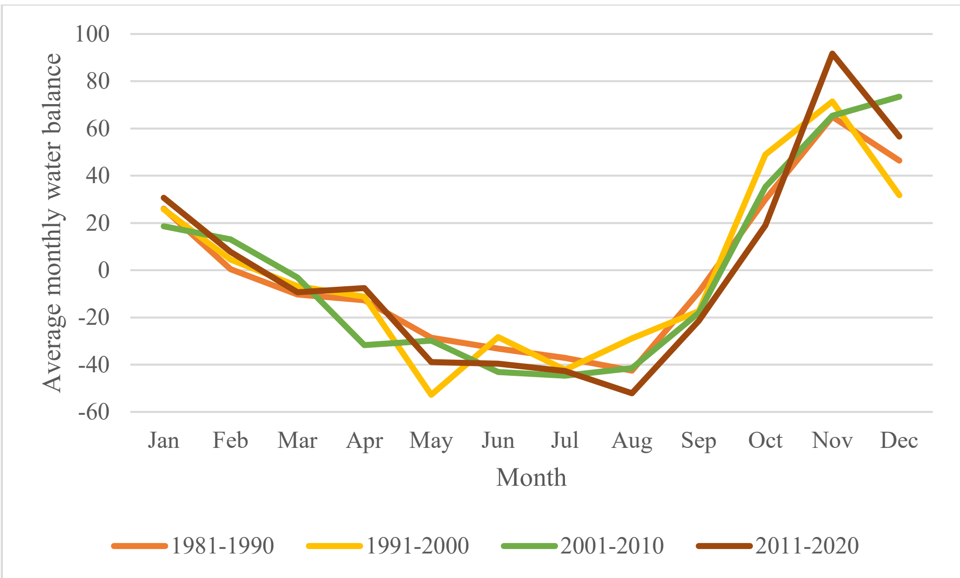

Figure 6 Water balance graph 1981-2020.

4) In-depth interviews

The interviews were conducted to collect data about rice and cassava production and the impact of climate change and ENSO on farmer crops. Rice and cassava are the most common crops and staple foods in Magelang Regency [15]. All rice production is applied to rice fields, while cassava uses dry fields, the majority of which are located on the slopes of the Bompon Watershed. Rice needs about 120 days for one growing season, whereas cassava is planted for twelve months. The rice fields are about 29.94 ha, while the area of the dry fields is about 21.09 ha. According to most farmers interviewed, drought has caused a reduction in rice production. The farmers further explained that drought happened during the growth period when the rice should be inundated. Frequent drought events have caused some farmers to produce rice only in the first cropping season because of the crop failure potential in the second cropping season. Therefore, when the dry season comes, rice production is less optimal than in the wet season. Meanwhile, few farmers stated that there was no decrease in crop production due to drought, especially in cassava. Cassava needs water only a month at the beginning of the growing season.

In the Bompon sub-watershed, 70% of farmers experience drought with increasing frequency compared to the last twenty years. Farmers feel that the existing water resources have been insufficient for agriculture in recent years. Sometimes, farmers start the second cropping for rice in mid-April to begin harvest in August. Furthermore, farmers stated that rice inundation was most challenging in July and August during the dry season.

Furthermore, around 77% of farmers agree that the weather has changed over the last twenty years. The weather is increasingly extreme and erratic. According to the farmers' experience, sometimes there are years with more frequent rains. However, there are also years of prolonged droughts. Farmers need to adjust the growing season for rice and cassava. If there is no water in the rice fields, the farmers leave their fields uncultivated. Previously, farmers had used diesel to extract and distribute water from the nearby river. However, the costs incurred are more expensive than agricultural products, so this practice is no longer implemented.

According to the ENSO cycle, a warm phase (El Nino) causes a long dry season. Also, a cold phase (La Nina) causes a long rainy season. It is aligned with the ONI Index chart. On the ONI Index time series, the repeat period of the ENSO cycle ranges from three to five years. Indonesia experienced a La Nina year with a more extended rainy season in 2020. This condition also affected the Bompon sub-watershed until May. A few farmers also noticed that the extended dry season would sometimes be followed by an extended rainy season. The farmers do not have adaptation strategies to deal with ENSO conditions. Farmers simply try to adjust the cropping date without basic information about ENSO prediction.

The farmers started cropping rice around December. Meanwhile, 75% of farmers said the planting is simultaneous with rice in December for cassava cropping. In comparison, the other 25% crop in October or November. Table 1 and Table 2 summarise the cropping season for rice and cassava production within a year, starting from December.

The best crop peak for rice is in December (Figure 7). The rainy season starts in November, but it is necessary to wet the rice fields before planting. The first planting season was not significantly affected by ENSO. Meanwhile, ENSO strongly influenced the second planting season.

Figure 8 shows the dry season started in May. May is the second rice cropping season when the rice is two months old. The lack of water in this season caused a decrease in rice production. Often, the farmers suffer production losses, even crop failure. During the dry season, most farmers do not use the rice fields for planting. However, others still choose to plant corn or peanuts using the rice field as a non-irrigated agricultural area. The farmers select corn or peanuts because they do not require much water, only take three months to mature, and are easy to manage. Nonetheless, this can also be unsustainable for farmers if the rice field is too dry for cultivation.

Table 1 Seasonal rice production calendar

1st Crop	Planting	Mid-season	Mid-season	Harvest								
2nd Crop					Planting	Mid-season	Mid-season	Harvest				
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov

Planting | Mid-season | Harvest

Table 2 Seasonal cassava production calendar

1st Crop	Planting	Planting	Planting	Planting	Mid-season	Mid-season	Mid-season	Mid-season	Harvest	Harvest	Harvest	Harvest
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov

Planting | Mid-season | Harvest

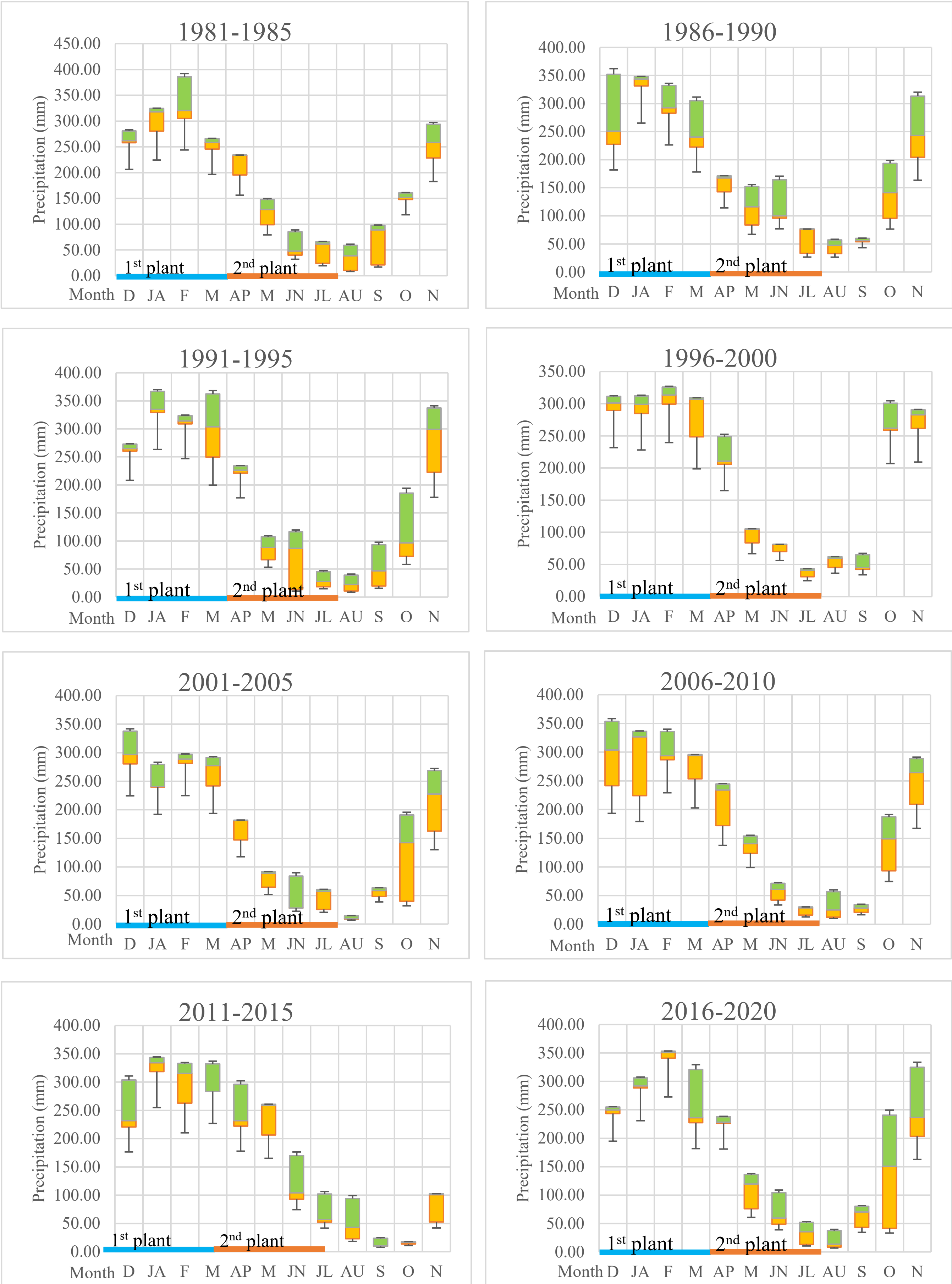

Figure 7 Correlation between precipitation box plot and rice cropping seasons.

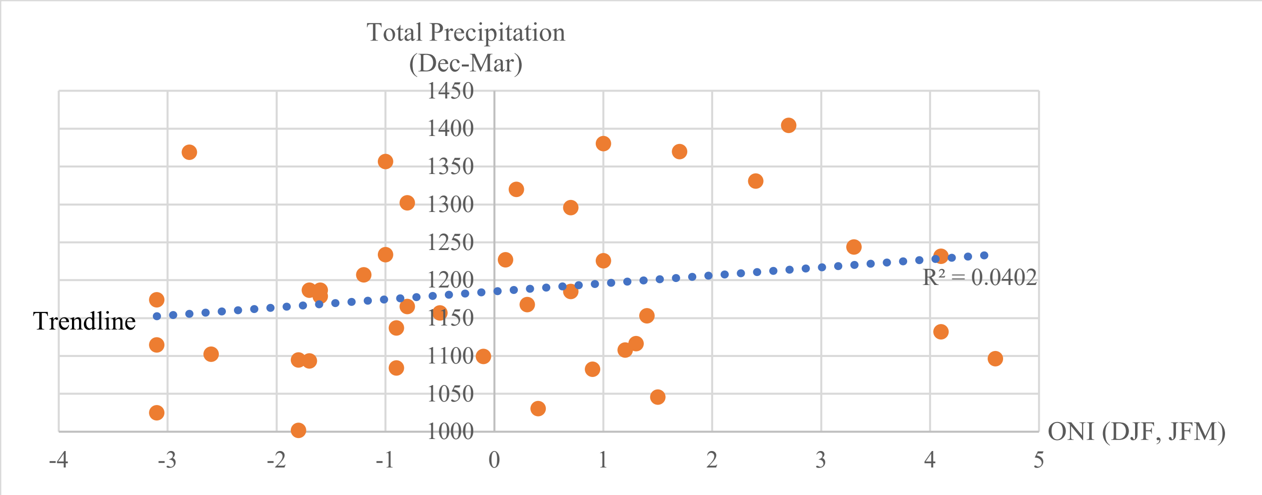

Figure 8 Correlation between ONI and precipitation in the first cropping season for rice.

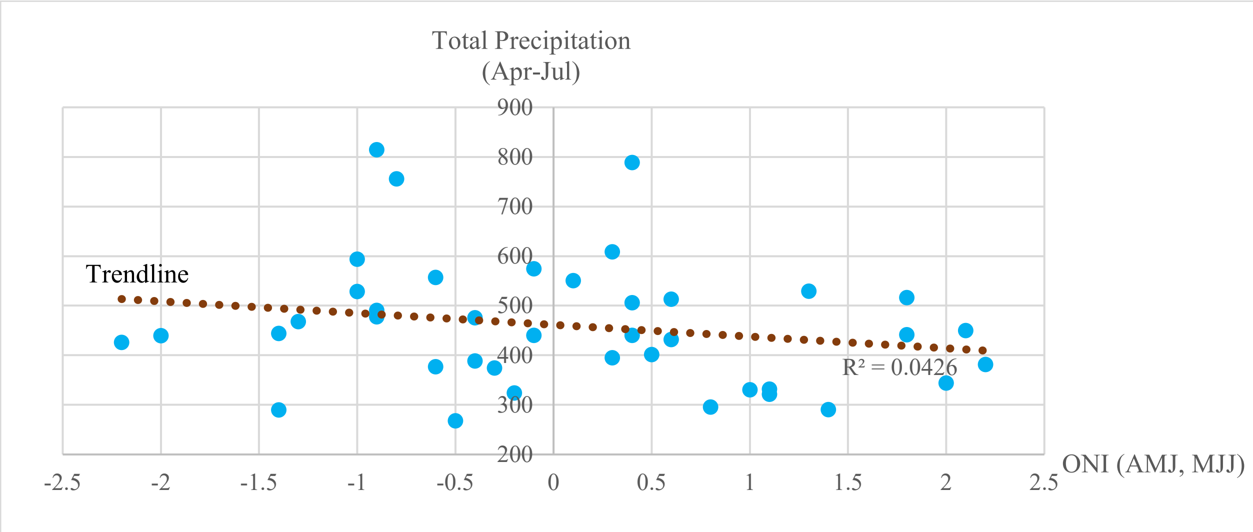

Figure 9 Correlation between ONI and precipitation in the second cropping season for rice.

Figure 8 presents in detail that ONI and precipitation positively correlate in the first cropping season for rice. The total precipitation from December until March is around 1000-1450 mm. In contrast, Figure 9 shows that ONI and precipitation no correlate in the second rice cropping season. Lower total precipitation, about 200-800 mm, was experienced from April until July. It aligns with the previous graph in Figure 7, showing that a water shortage was experienced in the second cropping season.

In summary, farmers feel the weather is getting more erratic. It makes it difficult for farmers to determine cropping times. Meanwhile, farmers do not have advanced knowledge about El Nino and La Nina. The drought phenomena experienced by farmers are likely related to ENSO. The second rice cropping season is affected by ENSO because the dry season has shifted up to May. Agricultural drought causes losses in rice production. Rice also cannot be planted in the third season. In comparison, cassava does not have a significant problem stemming from ENSO because cassava does not require much water.

5) Future impact on the farmers

If in line with projections, future global temperature changes will affect the sustainability of rice and cassava production. Projections of future climate change will continue to increase with rising global temperatures [33]. The extreme event that becomes increasingly concerning is drought intensity in the Bompon sub-watershed. Rice fields and non-irrigated agricultural areas will be drier while the water demand will increase. It dramatically affects the rainfed agriculture sustainability.

Stronger ENSO is more likely to cause an erratic season and lead to crop failure in the future. In addition, El Nino and La Nina are projected to become shorter, even recurring at 2-3-year cycles, meaning ENSO will happen more frequently [34]. The consequence is that precipitation increases in the rainy season while water availability decreases even more in the dry season.

The water availability for agriculture was sufficient in the first cropping season. It is because the first crop coincides with the wet season from November to April. In the future, farmers may only be able to produce rice once a year in the first cropping season. Therefore, it is essential to have adaptation strategies for sustainable rice production in the second cropping season.

The results showed that climate change and climate variability affect water availability in the sub-watershed. The ENSO phenomenon, especially El Nino, has a significant impact on the sustainability of rice production. The dry conditions of agricultural land during El Nino make farmers unable to grow rice. Although cassava can continue to be produced, it cannot wholly replace rice crops.

Discussion

1) Comparison to the other research

El Nino phenomenon correlates with precipitation, which affects water availability in the Bompon sub-watershed. Rainfall projections also indicate precipitation increases in the future [5]. From the data analysis results, the water availability in the Bompon sub-watershed often runs a deficit, especially during the dry season. Further analysis reveals that this is related to the ENSO impact. Furthermore, temperatures have increased in Magelang Regency with a decline in annual rainfall.

Several factors affect rainfall, such as climate change and climate variability. The factor that most affects precipitation is the ENSO event. During the El Nino, the water balance calculation shows large variability between the surplus and deficit. The correlation between water balance and the El Nino shows a deficit water balance during El Nino events.

Drought during El Nino years in the Bompon sub-watershed caused a reduction in rice production. The rice fields are in the valleys from upstream in the north to downstream in the south. Upstream rice fields have a higher drought vulnerability level than downstream areas. Extreme drought happened during the very strong El Nino in 2015. The rice fields could not be cultivated. Meanwhile, the non-irrigated agricultural area for cassava production is on the slope. As opposed to rice, cassava crops could still be produced due to lower water demands.

The farmers explained that the weather has changed over the last twenty years. Rainfall is more erratic, and it has become hotter. Unpredictable weather changes cause changes in the cropping season management. El Nino strongly affected the second season of rice production. In the third planting season, farmers cannot produce rice. Meanwhile, there is a need to implement adaptation strategies to deal with climate change, and ENSO has further driven climate variability.

Climate projections show that the global average temperatures will increase significantly. Projections for the Bompon sub-watershed in Java show rising average temperatures around 1°C under RCP 4.5 scenarios [5]. The sub-watershed could experience more frequent El Nino than La Nina events. ENSO influences the intensity, duration, and frequency of extreme precipitation in Indonesia [35]. Similar research shows Indonesia has a strong ENSO influence during the boreal summer, around June to October [36]. The study analysed climatology and interannual variability in Southeast Asia. The regional climate modelling succeeded in reproducing the Nico 3.4 correlation with precipitation [36].

Paddy Drought Impact Index (PDII) analysed the impact of El Nino on the damage to rice by droughts in Indonesia [37]. There is a correlation between the Nino 3.4 index and drought. As a result, drought has a moderate impact on reduced yields. Their analysis of the Nino 3.4 index or ONI aligns with the prolonged dry days, which results in drought in the Bompon sub-watershed.

Stronger projected changes in future extreme precipitation events [38]. Furthermore, the annual total precipitation parameter implies the extreme precipitation projection at the end of the 21st century [39]. There will be increases in extreme climate events in Indonesia both temporally and spatially [40]. There will be an increase in the minimum and maximum temperature and the successive rainy days, while there will be a decrease in consecutive dry days. A reduction in consecutive dry days indicates reduced drought conditions. The points found in their study differ from the data analysis and farmers' perspectives in interviews because the drought happens more often.

Interviews with the farmers show that the farmers do not have climate adaptation strategies to cope through agricultural management. They only adapt to the existing condition by adjusting the cropping season based on their predictions. Some farmers lack knowledge, causing them to be less adaptive to climate change [41]. Also, the farmers use past experiences to predict the cropping season [42]. They use a standard calculation from past experiences that is no longer suitable for rapid climate change.

Nevertheless, the lack of education among farmers makes strategic adaptations necessary to deal with climate change situations. Capacity building and training are needed to make farmers aware of climate variability and change. Also, awareness of the correlation between ENSO and precipitation will help farmers predict the cropping season more accurately in the future.

2) Future adaptation

The proper adaptation strategy is needed for the farmers to improve agricultural area production. Until now, farmers in the Bompon sub-watershed do not have an adequate adaptation strategy to cope with climate change and ENSO. There is no rice production in the dry season. Cassava production is quite enough when farmers do not have rice production, but cassava cannot completely replace rice as a staple food.

Building farmers' awareness about ENSO and climate change is essential. ENSO prediction could be the basis to help farmers manage their seasonal calendar for planting. Based on ENSO predictions, rice and cassava production can be predicted several months before planting. Moreover, other adaptation measures can be implemented in the Bompon sub-watershed. These include rainwater harvesting, a forecast of the ENSO cycle calendar, improved climate information broadcasting through radio and television, raising awareness of climate change and variation, and capacity building. Building capacity can be achieved through climate-resilient agricultural practices and agricultural plans in the Bompon sub-watershed. The agricultural plans implementing local adaptation should be integrated with farmer training as capacity building. The training should focus on climate change and the effects of ENSO to contribute to climate resilience in agriculture. It should aim to increase farmer's awareness of climate cycles.

The official climate website from NOAA, the ENSO predictions, is available three months in advance [43]. The climate prediction centre is open access data by NOAA [44], but the data needs to be translated and communicated to farmers. The local government and extension services in the Bompon sub-watershed can perform this task. Further training could also guide farmers to apply the forecasts in their management practices.

The seasonal forecast is the sea surface temperature consolidation in Nino 3.4 areas where ENSO events can be predicted. Rice can be produced when the prediction shows no El Nino or sea surface temperature anomalies (maximum 0.5°C) in the next three months. This tool will help the farmers to predict the exact date to start their cropping season. This adaptation will increase the success rate of agricultural production, and yields can be improved. A cropping calendar is essential for rice crops due to decreased water availability. Farmers should be informed if the second growing season is at risk due to El Nino conditions. The farmers can then focus on optimising the rice production in the first season and can better prepare to plant vegetables or maize in the second.

In the Bompon sub-watershed, rainwater reservoirs need to be increased, especially for agricultural purposes. During the dry season, farmers can use water from the reservoir to irrigate the rice fields. Another adaptation that can be applied in the future is increasing cassava production. Due to the relatively low maintenance, cassava crops had a higher success rate compared to rice in drought periods. Rice fields can be converted to non-irrigated agricultural areas during the dry season to produce cassava, maize, peanuts, beans, or a mix of secondary crops through intercropping. As a result, farmers and the government can better implement improved agricultural strategies in the future.

Conclusions

Climate change influences the ENSO phenomenon and affects water availability for rice and cassava production. As rapid climate change continues, it will affect the development of future ENSO cycles. The ENSO amplitudes will increase and cause more extreme events, such as prolonged droughts. In the practical aspects, it will become harder for farmers to predict the cropping season due to increasing uncertainty regarding the transition between dry and rainy seasons. Adaptation strategies are primarily needed in rice fields to deal with reduced agricultural water availability resulting from ENSO cycles. Without adaptation, farmers may only have one rice season within a year. It would have hugely detrimental implications for the local community, who rely on rice for daily basic food needs.

There is a non-significant correlation between climate change, ENSO, and precipitation in small areas such as the Bompon sub-watershed. But still, climate change, as it happens in longer periods, impacts changing ENSO cycles and affects precipitation intensity. Agricultural areas in the Bompon sub-watershed depend on rainfall, including rice fields and non-irrigated agricultural areas. When La Nina happens, precipitation will increase and optimise rice and cassava production.

The limitation of this research is that it needs expert statistical analysis in further analysis. Also, some other factors in water balance analysis are not considered because of data limitations. It can be modified in future studies so that the correlation between El Nino and water balance can include some parameters such as groundwater calculation and exact soil storage.

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