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ARTICLE REVIEW: The Influence Of Climate Change On Rice Production And Cultivation Patterns In Indonesia

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ABSTRACT

Climate change is marked by deviations in the conditions of several climate elements, whose intensity tends to change and deviate from dynamics and average conditions towards a certain direction (increasing or decreasing), whether occurring naturally or potentially occurring more rapidly due to human activities. Climate change is the biggest threat to agrarian countries in the world, including Indonesia. Agriculture is a part of national food security, so climate change will impact production stability because plant growth and development activities heavily rely on climatic conditions. El Nino is estimated to affect harvest yields on at least 25% of global agricultural land. Characteristics of El Nino, such as its intensity, will result in the severity level of global climate impacts. Based on the conducted review, it is understood that climate change indeed significantly influences many aspects, particularly in the field of agriculture (specifically the rice commodity). The impacts of reduced production and changes in rice planting patterns have been felt in various regions of Indonesia.

Keywords : *climate, cropping pattern, mitigation, paddy, production*

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1. INTRODUCTION

Global climate transformation is a negative impact arising from extensive development activities worldwide, the decreasing and deteriorating world forests, and the increasing concentration of CO and CO2 in the Earth's atmosphere, leading to the occurrence of global warming effects. The International Energy Agency (IEA) report (2023) stated that global carbon dioxide (CO2) emissions in 2022 from energy combustion and global industrial activities reached 36.8 gigatons. These emissions increased by approximately 0.5 gigatons compared to 2021, marking the highest value since 1900. Additionally, based on data from the University of Maryland available on Global Forest Watch (2023), tropical countries lost more than 10% of primary rainforests in 2022 compared to 2021, amounting to 4.1 million hectares. In 2021, tropical regions lost about 11.1 million hectares of tree cover. The rate of primary forest loss in tropical regions has been consistent over recent years; however, in 2021, the tropical areas lost 11% less primary forest compared to 2020, following an increase of 12% from 2019 to 2020, mostly due to forest fires. The loss of tropical primary forests in 2021 resulted in 2.5 gigatons of carbon dioxide emissions. Based on this data, Indonesia is one of the countries that experienced the largest loss of tropical primary forests in 2022 (230,002 hectares) (Fig. 2). This loss can occur due to mechanized land clearing for agriculture and logging, as well as natural causes such as wind damage and meandering rivers. The three-year moving average can provide a more accurate depiction of data trends due to uncertain year-to-year comparisons. All figures are calculated with a minimum tree canopy cover density of 30 percent.

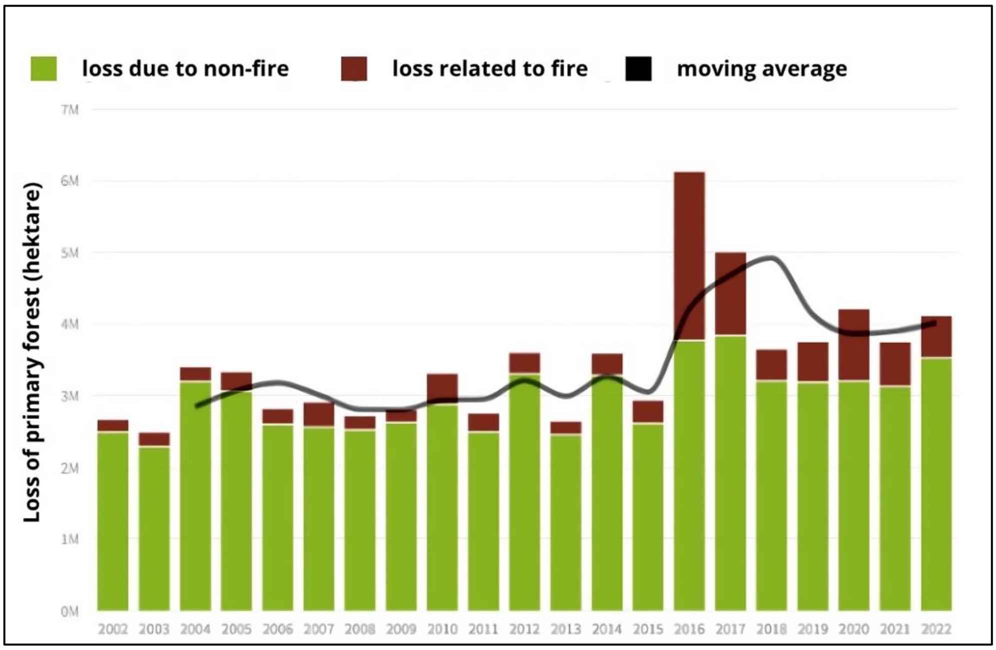

Figure 1. Graph of tropical primary forest loss worldwide from 2002 - 2022. (Source : Global Forest Watch, 2023).

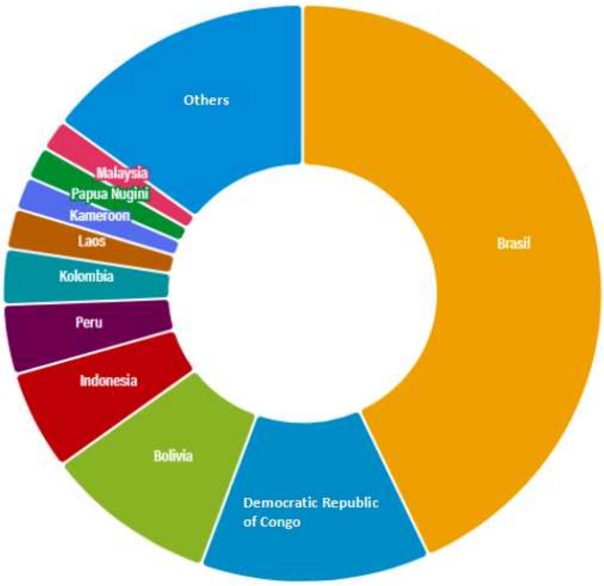

Figure 2. Top countries for the loss of primary forest based on their area in 2022 (Source : Weisse *et al*., 2023).

Global warming will impact climate change. Rejekiningrum & Heriyanto (2011) stated that this condition will be marked by deviations in several climate elements, whose intensity tends to change and deviate from dynamics and average conditions towards a specific direction (increasing or decreasing), whether occurring naturally or potentially accelerated due to human activities. Climate change is the greatest threat to agrarian countries in the world, including Indonesia.

The agricultural sector is part of national food security; thus, climate change will affect the stability of agricultural production because plant growth and development activities heavily depend on climatic conditions. Climate change will directly influence the physiological processes of cultivated plants. Irwan (2012) explains that plant responses due to environmental factors will be observed in the morphophysiology of these plants. High temperatures during critical phases disrupt plant development and flowering processes. Increases in temperature and humidity can also trigger outbreaks of pests and plant diseases. Droughts and floods can decrease agricultural production. Prolonged droughts and floods due to climate change and inadequate water management, leading to excessively low or high groundwater capacity, result in a significant decline in crop production (Ruminta & Handoko, 2016).

Rice, corn, and soybeans are the main staple food commodities nationally. The production of these commodities still experiences fluctuations, partly due to global climate change. Naylor *et al*. (2001) mention that climate variability related to ENSO (El-Nino Southern Oscillation) is highly vulnerable and has an impact on rice and legume production, especially in Indonesia, significantly affecting planting patterns. The El-Nino phenomenon will lead to drought, resulting in a delayed onset of the rainy season, a considerable decrease in production, and an early start to the dry season. Meanwhile, the La Nina phenomenon can cause floods that may trigger increased attacks from plant pests. The ENSO phenomenon has a greater impact on food crops compared to perennial crops because food crops have a relatively shorter lifespan and are highly dependent on seasonal and weather conditions (Irawan, 2006; Utami *et al*., 2011).

The Geoglam Crop Monitor (2015) explains that the occurrence of El Nino is estimated to affect harvest yields on at least 25% of global agricultural land. Characteristics of El Nino, such as its intensity, will determine the severity of global climate impacts. Current estimations for a strong El Nino will significantly impact regional rainfall patterns and agricultural harvests at both regional and global levels (Figure 3).

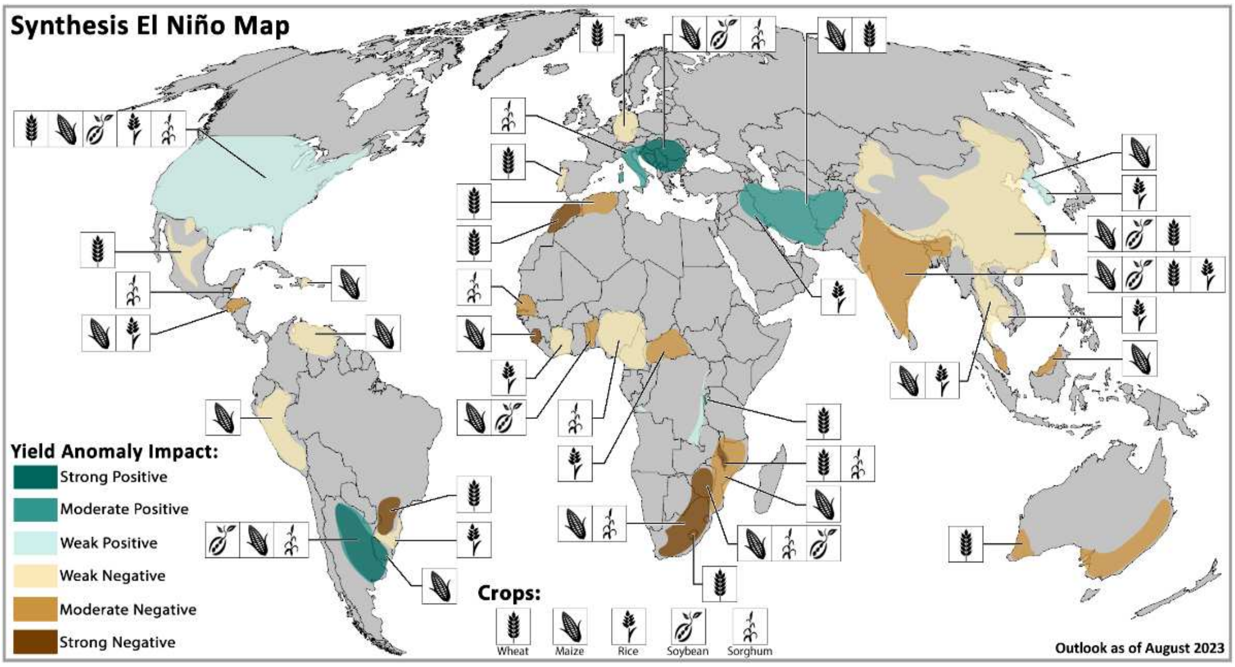

Figure 3. Historical crop yield conditions during El Niño events for wheat, maize, rice, soybeans, and sorghum using FAO country level yield data and ERSSTv5 from 1961-2020. In countries with more than one crop affected, the color reflects the strongest effect (Source : Geoglam Crop Monitor, 2023).

The occurrence of delayed planting seasons or crop failures will have significant impacts, both directly and indirectly, on national food security. The phenomenon of crop damage in food crops due to climate variability demonstrates changes in seasons and planting patterns in Indonesia. Therefore, the purpose of writing this article is to provide information on the impacts of climate change on planting patterns in rice cultivation occurring in Indonesia.

2. REVIEW

2.1 Climate Change and Decline in Rice Production

Climate change, particularly rainfall patterns, poses the most significant threat to agrarian countries like Indonesia, as water availability is a fundamental requirement in agricultural cultivation in tropical regions, especially in the cultivation of wetland rice. Based on research by Peking University and a team published in the journal Nature Food regarding the impact of climate change on global rice production, utilizing long-term weather observations and manipulative experiments on multi-level rainfall to explore the magnitude and mechanisms of extreme rainfall on rice productivity, the findings indicate that rice is one of the commodities most affected by climate change. Projections suggest a potential 8.1% decline in global rice production by the year 2100 (Arif, 2023). In Indonesia, during El Nino phenomena, it is predicted that there could be a reduction in rice production by about 300 thousand to 1.2 million tons (Damiana, 2023). From January to August 2023, it was recorded that in Subang Regency, West Java, there was a decrease in harvest yields and rice cultivation area due to the impact of El Nino. In 2022, the cultivated area was 114,854 hectares, while in 2023, it reduced to 109,806 hectares. The resulting production in 2022 was 661,094 tons, whereas in 2023, it was 620,499 tons (Efendi, 2023). Budianto and Sidik (2023) added that until September 2023, the El Nino level in Indonesia was at a moderate level, with an index value of 1.68. El Nino will reach a strong level if the index reaches a value of 2.0. Concurrently, the El Nino phenomenon with the peak of the dry season in Indonesia has the potential to trigger drought in rice cultivation areas, leading to reduced productivity.

Climate change is characterized by deviations in several climate elements whose intensity tends to change or deviate from dynamics and average conditions towards a specific direction (increase or decrease). As observed in Table 1, changes in climate elements occurred in Malang Regency, East Java, during two different periods. Analyzing the climate diversity in two observed time periods shows that 72% of rice productivity in Malang Regency is influenced by cultivation techniques such as irrigation systems, planting methods, varieties, spacing, and fertilization. Meanwhile, 28% of rice productivity in that area is influenced by climate change factors (precipitation, temperature, length of radiation, and moisture) (Pramasani & Soelistyono, 2018).

Table 1. Changes in climate elements in Malang Regency, East Java, in two different periods (1997-2006 and 2007-2016) (Source: Pramasani & Soelistyono, 2018).

Month	Period								Changes			
	1997-2006				2007-2016							
	Rainfall (mm)	Temperature (°C)	Length of Radiation (hours)	Moisture (%)	Rainfall (mm)	Temperature (°C)	Length of Radiation (hours)	Moisture (%)	Rainfall (mm)	Temperature (°C)	Length of Radiation (hours)	Moisture (%)
January	375,00	26,07	3,75	84,24	293,11	25,98	4,29	81,90	+81,89	-0,09	+0,55	-2,44
February	293,40	26,16	4,19	84,14	309,88	25,94	3,82	82,05	+16,48	+2,08	+0,38	-2,08
March	401,80	26,08	4,08	83,42	264,58	26,06	4,50	81,87	+137,22	-1,55	+0,42	-1,55
April	236,30	26,23	4,77	81,69	275,09	26,25	4,80	80,95	+38,79	+0,74	+0,03	-0,74
May	85,30	26,42	5,87	79,07	135,02	26,18	5,40	78,00	+49,22	-1,07	-0,47	-1,07
June	90,70	25,63	6,21	77,98	101,26	25,03	5,88	76,11	+10,56	-1,87	-0,34	-1,87
July	38,72	25,07	6,13	76,69	29,70	24,54	6,27	75,33	-9,02	-1,36	+0,14	-1,36
August	24,40	24,95	6,49	74,42	19,09	24,55	6,34	73,83	-5,31	-0,59	-0,15	-0,59
September	35,18	25,87	6,33	74,32	56,99	25,41	6,97	71,82	+21,81	-2,05	+0,64	-2,50
October	126,80	26,53	6,05	75,32	139,46	26,67	6,83	71,20	+12,66	+4,12	+0,78	-4,12
November	285,30	26,71	5,72	80,02	275,95	26,53	6,45	78,27	-9,35	-1,75	+0,73	-1,75
December	372,60	25,66	4,52	84,75	403,87	26,02	4,56	85,53	+31,27	-1,22	+0,04	-1,22
Average	197,13	25,95	5,34	79,67	192,00	25,76	5,51	78,07	-5,13	-0,16	+0,17	-1,60

Additionally, the study by Ruminta *et al*. (2018) indicates climate change indicators in several regions of South Sumatra Province, showing an increase in air temperature by 0.4-0.6°C and a decrease in rainfall by 0-197 mm (Figure 4). The rise in air temperature and decrease in rainfall resulted in a change in Oldeman's classification and hitergraph, indicating that these areas tend to become drier. Five regions in South Sumatra Province experienced changes in the Oldeman Classification, including Musi Rawas Regency (from B1 to D1), Musi Banyuasin (from B1 to D1), Ogan Komering Ulu Timur (from C2 to C1), Ogan Ilir (from C2 to C1), and Ogan Komering Ilir (from C1 and C2 to B1). With such conditions, Indonesia faces a potentially high-risk level of a 1.37% annual.

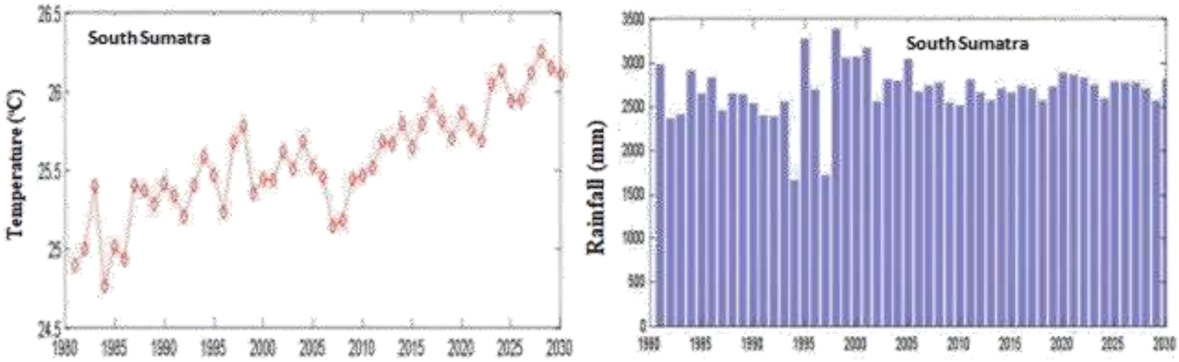

Figure 4. The pattern of air temperature and rainfall in South Sumatra Province from 1980 - 2030.

Climate experts believe that the occurrence of irregular climate variations is closely related to the extreme climate phenomenon known as ENSO (El Niño Southern Oscillation). Boer and Meinke (2002) suggest that in monsoon regions such as southern Sumatra, Java, and eastern Indonesia, the Southern Oscillation strongly influences climate factors such as radiation, rainfall, evapotranspiration, temperature, and air humidity, all of which affect the growth and development of cultivated plants. Extreme climate events like El Niño and La Niña in Indonesia significantly impact the development of food crop production. The substantial influence of ENSO can be observed in the occurrence of prolonged droughts and dry spells in various regions in Indonesia coinciding with El Niño events (Yasin *et al.*, 2002).

The relationship between the El Niño phenomenon and the decline in rice production in Indonesia is emphasized by Ruminta and Handoko (2012), as shown in Figures 5 and 6. El Niño has a significant impact on reducing rice production and productivity in Indonesia. Saputra *et al.* (2018) add that changes in the agro-climatic zone of the Oldeman classification have been observed to affect the alteration of rice planting patterns and decreased productivity in rain-fed paddy fields in several rice-producing regions of West Sumatra, including Luak Situjuh, Panti, and Lima Kaum.

The IPCC (Intergovernmental Panel on Climate Change) released a report on the situation of climate change, indicating a human-caused climate crisis that has rapidly escalated the intensity and frequency of extreme weather events worldwide. These events include increasingly intense heatwaves, heavy rainfall, droughts, and tropical cyclones. If global temperature warming reaches 1.5°C, it is estimated that 8% of agricultural land may no longer be usable (Greenpeace Indonesia, 2023). The impact of climate change on agricultural systems highly depends on various factors such as the cultivated commodities, agricultural orientation, operational scale, and the quality of natural resources and human resources. Due to the diversity of climate patterns, agricultural systems, social, economic, political, and environmental conditions, vulnerability and the risks associated with climate change will differ across regions.

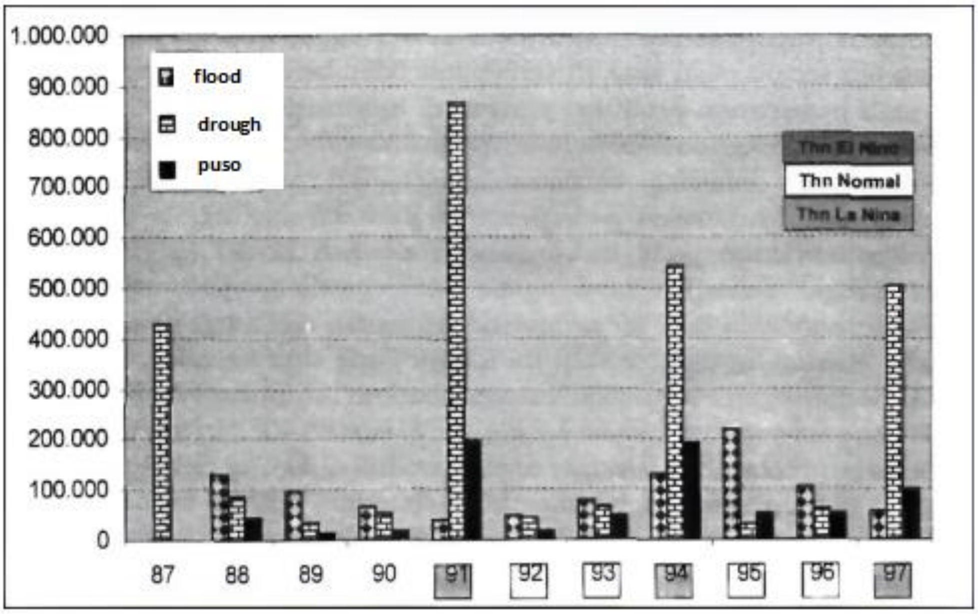

Figure 5. The influence of the ENSO phenomenon on agricultural productivity in Indonesia (1987 - 1997). (Source : Jasis & Kamara, 1999; Yusmin, 2000).

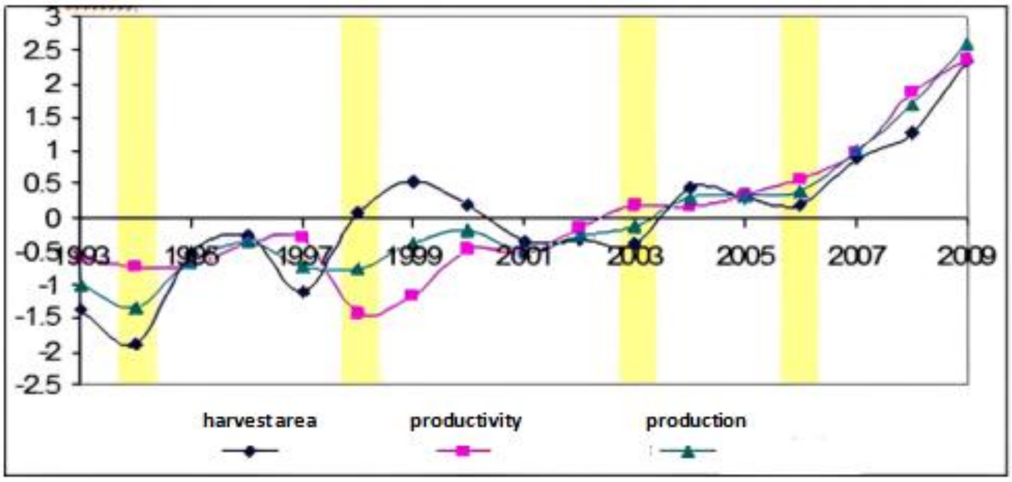

Figure 6. Harvested area and rice production in Indonesia (1993-2009) (The yellow line indicates the years of El Nino occurrence). (Source :Ruminta dan Handoko, 2012).

The potential decrease in crop production is obtained from empirical studies assuming a close relationship between reduced food crop production and changes in temperature and rainfall. The effect of climate change on rice production from irrigated fields is caused by increased temperatures and reduced rainfall, calculated based on the decreased yield and harvested area after climate change events (Ruminta, 2016). Reduced rainfall leads to increased water scarcity stress. If this condition is accompanied by rising temperatures, it will increase evapotranspiration, leading to reduced plantable paddy fields and harvested areas (Sulistyono *et al*., 2005; Handoko, 2007; Tubur *et al*., 2012; Ruminta and Handoko, 2016). Higher temperatures disrupt the agricultural system, making plants highly vulnerable, especially during critical phases like flowering and seed development. High temperatures occurring simultaneously with drought can cause disasters in agricultural lands (Yoshimoto *et al*., 2010; Shakoor *et al*., 2015).

According to estimations by Nurhayanti and Nugroho (2016), maximum temperature and rainfall significantly affect rice productivity in Indonesia. The impact simulation was conducted with an increase in maximum temperature and rainfall above the optimum point, ceteris paribus. A 1% increase in rainfall will decrease rice productivity by 0.00796% ceteris paribus. Meanwhile, a 1% increase in maximum temperature above the tipping point will reduce rice productivity by 0.09039% ceteris paribus. Continuous increases in rainfall and maximum temperature will correlate with the decline in national rice productivity.

2.2 Climate Change and Shifting Rice Planting Patterns

Climate change, such as the tendency for shortened rainy seasons and fluctuations in rainfall, leads to changes in the planting season, cultivated area, planting patterns, and production (Balitbang Pertanian, 2011). Tjasyono (2004) adds that the rice growth period is determined by the cultivated varieties, assuming that a sequence of five consecutive wet months in a year is optimal for one planting period. If there are more than nine consecutive wet months, farmers can conduct two planting periods. Conversely, if there are fewer than three consecutive wet months, rice cultivation without additional irrigation is not possible.

Based on the research by Widoretno and Hadi (2013) on climate change and planting patterns in the provinces of Yogyakarta and Central Java using the overlay method (comparing agroclimatic maps in 1975 and 2008), it was found that several regions in these provinces had significant changes in agroclimatic zones, encompassing both extensive and narrow areas (Figure 4). Some areas experienced changes in agroclimatic zones, such as a shift from climate type B1 to B2 in Cilacap district, B1 to C2 in Wonosobo and Cilacap districts, C2 to C3 in Kulon Progo, Blora, Purworejo, and Boyolali districts, C2 to D3 in Blora, Sleman, and Demak districts, C3 to D2 in Klaten, Bantul, and Gunungkidul districts, D3 to C3 in Jepara and Tegal districts, and from E to D3 in Pati and Rembang districts.

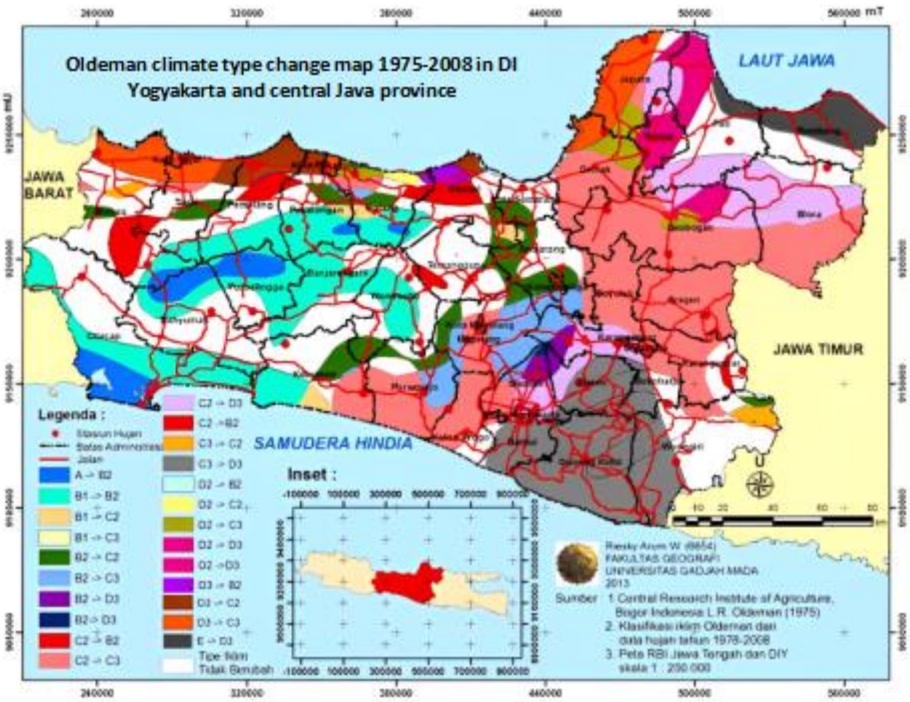

Figure 7. The map resulting from overlaying the agroclimatic maps of 1975 and 2008 in the provinces of Central Java and Yogyakarta.(Source : Widoretno & Hadi, 2013).

There have been changes in cropping patterns in both irrigated and rainfed rice fields in areas experiencing changes in climate types, based on research conducted in the provinces of Central Java and Yogyakarta (Table 2). However, in some areas, the cropping patterns could be maintained without changes due to farmers' adjustments in irrigation techniques and the use of specific plant varieties. The shift in climate types is caused by changes in rainfall patterns, altering the number of dry and wet months within a year. Climate type changes will affect the cropping patterns of cultivated plants, as the transition in climate types influences the shift in planting seasons. Faced with these conditions, farmers adjust the planting timing, leading to changes in cropping patterns. Overall, cropping patterns in regions experiencing changes in climate types have shifted, but there are various adjustments made by farmers in response to these changes. Due to these adaptations or adjustments made by farmers, cropping patterns can remain constant or change to yield essential food crops to meet demands.

Table 2. Changes in cropping patterns in sample areas in the provinces of Central Java and Yogyakarta. (Source : Widoretno & Hadi, 2013).

Changes in cropping patterns		Irrigated rice fields	Rain-fed rice field	Totally	%
Rice three times	Rice two times - Palawija	Cilacap district, Boyolali district, Demak district, Sleman district, Klaten district	-	5	22,7
Rice two times - Palawija	Rice one time-Palawija	-	Rembang district	1	4,55
Rice two times - Palawija	Rice three times	Purworejo district	-	1	4,55
Rice one time-Palawija-Fallow	Rice two times-Palawija	Bantul district	-	1	4,55
Rice two times-Fallow	Rice two times-Palawija	Pati district, Jepara district	-	2	9,09
Rice one time-Fallow	Rice one time-Palawija-Fallow	-	Jepara district	1	4,55

The research findings by Saputra *et al*. (2018) indicate a shift in climate types in five rice-producing districts in the province of West Sumatra across three different periods (1910-1941, 1977, and 1985-2015). The five locations observed are as follows: Lima Kaum shifted from E1 (Very dry) to D1 (Dry) and became E3 (Very dry), Rao changed from D2 (Dry) to D1 and became C1 (Fairly wet), Luhak Situjuh transitioned from B1 (Wet) to E1 (Very dry), Gunung Talang shifted from A1 (Very wet) to B1 (Wet), and Sijunjung shifted from C1 (Fairly wet) to B1 and became D1 (Dry). Meanwhile, changes in cropping patterns are outlined in Table 3.

Table 3. Changes in rice cropping patterns from 1977 to 2015 in several rice-producing regions in the province of West Sumatra (Source : Saputra *et al.*, 2018).

No.	Location	Planting Pattern					Compatibility
		Based on Oldeman Classification		Actual			
					2015		
		1977	2015	1980	Irigasi	Tadah Hujan	
1.	Luhak Situjuah	B1 : paddy - palawija - paddy (2PS)	E1 : 1 time Palawija	paddy - paddy (1,5)	Paddy - paddy (1,5)	2 times Palawija	Not suitable
2.	Rao	D1 : paddy - palawija	C1 : paddy - Palawija - Palawija	paddy umur lama	paddy - paddy (1,5)	paddy - paddy (1,5)	Not suitable
3.	Limo Kaum	D1 : paddy - palawija	E2 : 1 time Palawija	paddy	paddy - paddy	1 time paddy, 2 times Palawija	Not suitable
4.	Gunung Talang	B1 : paddy- palawija - padi (2PS)	B1 : paddy - palawija - padi (2PS)	paddyi - paddy	paddy - paddy	paddy - paddy	Suitable
5.	Sijunjung	B1 : paddy - palawija - paddy (2PS)	D2 : 1 time paddy Sawah/ 1 time Palawija	paddy umur lama	paddy - paddy (1,5)	paddy - paddy (1,5)	Not suitable

3. CONCLUSION

Based on the conducted reviews, it is understood that climate change significantly impacts various aspects, including the agricultural sector, particularly in rice cultivation. The impact of reduced production and changes in rice planting patterns has been felt in various regions of Indonesia.

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