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RESEARCH ARTICLE

Climate Change Impact Analysis on Food Availability in the Province of Kalimantan Utara, Indonesia

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Abstract Climate change directly affects crop yields as a measure of food availability by, e.g., causing harvest causing harvest failure. El Niño and La Niña are two weather patterns that affect the climate of Indonesia, a country at low latitudes, and reportedly increase its vulnerability to food insecurity. This study was designed to analyze the impact of climate change on food availability in the Province of Kalimantan Utara using secondary data (i.e., temperature, rainfall, and agricultural production) as the base data. This study employed quantitative descriptive analysis to explain the results expressed in maps, tables, and graphs and the regression technique to determine the impact of climate change on food availability. Regression analysis revealed that climate change significantly shaped the availability of rice (0.008) and vegetable commodity (0.000) but posed insignificant effects on tubers, legumes, and fruits. Apart from climate change, food availability also depends on land management, land suitability, capital, technology, and cultivated plant variety.

1. Introduction

Climate change in the medium and long terms adversely threatens national and even global food security and agricultural system stability (Liu, 2016). Weather conditions, as well as microclimate and macroclimate (i.e., rainfall and temperature) that are less conducive to vegetative and generative plant growth can interfere with the farming system (Ruminta, Handoko, & Nurmala, 2018; Sumaryanto, 2012), leading to perturbed growing seasons and decreased harvest quantity (Lobell, Schlenker, & Costa-Roberts, 2011) and area (Müller, Cramer, Hare, & Lotze-Campen, 2011; Niang & et al., 2014; Sarr, 2012). Temperature increase that results in climate change can alter rainfall intensity (Songok, Kipkorir, & Mugalavai, 2011), which is the foremost determinant of food production (Weldearegay & Tedla, 2018). Wet years are generally associated with higher food production, whereas dry years are generally associated with lower production (Nath & Behera, 2011).

Global warming, a fundamental aspect of climate change, brings about anomalies in rainfall, consequently, elevating the risks of drought (El Niño) and flood (i.e., La Niña)(Niang & et al., 2014; Tschakert, Sagoe, Ofori-Darko, & Codjoe, 2010). El Niño and La Niña tend to lower agricultural production and threaten food availability, which have a connection to Goal 13: Climate Action in Sustainable Development Goals (Niang & et al, 2014; Thornton, Jones, Ericksen, & Challinor, 2011). Generally, the El Niño Southern Oscillation can intensify rainfall, tropical cyclones, drought, forest fires, and floods, increase the emergence of other extreme weather, and disrupt agricultural production worldwide (Winarto, Stigter, Dwisatrio, Nurhaga, & Merryna Bowolaksono, 2013). La Niña is linked to flooding in agricultural areas and subsequent crop damage. At the vegetative stage, flooding can decrease grain yields by as much as 124 kg/ha/day, whereas at the reproductive stage, the loss can reach 157 kg/ha/day (Akhmad, 2017).

Compared with other parts of the world, countries at low latitudes or the tropics are more vulnerable to climate change (Weldearegay & Tedla, 2018) and at a higher risk of depletion because they have a wide rainfall variability (Slingo, Challinor, Hoskins, & Wheeler, 2005). The Food and Agriculture Organization (FAO) reported that, in 2010, 65 countries were on the verge of losing their cereal production by 280 million tons because of global climate change. FAO also estimated that several developing countries in Asia and Africa will suffer from hunger by 2030. Long-term climate change projections have shown that such negative impacts will be even worse after 2030. Climate change vulnerability, as measured from the yields of agriculture, will be higher in developing countries in-the-tropics-than-in developed countries (FAO, 2016) because of slow technological advancements. Moreover, the lack of resources to diminish the negative impact on agriculture, high dependence on the farming sector, and large population size (FAO, 2010) can reduce food availability. Studies of the impact of climate change on food crop production are thereby necessary to determine the extent to which climate change affects agricultural yields, particularly in Indonesia as a developing country.

2. Methods

This study was conducted on the border of Indonesia and Malaysia, i.e., the Province of Kalimantan Utara (Figure 1).

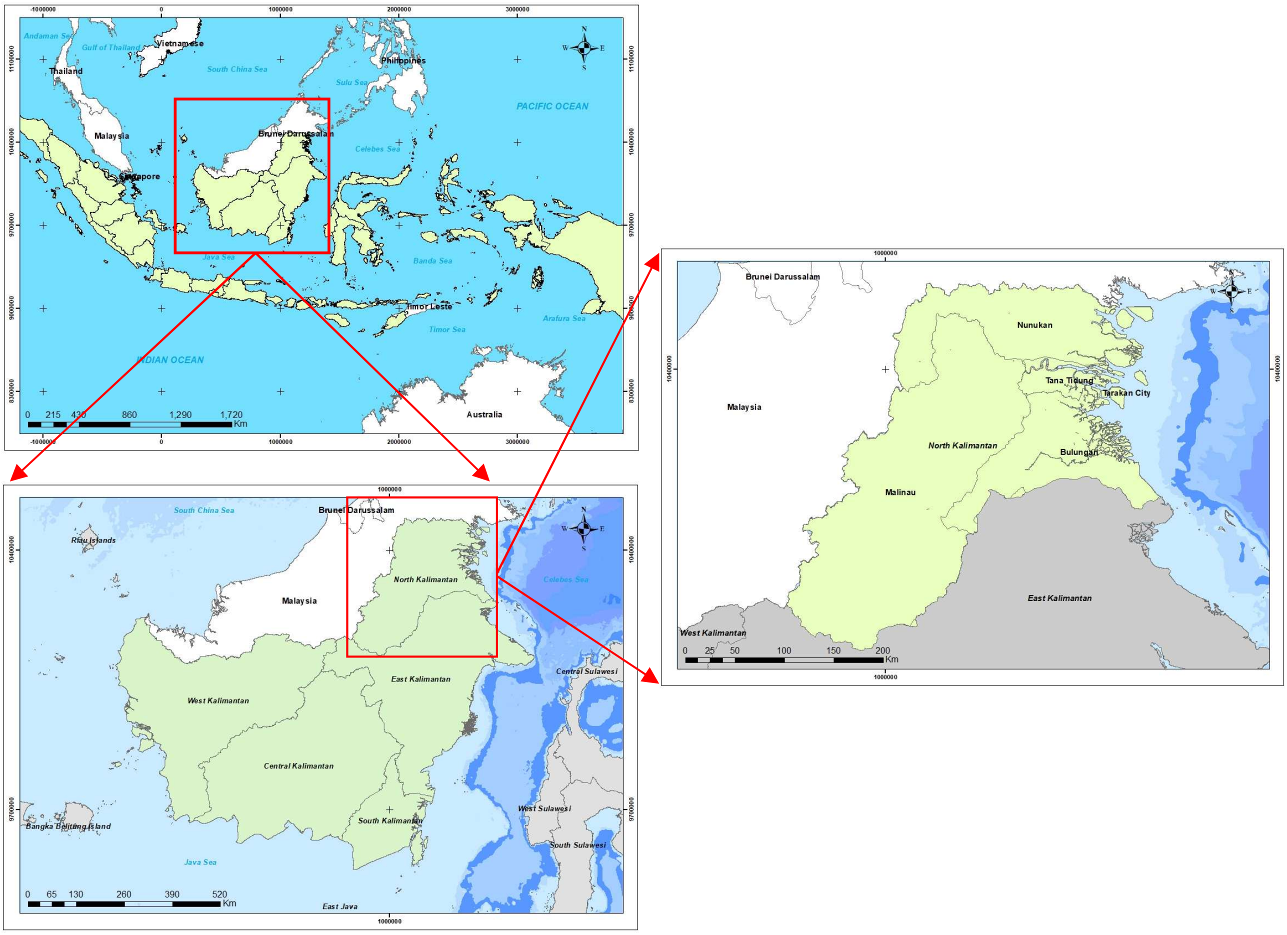


Figure 1: Location of the research area in the Province of Kalimantan Utara, Indonesia.

The data were analyzed using quantitative descriptive and statistical regression methods to obtain information on climate change (i.e., temperature and rainfall), changes in food availability, and the impact of climate change on food availability. Climate change was determined from trend charts and isohyetal maps processed in the ArcGIS application. Food availability, was assessed from the data on agricultural production in the Province of Kalimantan Utara. The data on the annual yields of grains, tubers, legumes, fruits, and vegetables were obtained from Statistics Indonesia (Badan Pusat Statistik), processed by the trends method, and presented in graphs for further spatial analysis. The impact of climate change on food availability was analyzed by multiple linear regression in the SPSS software, with rainfall and temperature as independent variables and food availability as the dependent variable. The simultaneous effects that all independent variables had on the dependent variable were identified by an F-test, commonly known as concurrency testing, model testing, or ANOVA. This test indicated whether the regression model developed was good/significant or not good/not significant. The model considered significant if F_{count} is higher than F_{table} with a significance value of <5%, whereas it is considered insignificant if F_{count} is lower than F_{table} with a significance value of <5%.

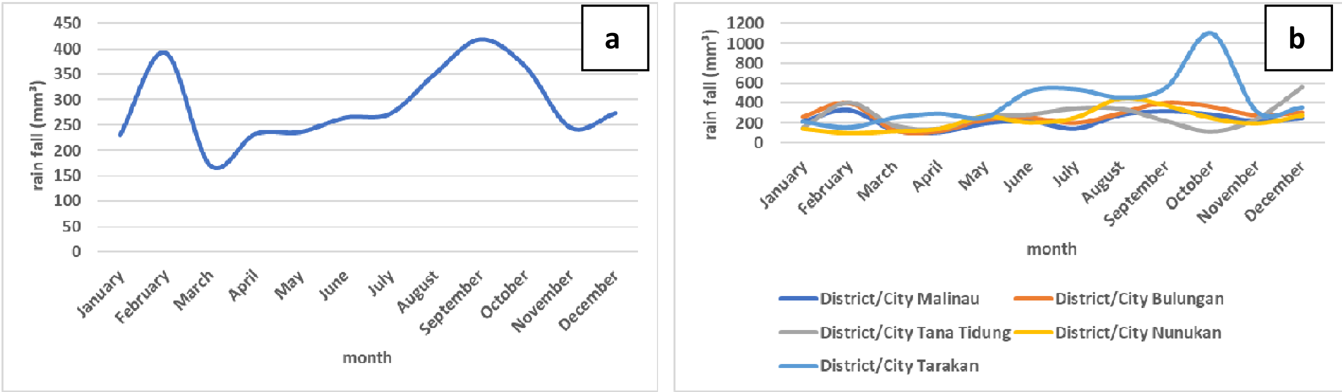
3. Results and Discussion

Climate Change

Food production is largely influenced by interannual climate variability (i.e., optimal temperature, precipitation, and radiation). Extreme events such as climate change (Hansen, Sato, & Ruedy, 2012), account for the failure in food availability (Weldearegay & Tedla, 2018). Research on climate variability in the Province of Kalimantan Utara is vital, given that it is relatively vulnerable to climate change.

Changes in rainfall patterns and temperatures can characterize climate change. A trend of variation was observed in the rainfall pattern of the province. There were no rain months when rainfall was expected, and the rainy seasons extended to the dry periods. According to the Meteorological, Climatological, and Geophysical Agency (BMKG), in March 2018, the rainfall in the Province of Kalimantan Utara was above average.

This province has a bimodal monthly rainfall distribution with two rainfall peaks and categorically rainy seasons nearly throughout the year, or called an equatorial rainfall pattern. Rainfall usually peaks in March and October or during the equinoxes, i.e., when the sun is near or perpendicular to the equator (Hermawan, 2010) twice a year (Fadholi, 2013). Apart from the two peaks, the equatorial rainfall pattern also consists of two lows during the dry season, which often occur in January and July. Figure 2 shows the shifts in the maximum and minimum rainfall in the Province of Kalimantan Utara that have modified the rainfall pattern. For instance, two rainfall highs occurred in February and September (instead of March and October), whereas two rainfall lows were identified in January and March (instead of January and July). Changes in rainfall patterns are one factor responsible for the loss of arable land (Kotir, 2010; Niang & et al., 2014), where food crops are produced (Lindgren, Albihn, & Andersson, 2011).



Source: Secondary Data Processing, 2018

Figure 2: Monthly rainfall charts of the province (a) and the regencies (b) of Kalimantan Utara in 2012-2018

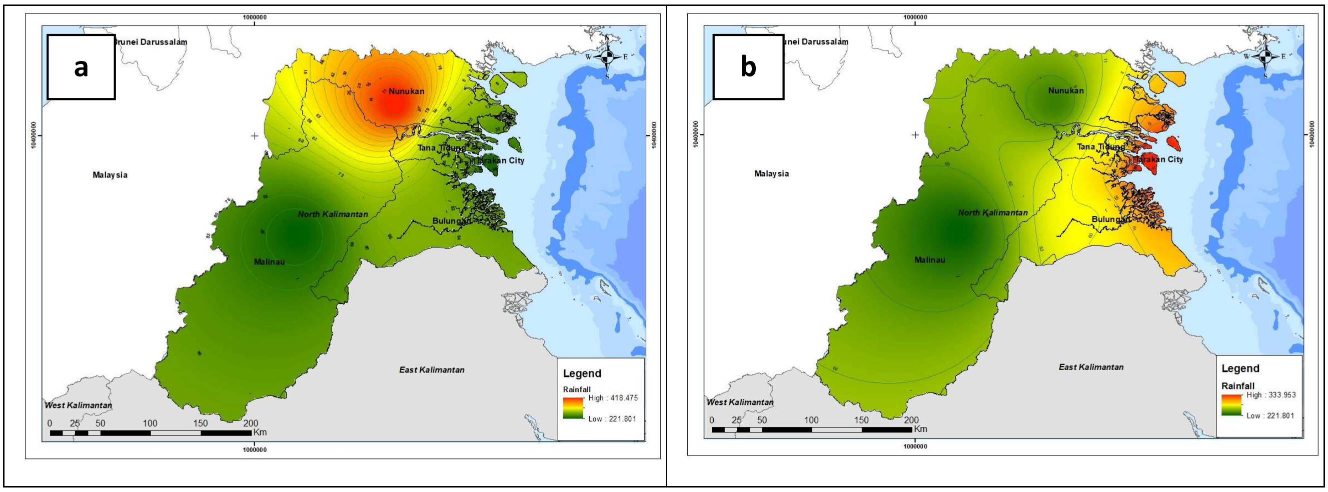


Figure 3. Average rainfall maps of the Province of Kalimantan Utara in 2012 (a) and 2018 (b)

Changes in average rainfall in the period between 2012 and 2018 are shown in Figure 3. In 2012, the average rainfall was generally high in all areas of the province, except for Tarakan City and Malinau Regency. Meanwhile, in 2018, the average rainfall of nearly the entire region was low, signifying a categorically rapid change in precipitation.

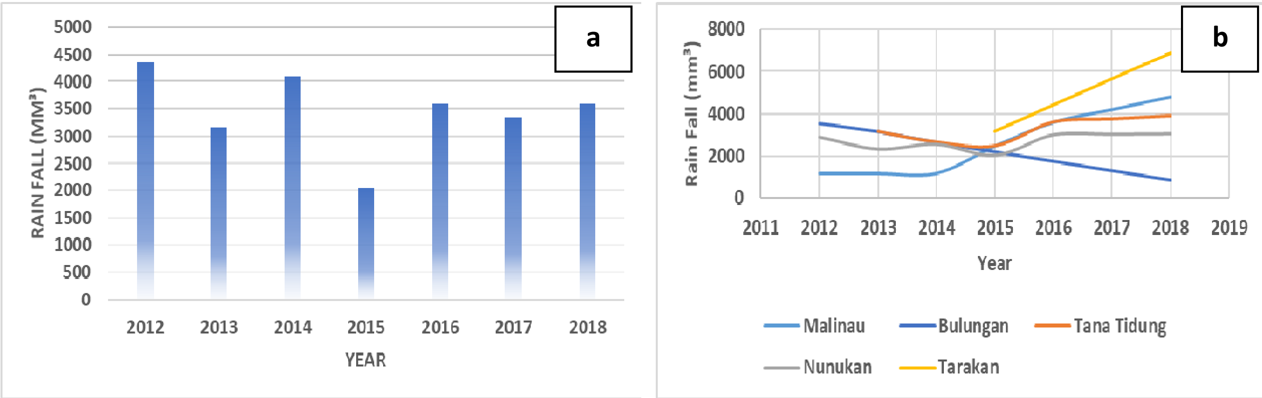
Apart from the province, a significant change also occurred in several regions in Indonesia. Between 2010 and 2039, Indonesia is estimated to experience an increase in rainfall, as evidenced by positive anomalies of the convection zone, temperature increease, and changes in evaporation, particularly for the highest convection zones along the Malacca Strait, Banda Sea, Karimata Sea, and Arafura Sea (Syahbuddin & Wihendar, 2014). Such an increase has been identified in, among others, Kulon Progo Regency in Yogyakarta (Harini & Nurjani, 2014).

In the 6 years (i.e., 2012-2018), rainfall fluctuated annually (Figure 4). The 2012 data showed the highest rainfall in the province, which amounted to 4,364.3 mm^3, whereas the 2015 data showed the lowest rainfall (wich amounted to 2,043.3 mm^3). In 2018, rainfall was the highest in Tarakan City and the smallest in Bulungan Regency. The optimum amount of rain is required to improve productivity and food security. In high quantities, rainwater can trigger soil erosion or landslides (i.e., environmental degradation), resulting in decreased agricultural production and crop failure—the two determinants of food availability.

Figure 5 shows the monthly fluctuation of temperature in the Province of Kalimantan Utara. The highest temperature was in April, and the lowest temperature was in December. The graph also illustrates the absence of a relationship between rainfall and temperature. For instance, the rain peaked twice in 1 year, but the temperature was at its highest level only once.

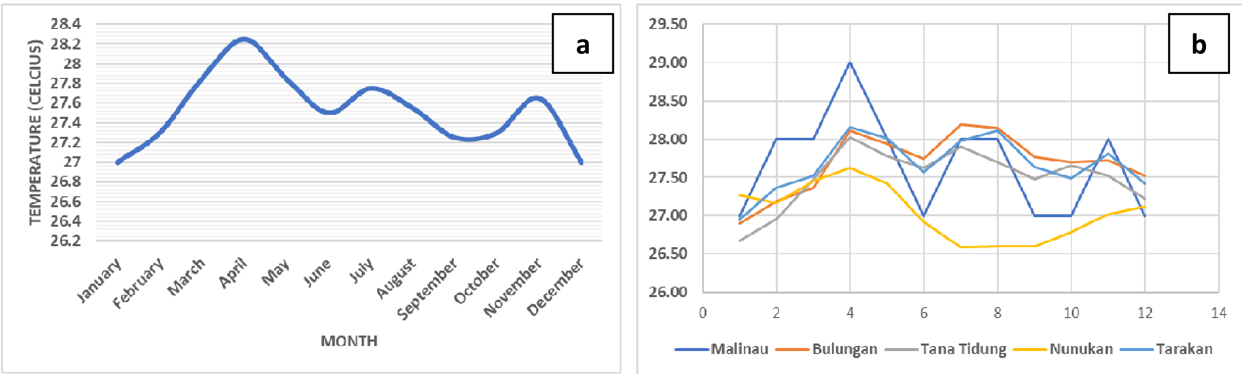
The annual rainfall maps shown in Figure 6 indicate that the rain fluctuated constantly from 2012 to 2018. In 2012, the maximum and minimum rainfall occurred in Bulungan and Malinau Regencies, respectively. For Nunukan, and Tana Tidung Regencies and Tarakan City, the rain was moderate. In 2018, Bulungan Regency no longer received the highest rainfall. By contrast the lowest, and the highest rainfall were identified in Tarakan City. In other words, from 2012 to 2018, Tarakan City and Malinau Regency experienced increased rainfall, whereas Nunukan, Tana Tidung, and Bulungan Regencies received annual rainfall that was lower than average.

The graph shown in Figure 7 illustrates the annual temperature fluctuation in the Province of Kalimantan Utara between 2012 and 2018. The highest and lowest temperatures occurred in 2015 and 2018, respectively. During this period, the temperature of the entire province increased, except for Nunukan Regency, wich instead experienced a temperature, decrease because of several conservation practices. Temperature increase perturbs the plant production process directly and indirectly (Weldearegay & Tedla, 2018).



Source: Secondary Data Processing, 2018

Figure 4. Monthly rainfall charts of the province (a) and regencies (b) of Kalimantan Utara in 2012-2018



Source: BPS Data Analysis

Figure 5: Monthly temperature charts of the province (a) and the regencies (b) of Kalimantan Utara

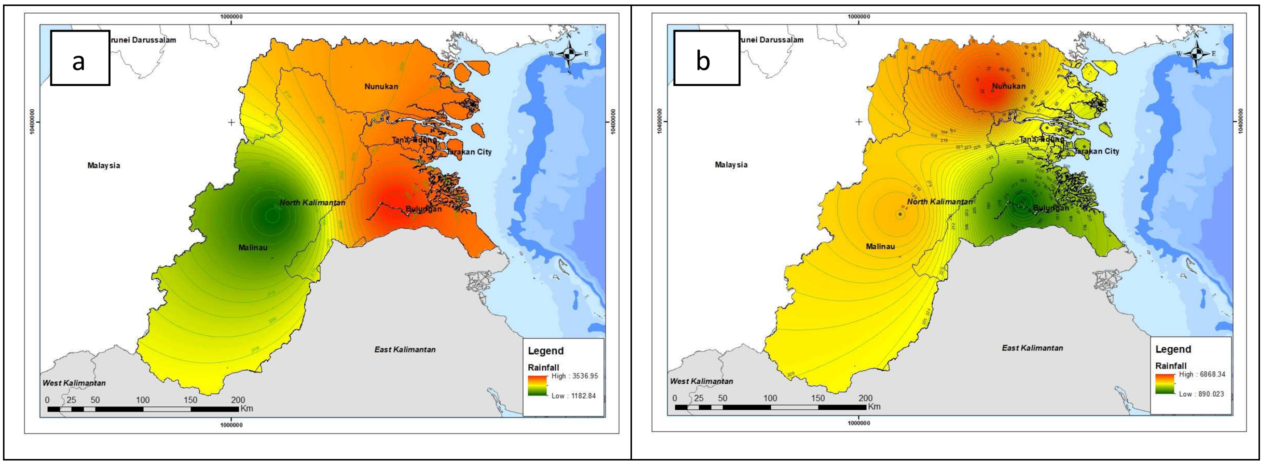
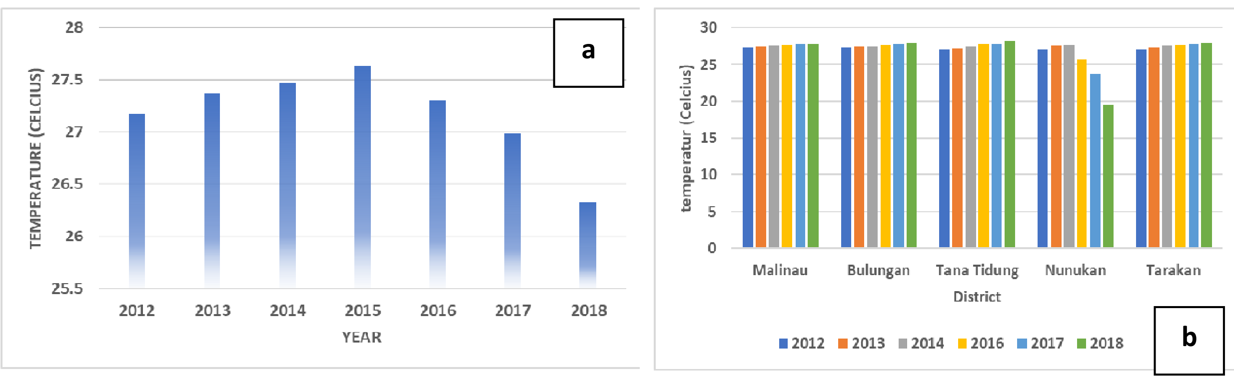


Figure 6. Annual rainfall maps of the Province of Kalimantan Utara in 2012 (a) and 2018 (b)



Source: BPS Data Analysis

Figure 7: Temperature bar charts of the province (a) and regencies (b) of Kalimantan Utara in 2012-2018

Table 1: Average production and growth rate of food commodities in the Province of Kalimantan Utara in 2012-2018

Types of food commodities	Average availabilities in 2012-2018 (tons)	Growth rates
Source of carbohydrate		
1. Grains	70,017.12	-0.0637
2. Tubers	33,751.80	0.0123
Source of plant protein - Legumes	1,065.56	0.1406
Source of vitamins and minerals		
1. Fruits	32,622.17	0.1175
2. Vegetables	33,830.88	0.2469

Source: BPS Data Analysis

Although the yearly rainfall in the study area fluctuated, the temperature from 2012 to 2018 exhibited an increasing trend. This condition corresponded to weather anomalies (i.e., La Niña and El Niño) arising from several factors, such as global warming, that increase the CO2 concentrations and temperatures, causing a decrease in photosynthesis and biomass production and increase in the vulnerability of some commodity crops, particularly in the tropics, such as the Province of Kalimantan Utara. In general, extreme weather changes can alter the transmission of pathogens and the presence of insects and pests that can interfere with crop production (Jaggard, Qi, & Ober, 2010).

Food Availability

The growth of food crop production in an area is determined by two factors: (1) the expansion of the harvested area and (2) the increase in productivity. The average food availability and growth rates from 2012 to 2018 in the Province of Kalimantan Utara are presented in Table 1.

Cereals or grains are a source of carbohydrates and the main staple food of the Indonesian population. Grain needs as a staple food increase from year to year with population growth. However, rice production cannot meet people's needs for grain, because productive agricultural land is used for nonagricultural activities. To meet the community's need for grain, new areas that have the potential to be planted need to be discovered (Harini, Susilo, & Nurjani, 2015). As shown in Table 1, the availability of grains from 2012 to 2018 in the Province of Kalimantan Utara fluctuated with an average of 70,017.12 tons and annual reduction rate of -0.0637. This reduction was attributed to the lower profitability of grains compared with that of other commodities, e.g., guava. Even worse, the less lucrative agricultural sector has caused farmers to work in different fields e.g., the grain farmers in Nunukan (Sebatik) Regency who have chosen to work as seaweed farmers instead because the selling price of seaweed is more promising than that of grains. This finding is consistent with that of Tulangow, Waney, and Timban (2017), who reported that most people in Tatelu—a village in the Province of Sulawesi Utara—prefer to work in mining because the wages obtained from the agricultural sector are categorically low, and the nonagricultural industry is considered to be economically prospective. Moreover, the extent of arable land has shrunk significantly and, when coupled with climate uncertainty, led to a steady decline in crop yields and farmers-incomes (Pesik, Kapantow, & Katiandagho, 2016).

Aside from grains, farmers also plant tubers. Table 1 shows that tuber production in 2012-2018 increased in quantity, with an annual growth rate of 0.0123. In the Province of Kalimantan Utara, tubers are usually consumed as a side dish instead of staple food. Similar to grains, the availability of beans as a source of plant proteins increased at an annual rate of 0.1406, with an average production of 1,065.56 tons. Sources of vitamins and minerals, i.e., fruits and vegetables, showed increasing trends with annual growth rates of 0.1175 and 0.2469, respectively.

Figure 8 shows the distribution of food availability in the Province of Kalimantan Utara. Based on this map, Bulungan Regency produced the highest average of grain, which was 37,575 tons. This condition was supported by the provincial government which designated 50,000 ha of land for integrated agriculture called the Delta Kayan Food Estate. According to Suwarno (2010), the expansion of agricultural land in Indonesia is essential in an attempt to improve food security. In Indonesia, a vast area currently used for dry cultivation and covered by swamps has the same potential for agriculture as the Delta Kayan Food Estate. Furthermore, 18.7 million ha out of the 29.8 million ha of abandoned land in the country is suitable for the cultivation of agricultural commodities (Mulyani & Agus, 2017). Wahyunto et al, (2013) confirmed that the degraded peatlands nationwide cover an area of 3.7 million ha, 20% of which is suitable for food crops and horticulture farming.

In addition to grains, Bulungan Regency had the highest availability of beans (869 tons) and fruits (11,358 tons). Nevertheless, fruit production showed a steady decline at an annual rate of -0.091. In contrast to Bulungan Regency, Tana Tidung Regency had the lowest availability of grains (1,573 tons) and beans (2.71 tons). Nunukan Regency had the highest availability of tubers, with an average of 20,904 tons and an annual growth rate of 0.0625, whereas Tana Tidung Regency had the lowest, i.e., an average of 1,179 tons. For vegetables, the highest availability was observed in Tarakan City, with an average of 21,640 tons and an annual growth rate of 0.4376. This abundance was supported by the Department of Agriculture in Tarakan City, which introduced hydroponics and organic agriculture programs, particularly for vegetables. Agricultural products can also be maximized by implementing urban agriculture (Nordahl, 2009). Urban agriculture can produce on average 15% to 20% of food in the world (Smith, Nasr, & Ratta, 2001). For this reason, Haletky and Taylor (2006) reported that, if implemented sustainably, these farming practices can be a solution to the issues related to food availability and security.

Malinau Regency produced the lowest quantity of vegetables, with an average of 528 tons and an annual growth

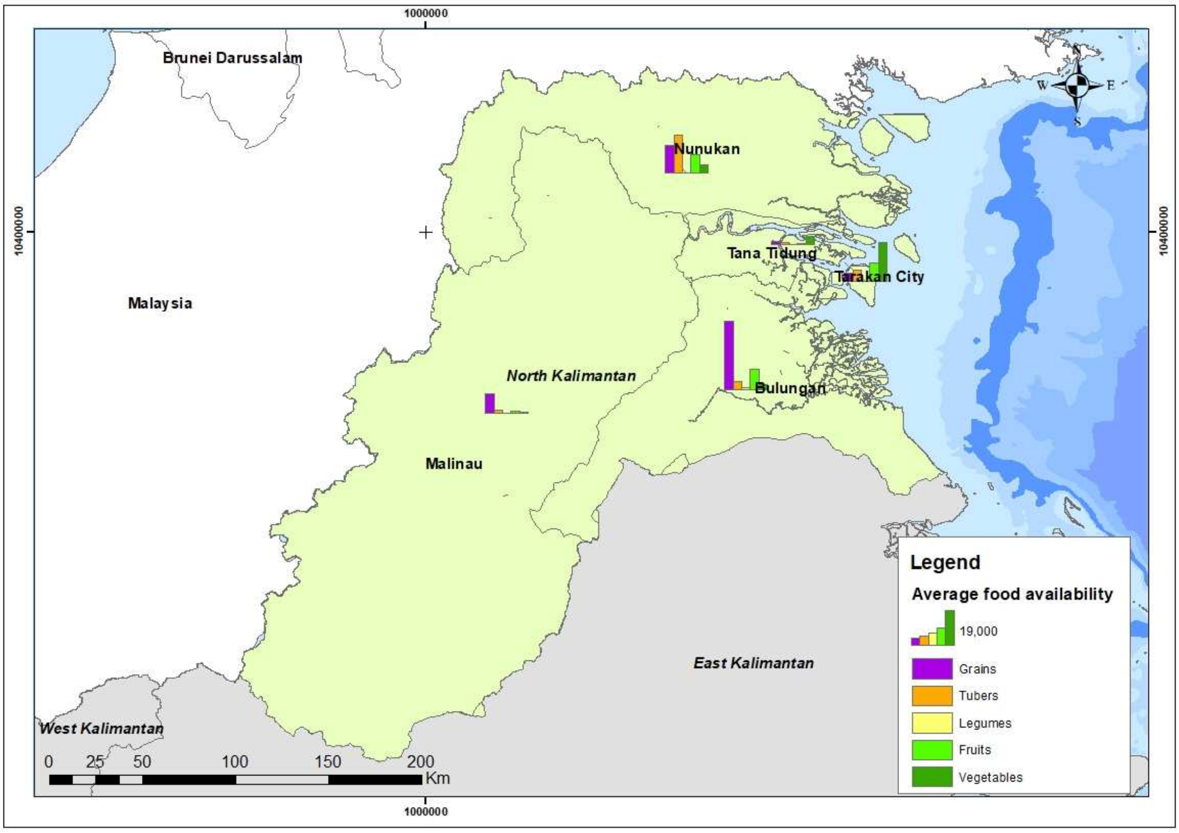


Figure 8 Map of Average food availability in the Province of Kalimantan Utara in 2012-2018

rate of -0.1667. According to Springmann et al., (2016), vegetable and fruit scarcity causes vitamin deficiency that, unless addressed properly, is projected to be responsible for 534,000 deaths per year in 2050.

Decreased productivity and increased risk of crop failure or crop damage caused by extreme weather can severely impact food availability (Noiret, 2016). The impact of climate change is estimated to start spreading globally in 2030 (FAO, 2016), and by 2080, the agricultural outputs will have declined by 20% in developing countries, should agricultural systems fail to implement adaptation measures. Agricultural yields are predicted to worsen significantly if El Niño occurs at the same time as the temperature increases. A temperature increases of 20°C will reduce corn yields by 20% and rice production by 10%, and regions at low latitudes, such as the Province of Kalimantan Utara, will experience a higher loss in corn production (Porter et al, 2014). Global warming is associated with a 10% to 40% decrease in rainfall, which results in a reduction in peanut production by 2.5% to 15% (Akhmad, 2017).

Impacts of Climate Change on Food Availability

The agricultural sector, particularly food crops, is most vulnerable to climate change because climate variability explains approximately 60% of the primary factors of food production (Matiu, Ankerst, & Menzel, 2017; Osborne & Wheeler, 2013; Ray, Gerber, MacDonald, & West, 2015). The impact climate change on multidimensional agriculture needs to be anticipated by observing changes in rainfall and fluctuations in temperature. Generally, in tropical regions, such as the Province of Kalimantan Utara, crop productivity decreases because of the 2°C to 3°C increase in warming (Mariara & Drb, 2015). In this study, the impact of climate change on food availability was assessed statistically using multiple linear regression between rainfall-temperature and food availability. There were three hypotheses, i.e., that air temperature (1) and rainfall (2) significantly influence food availability and that both temperature and rainfall simultaneously affect food availability (3). The results are presented in Tables 2 and 3.

Table 2 shows that changes in temperature and rainfall significantly influenced the availability of grains and vegetables, with a significance level of ≤0.05. This result was also supported by the F-test: $F_{count} > F_{table}$ (6.94). In contrast to that of tubers, the production of legumes and fruits was not significantly affected by the changes in temperature and rainfall, as evidenced by $F_{count} < F_{table}$ (6.94) and a significance value greater than alpha (0.05). The analysis results showed that the effects of rainfall and temperature on the production of sweet potatoes, fruits, and legumes (R^2) amounted to ≤50%, whereas the remaining percentage accounted for the effects of other factors that were excluded in this study.

Table 2 also shows that rainfall had a higher significance value than temperature, which is consistent with previous studies in which precipitation was confirmed to have a higher explanatory power to change yields than temperature. The same case applies to the rainfall-yield correlation, which is higher or stronger than the temperature-yield correlation.

Climate change, particularly rainfall, was concluded to have an impact on food production, particularly rice. This conclusion is consistent with the results of the climate change study conducted by Ruminta et al., (2018), who claimed that temperature increase and changes in rainfall patterns are responsible for the decrease in rice production in Sumatra Selatan and Malang. This finding is consistent with that of Hosang, Tajuh, and Rogi, (2012), who catagorized both variables as influencing factors of rice production in the Province of Sulawesi Utara.

Table 2: Effects of air temperature and rainfall on food availability in the Province of Kalimantan Utara

Dependent variables	Independent variables	R^2	F	Significance	Description
Grain availability	Air temperature	0.634	8.652	0.032	Significant
	Rainfall	0.784	18.198	0.008	Significant
Tuber availability	Air temperature	0.145	0.846	0.400	Insignificant
	Rainfall	0.295	2.088	0.208	Insignificant
Fruit availability	Air temperature	0.140	0.816	0.408	Insignificant
	Rainfall	0.119	0.675	0.449	Insignificant
Legume availability	Air temperature	0.019	0.097	0.768	Insignificant
	Rainfall	0.072	0.387	0.561	Insignificant
Vegetable availability	Air temperature	0.702	11.771	0.019	Significant
	Rainfall	0.979	235.100	0.000	Significant

Source: BPS Data Analysis

Table 3 Simultaneous effects of temperature and rainfall on food availability

Dependent variables	Independent variables	R^2	F	Significance	Notes
Grain availability	Temperature and rainfall	0.805	8.246	0.038	Significant
Tuber availability		0.303	0.870	0.486	Insignificant
Fruit availability		0.146	0.341	0.730	Insignificant
Legume availability		0.089	0.195	0.830	Insignificant
Vegetable availability		0.984	126.751	0.000	Significant

Source: BPS Data Analysis

The regression analysis between temperature-rainfall and food availability (Table 3) proved that temperature and rainfall simultaneously had a significant impact on the availability of grains and vegetables, with significance values of 0.038 and 0.000. Respectively, as evidenced by the F-test: $F_{count} > F_{table}$ (6.94) and a significance value of 0.05. This result was attributed to the limited data available for temperature and rainfall analyses. The ideal duration of time-series data for analyzing rainfall and temperature change 10 years, but in the Province of Kalimantan Utara, only 6 years of data was available. Food availability is influenced not only by climate change but also by several other factors controlling food production, namely land management, soil fertility, land suitability, capital/asset, technology, cultivated plant variety (Crespo, Hachigonta, & Tadross, 2011), irrigation, fertilization, and harvest area. The statement that climate change negatively impacts the agricultural sector in the Province of Kalimantan Utara is consistent with that of Harini and Nurjani, (2014), who claimed that ≥70% of corn, sweet potato, and cassava in the Special Region of Yogyakarta are affected by climate change and that agricultural production continues to decline.

4. Conclusion

Climate change due to rainfall fluctuations and extreme temperatures has been attributed to drought and floods that directly and indirectly affect agricultural systems, particularly crop production that support food availability. This study has proven that climate change negatively affects the production of grains and vegetables, which is consistent with the hypothesis that climate change reduces crop yields in tropical regions, such as the Province of Kalimantan Utara. Grains and vegetables are more vulnerable to climate change than tubers, legumes, and fruits. Based on the analysis results, climate and rainfall determine 80% of grain production and 98% of vegetable production. For tubers, legumes, and fruits, the effects of precipitation and temperature on their availability were ≤50%. Apart from rainfall and temperature, agricultural production is also influenced by several other factors, namely land management, soil fertility and land suitability, capital/asset, technology, and cultivated plant variety. However study, excludes these factors to highlight the connection between the study results and the existing theories.

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