

Impact of Climate Change and Technology on Food Availability in Sumatera, Indonesia

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Abstract

This study explores the impact of climate change and technology on food supply and demand, which complements the limits of previous findings. The main foundations are Hessian food production and Marshallian demand theories. It aims to analyze the factors influencing food availability and the response of each variable, as well as simulate the effect of climate change and technology. Secondary data from the Food Security and the Central Statistics Agency of 10 provinces in Sumatra will be used between the periods of 2010 to 2019. Furthermore, this study uses the simultaneous method of 8 structural and 2 identity equations. The influencing variables of production include price, expected food pattern of grains and tubers, CPO price, temperature, rainfall, and irrigation network area. Meanwhile, consumption is influenced by price, poverty, food inflation, population, per capita income, and farmers' exchange rate. The increase in temperature and rainfall reduces the production and consumption of rice, corn, cassava, and sweet potatoes. Meanwhile, technology development will increase food production and consumption. The availability is an essential dimension of food security that should be prioritized. Likewise, climate change and technology development need to be anticipated to mitigate these impacts.

Keywords: *Climate Change, Technology, Food Availability.*

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A. INTRODUCTION

Food availability is one of four critical dimensions of its security. Law No. 18 of 2012 defines urgency as the availability of food for consumption from domestic production, national food reserves, and imports when the two principal sources cannot meet the population's needs. The regulation clearly shows that production and consumption are the regional food availability benchmarks. After Java, Sumatra is the second-most populous island, making food production and consumption essential to ensuring the well-being of residents.

Study of food availability is essential because it is motivated by several factors. *First*, the Expected Food Pattern (PPH) in most regions shows conditions that are not yet ideal, including Sumatra (FSA, 2019). This requires increased food production to improve the population's food consumption. *Second*, the dilemma of increasing the Expected Food Pattern and the rapidly increasing population will directly promote food production and agricultural technology

(irrigation). *Third*, the threat of climate change affect production and decrease population consumption.

Several previous studies were conducted on the effect of climate change and technology on food security. (Srnita, 2018) carried out a study with dimensions of food availability, accessibility, and absorption. Meanwhile, Rahayu et al. (2019) examined three regional groups using the variables of crop availability, poverty line, GRDP per capita, life expectancy, and average consumption of calories and protein per day. These two studies do not examine the impact of food production, technological interactions, and the threat of climate change as described. Fajri et al. (2019) conducted a study using the main climate change factors, such as the El Niño–Southern Oscillation (ENSO). This affects the agricultural sector, specifically the food crop sub-sector, which is very vulnerable. The study did not examine the role of technology and other determinants of food availability dimensions. In the same year, Prasada and Masyhuri (2019) conducted a study in Java using food expenditure variables as an indicator of security and other independent variables such as beef prices, sugar prices, cooking oil prices, rice prices, per capita income, and agricultural land area. Furthermore, it did not examine the impact of the food crop sub-sector, specifically rice, corn, cassava, and sweet potatoes, which also strongly affects food security. It does not include aspects of agricultural technology and the threat of climate change.

The novelty of this study is to 1) integrate all variables influencing the availability of strategic food such as rice, corn, cassava, and sweet potatoes into econometric models on the demand and supply sides, 2) accommodate climate change and technology as independent variables in seeing their impact on food demand and supply, and 3) analyze each dependent response in the food availability equation model. The aims of this study are to 1) analyze the factors influencing food availability and the response of each variable, and 2) simulate the effects of climate change and technology on food availability in Sumatra from the context of supply and demand.

B. METHOD

This study uses secondary data with a time series of 2010-2019. The cross-section data consists of 10 provinces, including Aceh, West Sumatra, North Sumatra, South Sumatra, Riau, Riau Islands, Jambi, Bengkulu, Lampung, and Bangka Belitung. The data are sourced from the Food Security Agency of the Ministry of Agriculture and the Central Statistics Agency. Sumatra Island is a study site because it is vulnerable to food, has an Expected Food Pattern (PPH) that is not yet ideal and has experienced a rapid population increase from year to year after Java.

This study uses the simultaneous equation model because it has several advantages compared to other approaches. First, it can show a two-way causality relationship because some equations describe the dependence between

variables. Second, estimating the equation model does not ignore the existing information. Therefore, it is more potent because it avoids bias and inconsistency in the equation model. The model includes 10 simultaneous equations, consisting of 8 structural and 2 identity equations.

The equation model for the impact of climate change and technology on food availability can be explained in a simultaneous equation system as follows:

1. Food Production Block (supply side)

The food production block consists of 1 identity equation, namely Total Calorie Food Production (TPPK), as well as 4 structural equations for Rice Production (PPAD_{it}), Corn Production (PJAG_{it}), Cassava Production (PUKA_{it}), and Sweet Potato Production (PUJA_{it}). The equation model is written in detail as follows:

$$a. \text{TPPK}_{it} = \text{PPAD}_{it} + \text{PJAG}_{it} + \text{PUKA}_{it} + \text{PUJA}_{it} \quad (1)$$

$$b. \text{PPAD}_{it} = a_0 + a_1 \text{HKBR}_{it} + a_2 \text{PPHP}_{it} + a_3 \text{L4HCPR}_{it} + a_4 \text{LJITU}_{it} + a_5 \text{SURA}_{it} + a_6 \text{LPPAD}_{it} + U_{1it} \quad (2)$$

$$\text{Hypothesis: } a_1, a_2, a_4, a_6, > 0; a_3, a_5, < 0$$

$$c. \text{PJAG}_{it} = b_0 + b_1 \text{LHKJG}_{it} + b_2 \text{PPHP}_{it} + b_3 \text{L4HCPR}_{it} + b_4 \text{LJITU}_{it} + b_5 \text{SURA}_{it} + b_6 \text{CUHU}_{it} + b_7 \text{LPJAG}_{it} + U_{2it} \quad (3)$$

$$\text{Hypothesis: } b_1, b_2, b_4, b_7, > 0; b_3, b_5, b_6, < 0$$

$$d. \text{PUKA}_{it} = c_0 + c_1 \text{DHKUK}_{it} + c_2 \text{PPHU}_{it} + c_3 \text{L4HCPR}_{it} + c_4 \text{JITU}_{it} + c_5 \text{SURA}_{it} + c_6 \text{CUHU}_{it} + c_7 \text{LPUKA}_{it} + U_{3it} \quad (4)$$

$$\text{Hypothesis: } c_1, c_2, c_4, c_7, > 0; c_3, c_5, c_6, < 0$$

$$e. \text{PUJA}_{it} = d_0 + d_1 \text{DJITU}_{it} + d_2 \text{PPHU}_{it} + d_3 \text{DCUHU}_{it} + d_4 \text{DSURA}_{it} + d_5 \text{LPUJA}_{it} + U_{4it} \quad (5)$$

$$\text{Hypothesis: } d_1, d_2, d_5, > 0; d_3, d_4, < 0$$

2. Food Consumption Block (demand side)

The food consumption block in Sumatra consists of 1 identity equation, namely Total Calorie Food Consumption (TKPK), as well as 4 structural equations, namely the equation for Rice Consumption (KBER_{it}), Corn Consumption (KJAG_{it}), Cassava Consumption (KUKA_{it}), and Sweet Potato Consumption (KUJA_{it}). The equation model is written in detail as follows:

$$a. \text{TKPK}_{it} = \text{KBER}_{it} + \text{KJAG}_{it} + \text{KUKA}_{it} + \text{KUJA}_{it} \quad (6)$$

$$b. \text{KBER}_{it} = e_0 + e_1 \text{POVE}_{it} + e_2 \text{DHKBR}_{it} + e_3 \text{HKJG}_{it} + e_4 \text{LINFL}_{it} + e_5 \text{POPU}_{it} + e_6 \text{LIPER}_{it} + e_7 \text{LKBER}_{it} + U_{5it} \quad (7)$$

$$\text{Hypothesis: } e_3, e_5, e_6, e_7, > 0; e_1, e_2, e_4, < 0$$

$$c. \text{KJAG}_{it} = f_0 + f_1 \text{HKJG}_{it} + f_2 \text{NTTP}_{it} + f_3 \text{INFL}_{it} + f_4 \text{LHKBR}_{it} + f_5 \text{LIPER}_{it} + f_6 \text{POPU}_{it} + f_7 \text{LKJAG}_{it} + U_{6it} \quad (8)$$

$$\text{Hypothesis: } f_2, f_4, f_5, f_6, f_7, > 0; f_1, f_3, < 0$$

$$\begin{aligned} \text{d. } KUKA_{it} = & g_0 + g_1 HKUK_{it} + g_2 DPOPU_{it} + g_3 LHKJG_{it} + g_4 INFL_{it} + \\ & g_5 LIPER_{it} \\ & + g_6 LKUKA_{it} + U_{7it} \end{aligned} \quad (9)$$

Hypothesis: $g_2, g_3, g_5, g_6, > 0; g_1, g_4, < 0$

$$\begin{aligned} \text{e. } KUJA_{it} = & h_0 + h_1 HKUJ_{it} + h_2 NTTP_{it} + h_3 LHKBR_{it} + h_4 IPER_{it} + \\ & h_5 LKUJA_{it} \\ & + U_{8it} \end{aligned} \quad (10)$$

Hypothesis: $h_2, h_3, h_4, h_5, > 0; h_1, < 0$

The statistical criteria used for model validation is Theil's Inequality Coefficient (U-Theil). U-Theil is a comparison of RMSE with the average sum of the squares of the estimated and the observed values in a model or variable. This is grouped into two categories: the maximum and minimum values of one (naive model or variable estimation) and zero (perfect model or variable estimation). The U-Theil value of each variable is shown as follows.

Table 1. Model Validation Results

Variable	Label	U-Theil*	Description
PPAD	Rice Production	0.3925	Perfect Model Estimation
PJAG	Corn Production	0.5295	Perfect Model Estimation
PUKA	Cassava Production	0.5046	Perfect Model Estimation
PUJA	Sweet Potato Production	0.5482	Perfect Model Estimation
TPPK	Total Food Calorie Production	0.4488	Perfect Model Estimation
KBER	Rice Consumption	0.0535	Perfect Model Estimation
KJAG	Corn Consumption	0.1795	Perfect Model Estimation
KUKA	Cassava Consumption	0.1341	Perfect Model Estimation
KUJA	Sweet Potato Consumption	0.1487	Perfect Model Estimation
TKPK	Total Food Calorie Consumption	0.0470	Perfect Model Estimation

* U = 0 perfect model estimation; U = 1 naive model estimation

Policy simulation can be carried out after the model is validated and fulfills the statistical criteria. The simulation is intended to analyze the future impact of several alternative policy scenarios when changes are made to the value of exogenous variables or policy instruments. Alternative simulation scenarios for the impact of climate change and technology on food availability are described in the following table:

Table 2. Basic Simulation of The Impact of Climate Change and Technology on Food Availability in Sumatera

No	Simulation scenario	Consideration
1	An increase in the average annual temperature of 0.9°C	Most places in Indonesia will see an increase of 0.9°C over the next 30 years based on current temperature trends, such as minimum, average, and maximum temperatures with a positive value of roughly 0.03 degrees Celsius per year.

2	An increase in maximum rainfall of 20mm	According to the Meteorology, Climatology, and Geophysics Agency, Indonesia's rainy day trends have increased by 0.1149 days per year or 1.149 days per decade, based on the 20 mm/day category.
3	Agricultural technology development by 30%	The National Research Priority Flagship (PRN) is an attempt to assist the achievement of the National Research Priority Flagship (PRN), which creates quality study and innovation products with competitive advantages.

Key Reference: *) Indonesia's climate projection, meteorology, climatology, and geophysics agency, 2020; **) The agricultural technology development is 30% based on the minister of finance regulation No. S-338/MK.02/2019 and the minister of national development planning/head of national development planning agency regulation No. B241/M.PPN/D.8/KU.01.01/04/2019

C. RESULTS AND DISCUSSION

1. Determinants of food availability and response from the production side

Rice production is influenced by consumer-level rice price, expected food pattern of grains, Rotterdam CPO price in year t-4, irrigation network area in year t-1, temperature, and rice production in year t-1.

Table 3. Parameter Estimation Results and Food Availability Block Response from the Production Side

Equations	Parameter	Estimate	t value	Description
Rice Production (PPAD) $R^2 = 0.1875$ $D_w = 1.9568$	INTERC	-63807	-1.18	Intercept
	HKBR	2.8144*** (10.1070)	1.22	Consumer-Level Rice Price (Thousand Rupiah)
	PPHP	2550.1*** (4726.91)	1.18	Expected Food Pattern of Grains (Percent)
	L4HCPR	-2.9401*** (-2.1569)	-0.40	Rotterdam CPO Price in Year t-4 (Thousand Rupiah)
	LJITU	0.0076** (0.1025)	0.65	Irrigation Network Area in Year t-1 (Hectares)
	SURA	-92.4404*** (-1.8483)	-0.14	Temperature (Celsius)
	LPPAD	0.5296	1.42	Rice Production in Year t-1 (Tons)

(*) elasticity = 1; (**) elasticity < 1; (***) elasticity > 1

Furthermore, corn production is influenced by consumer-level corn price in t-1, expected food pattern of grains, Rotterdam CPO price in year t-4, irrigation network area in year t-1, temperature, rainfall, and corn production in year t-1.

Table 3. Parameter Estimation Results and Food Availability Block Response from the Production Side (Continued)

Corn Production (PJAG) $R^2 = 0.4707$ $D_w = 1.7390$	INTERC	-14857	-2.09	Intercept
	LHKJG	0.0477** (0.4092)	0.10	Consumer-Level Corn Price in Year t-1 (Thousand Rupiah)
	PPHP	59500.19*** (3619.19)	2.10	Expected Food Pattern of Grains (Percent)
	L4HCPR	-1.4794*** (-3.5606)	-0.92	Rotterdam CPO Price in Year t-4 (Thousand Rupiah)
	LJITU	0.0013** (0.0597)	0.56	Irrigation Network Area in Year t-1 (Hectares)
	SURA	-0.9104** (-0.0598)	-0.01	Temperature (Celsius)
	CUHU	-0.0744** (-0.4615)	-0.65	Rainfall (Millimeter)
	LPJAG	0.6950	4.91	Corn Production in Year t-1 (Tons)
Cassava Production (PUKA) $R^2 = 0.4468$ $D_w = 1.4901$	INTERC	7194.51	0.65	Intercept
	DHKUK	2.8013*** (5.8455)	1.10	Changes in Consumer-Level Cassava Price in Years t and t-1 (Thousand Rupiah)
	PPHU	4659.48*** (4.5436)	1.39	Expected Food Pattern of Tubers (Percent)
	L4HCPR	-3.8210*** (-3.7802)	-0.84	Rotterdam CPO Price in Year t-4 (Thousand Rupiah)
	JITU	0.0100** (0.1773)	1.28	Irrigation Network Area (Hectares)
	SURA	-235.83*** (-6.3591)	-0.63	Temperature (Celsius)
	CUHU	-0.5318*** (-1.3553)	-1.62	Rainfall (Millimeter)
	LPUKA	0.6262	5.15	Cassava Production in Year t-1 (Tons)

(*) elasticity = 1; (**) elasticity < 1; (***) elasticity > 1

Cassava production is influenced by changes in consumer-level price in years t and t-1, expected food pattern of tubers, Rotterdam CPO price in year t-4, irrigation network area, temperature, rainfall, and cassava production in year t-1. Meanwhile, sweet potato production is influenced by changes in irrigation network area in years t and t-1, expected food pattern of tubers, changes in rainfall in years t and t-1, changes in temperature in years t and t-1, and production in year t-1. These four equations are consistent with the hypothesis and theory of food production built in this model.

Table 3. Parameter Estimation Results and Food Availability Block Response from the Production Side (continued)

Equations	Parameter	Estimate	t Value	Description
Sweet	INTERC	-26.8939	-0.84	Intercept
Potato	DJITU	0.00005** (0.0246)	0.74	Changes in Irrigation Network Area in Years t and t-1 (Hectares)
Production (PUJA)	PPHU	35.6011** (0.8639)	1.10	Expected Food Pattern of Tubers (Percent)
$R^2 = 0.6625$				
$D_w = 1.7866$	DCUHU	-0.00084** (-0.0532)	-0.13	Changes in Rainfall in Years t and t-1 (Millimeters)
	DSURA	-3.0567*** (-2.0511)	-0.72	Changes in Temperature in Years t and t-1 (Celsius)
	LPUJA	0.8201	10.09	Sweet Potato Production in Year t-1 (Tons)

2. Determinants of Food Availability and Response from the Consumption Side

The food consumption block shows that rice consumption factors are poverty, changes in consumer-level rice price in years t and t-1, consumer-level corn price, food inflation, population, per capita income in years t-1, and rice consumption in year t-1. These results are consistent with the hypothesis and food demand theory. Furthermore, the factors influencing corn consumption include consumer-level corn price, farmers' exchange rate, food inflation, consumer-level rice price in year t-1, per capita income in year t-1, population, and corn consumption in year t-1. This result is in line with the hypothesis and food demand theory.

The determinants of cassava consumption are consumer-level price, changes in population in years t and t-1, consumer-level corn price, foodstuff inflation, and per capita income. The hypothesis and food demand theory also align with the results. Meanwhile, sweet potato consumption is affected by consumer-level sweet potato price variables, farmers' exchange rate, consumer-level rice price in year t-1, per capita income, and sweet potato consumption in year t-1 under the hypothesis and food demand theory.

Table 4. Parameter Estimation Results and Food Availability Block Response From the Consumption Side

Equations	Parameter	Estimate	t Value	Description
Rice Consumption (KBER) R2 = 0.6822 DW = 1.9060	INTERC	-14.8261	-0.64	Intercept
	POVE	-2.5202** (-0.0072)	-0.26	Poverty (Thousand People)
	DHKBR	-0.00099** (-0.0501)	-0.31	Changes in Consumer-Level Rice Price in Years t and t-1 (Thousand Rupiah)
	HKJG	0.00814** (0.3001)	1.39	Consumer-Level Corn Price (Thousand Rupiah)
	LINFL	-0.1755** (-0.0082)	-0.99	Foodstuff Inflation in Year t-1 (Percent)
	POPU	0.347286** (0.0203)	0.57	Total Population (Million People)
	LIPER	0.0571** (0.0132)	0.79	Per capita income in Year t-1 (Thousands/Person)
	LKBER	0.8368	9.53	Rice Consumption in Year t-1 (Kcal)
Corn Consumption (KJAG) R2 = 0.3512 Dw = 2.2049	INTERC	0.4034	0.18	Intercept
	HKJG	-0.00022*** (-2.0110)	-0.54	Consumer-Level Corn Price (Thousand Rupiah)
	NTTP	0.0012** (0.3213)	0.04	Farmers' Exchange Rate
	INFL	-0.0223** (-0.2615)	-0.83	Foodstuff Inflation (Percent)
	LHKBR	0.00012*** (1.5353)	1.22	Consumer-Level Rice Price in Year t-1 (Thousand Rupiah)
	LIPER	0.00089** (0.0509)	0.47	Per capita income in Year t-1 (Thousands/Person)
	POPU	0.00067** (0.0097)	0.07	Total Population (Million People)
	LKJAG	0.3069	1.90	Corn Consumption in Year t-1 (Kcal)

(*) elasticity = 1; (**) elasticity < 1; (***) elasticity > 1

Table 4. Parameter Estimation Results and Food Availability Block Response From the Consumption Side (continued)

Equations	Parameter	Estimate	t Value	Description
Cassava Consumption (KUKA) R ² = 0.4159 D _w = 2.1789	INTERC	12.0667	1.40	Intercept
	HKUK	-0.0043*** (-1.2939)	-0.81	Consumer-Level Cassava Price (Thousand Rupiah)
	DPOPU	0.2669** (0.2146)	2.44	Changes in Population in Years t and t-1 (Million People)
	LHKJG	0.00018** (0.0928)	0.12	Consumer-Level Corn Price in Year t-1 (Thousand Rupiah)
	INFL	-0.0178** (-0.0116)	-0.06	Foodstuff Inflation (Percent)
	LIPER	0.0065** (0.0206)	0.40	Per capita income in Year t-1 (Thousands/Person)
	LKUKA	0.4618	3.92	Cassava Consumption in Year t-1 (Kcal)
Sweet Potato Consumption (KUJA) R ² = 0.5099 D _w = 1.9413	INTERC	-5.6283	-0.85	Intercept
	HKUJ	-0.0013*** (-2.3268)	-1.77	Consumer-Level Sweet Potato Price (Thousand Rupiah)
	NTTP	0.0642*** (3.600)	0.72	Farmers' Exchange Rate
	LHKBR	0.00085*** (2.3829)	3.74	Consumer-Level Sweet Rice Price in Year t-1 (Thousand Rupiah)
	IPER	0.00050** (0.0064)	0.08	Per capita Income (Thousands/Person)
	LKUJA	0.6028	6.24	Sweet Potato Consumption in Year t-1 (Kcal)

(*) elasticity = 1; (**) elasticity < 1; (***) elasticity > 1

3. Impact of climate change and technology on food availability: a simulation analysis

The impact of an increase in temperature of 0.9°C causes a decrease in rice production by -74.4293208% and -2.8658672%. The increase in temperature also causes the production of corn, cassava, and sweet potatoes to decrease by -54.0994571, -79.6295566, and -48.6780028%, respectively. The decrease in food crop production is affected by reduced consumption of -1.4274927% for corn, -0.7370158% for cassava, and -0.3122344% for sweet potatoes. This causes the total production and consumption of caloric food to decrease by -72.9323476 and -2.6766936%, respectively.

An increase in rainfall of 20 mm causes a decrease in rice and corn production by -66.0771117 and -67.6892697%, respectively. This causes their consumption to decrease by -2.8650023 and -1.4270577%. Furthermore, the

increase in rainfall causes the production and consumption of cassava and sweet potatoes to decrease. Cassava production and consumption decreased by -13.7135855% and -0.7367913%. Production and consumption of sweet potatoes decreased by -3.1015448 and -0.3121392%, respectively. The decrease of these four food commodities affects the total production and consumption of caloric food by -46.7070414 and -2.6758856%, respectively.

The impact of increasing temperature and rainfall on decreasing production is more significant than decreasing consumption due to low production. This shows that consumption is not as sensitive as production. Agricultural items typically experience an increase in prices as production falls. This is evidenced by the national rice consumption, which reached 53.5%. The remaining 22.26 % and 18.9 % come from cassava and corn.

Table 5. Simulation Results of the Impact of Climate Change and Technology on Food Availability in Sumatra

No	Variable	Unit	Basic Value	Simulation Change Δ (%)		
				Sim 1	Sim 2	Sim 3
1	PPAD	Tons	1348.25	-74.4293208	-66.0771117	102.0413
2	PJAG	Tons	410.968	-54.0994571	-67.6892697	119.0852
3	PUKA	Tons	999.800	-79.6295566	-13.7135855	30.1353
4	PUJA	Tons	40.1760	-48.6780028	-3.1015448	10.0110
5	TPPK	Tons	2799.19	-72.9323476	-46.7070414	77.5398
6	KBER	Kcal	95.5836	-2.8658672	-2.8650023	7.0377
7	KJAG	Kcal	0.38513	-1.4274927	-1.4270577	0.1420
8	KUKA	Kcal	6.94926	-0.7370158	-0.7367913	0.40190
9	KUJA	Kcal	1.74308	-0.3122344	-0.3121392	1.47848
10	TKPK	Kcal	104.661	-2.6766936	-2.6758856	6.4792

Simulation 1: impact of an increase in temperature of 0.9°C

Simulation 2: impact of an increase in rainfall of 20 mm

Simulation 3: impact of an increase in irrigation network area (technology) by 30%

The decrease in production and consumption of major food commodities due to climate change is consistent with Ringler et al. (2010). Changes in temperature and rainfall severely threaten the production of rice, corn, and sweet potatoes. Food production and production of micro and small-scale industries (MSI) is very vulnerable to supply disruptions such as El Nino weather and other weather disturbances (Marpaung et al., 2019; Siregar et al., 2020). Food availability is projected to decrease by 3.2%, with a decrease in the yield of 4.6%. Bocchiola et al. (2019) stated that the increase in temperature and rainfall caused the production of rice and corn to decrease by 42 and 46%, respectively. Changes in air temperature cause a decrease in rice production, and the majority of 75.5% of households face the problem of food insecurity (Badjie et al., 2019). Climate change threatens subsistence agriculture production that focuses on cultivating foodstuffs such as cassava and sweet potatoes (Barnett, 2020).

Technology development (irrigation) can increase rice, corn, cassava, and sweet potato production by 102.0413%, 119.0852%, 30.1353%, and 10.0110%, respectively. Therefore, the total production of calorie food has increased by 77.5398%. The increase in food production of each of these commodities directly affects consumption. Rice, corn, cassava, and sweet potato consumption increased by 7.0377%, 0.1420%, 0.40190 and 1.47848%, respectively. In aggregate, total calorie food consumption increased by 6.4792%.

Irrigation development significantly increases rice production without compromising infrastructure, policy, and institutions. These aspects are fundamental in supporting regional irrigation investment to increase production and farmers' welfare (Nonvide, 2019). The use of full irrigation results in significant corn production, reaching 2200.4 kg/ha. Meanwhile, the production without irrigation reaches 1068.3 kg/ha (Gadedjisso et al., 2020). Nedunchezhiyan et al. (2012) and Boansi (2017) emphasized the importance of increasing irrigation area to increase water supply and utilizing cassava and sweet potato plants efficiently.

D. CONCLUSION

The context of production and consumption still influences Sumatra's food availability. The influencing variables of production include price, expected food pattern of grains, expected food pattern of tubers, CPO price, temperature, rainfall, and irrigation network area. Meanwhile, consumption is influenced by price, poverty, food inflation, population, per capita income, and farmers' exchange rate. The simulation results show that the increase in temperature and rainfall decreases the production of rice, corn, cassava, and sweet potatoes. Meanwhile, technology development will increase food production and consumption.

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