The Impact of Climate Change on Indonesian Rice and Coffee Sectors

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Abstract
Rice and coffee are strategic agricultural commodities in Indonesia. Rice is Indonesian main staple food and coffee is globally traded commodity that grown by Indonesian smallholders. There is growing concern regarding its production that sensitive to the change of temperature, rainfall and humidity. Therefore, it is important to conduct a study on the impact of climate change on rice and coffee production in Indonesia. The objective of the study is to assess the impacts of climate change on Indonesian macroeconomic performance and sectoral output. This paper using Computable General Equilibrium model with three simulations of productivity change under two climate scenarios of RCP 4.5 and RCP 8.5. Climate change that reduces rice and coffee productivity affects Indonesia's macroeconomic performance. Climate change will reduce real GDP, real household consumption and exports. On the other hand, climate change will increase Indonesia's imports. Changes in macroeconomic performance in all scenarios of RCP 8.5 are worse than scenario 4.5. It is identified that climate change poses a negative risk to the quantity and quality of rice and coffee output and has a spiraling impact on increasing domestic prices, hence decrease the competitiveness. Climate change also contributed to reducing real income of households particularly for agricultural workers, agricultural entrepreneurs and low-income households in urban areas. Government climate change adaptation policies for rice and coffee are very important to overcome the decline in productivity and production. In addition, government should develop financial support and risk management system targeted towards vunerable groups affected by climate change.

Keywords: climate change, yield, production, CGE
JEL code: Q10, Q54, Q59
SDG goals: Climate Action, Zero Hunger, No Poverty

Introduction
According to the latest IPCC (Intergovernmental Panel Climate Change) report, climate change over the past 30 years has reduced global agricultural production in the range of 1-5% per global decade, with particularly negative effects for tropical cereal crops such as maize and rice (Porter et al, 2014). Challinor et al (2014) say that at low levels of warming (+2^{o}C), agricultural productivity is likely to decline worldwide, but particularly in the tropics.
Demand for agricultural commodities is increasing along with population growth. This needs to be balanced by increased production of agricultural commodities as well. However, in the cultivation of agricultural commodities, there are challenges that need to be addressed, especially with regard to environmental conditions that are also changing. Environmental conditions are one of the factors that determine success in the development of agricultural business cultivation. Suitable climatic, soil and biophysical conditions need to be analyzed as a basis for developing crop commodities in an area (Sarkar et al. 2014; Bonfante et al. 2018). The mismatch of these environmental conditions with plant growth requirements will have an impact on the low productivity of agricultural commodities.

Land suitability for agricultural commodity cropping areas is determined by soil typology, climatic and biophysical conditions. Fertile soil with sufficient nutrient content is an ideal area

for planting. Ideal climatic conditions are also required so that extreme climatic stresses do not result in reduced production or crop failure. In food crops such as rice, the availability of water, especially from rain, is an important factor. Long drought stress in rice plants results in crop failure (Zhong et al., 2010; Estiningtyas et al, 2012). In plantation crops such as coffee, suitable temperature and rainfall conditions determine the ideal cultivation location (Camargo, 2010; Davis et al., 2012).

Another challenge facing the agricultural sector is climate change, which has an impact on economic value. Some of the studies below look at the impact of climate change on the economic value of rice and coffee, both in terms of production and increased rice prices. For example, research conducted by Jati (2018) analyzed the effects of the rainy and dry seasons on rice prices. The data used were daily rice stocks and prices from January 29, 2014 to January 29, 2018. The ARMA (0,1)-ARCH (1) model with a dummy variable, namely the dry season, significantly affects the conditional variance of rice prices more than the rainy season dummy variable. Stakeholders need to pay more attention to rice price fluctuations, especially when the dry season dummy variable is significantly more influential than the rainy season dummy variable. Another study conducted by Rum and Sihaloho (2017) tried to answer commodity price anomalies based on the level of climate change vulnerability. The results show that the level of climate change vulnerability has an impact on the volatility of rice commodity prices in Indonesia. The results show that the volatility of rice commodity prices is related to the level of regional vulnerability to climate change. Regions vulnerable to climate change tend to have higher price volatility than regions not vulnerable to climate change.

Sadelina (2020) said the impact of climate change is the increase in climate extremes. Climate change creates striking temperature anomalies such as the El Nino and La Nina phenomena or commonly referred to as the ENSO (El Nino Southern Oscillation) phenomenon. The ENSO phenomenon causes fluctuations in rainfall, which has an impact on the agricultural sector, especially the plantation subsector. This study examines the impact of climate change on coffee prices using the static panel data method. The data used in this study are 12 affected provinces with a span of 2010 to 2017. The ENSO phenomenon is shown through rainfall indicators. The results obtained in this study were that El Nino had a significant effect in increasing coffee prices, and was followed by other factors, namely the price of substitute goods (chocolate prices), productivity and Real GRDP. Another study conducted by Bongase (2017) said the increase in temperature and water shortage will negatively affect the suitability of coffee production in the lowlands and vice versa. It is estimated that in the future the impact of climate change on coffee production will not only be a threat to small-scale farmers but also all coffee industry players including consumers. In this scenario, coffee production will also tend to decline globally, particularly in Africa. Coffee prices vary inversely with changes in production and cause the largest price increases. Only half of the area currently available for coffee production in 2050. 2.5 times the current area will be needed to meet future demands. Declining yields and rising prices will evidently reduce the coffee market by more than 5 million tons per year. As a result, many researchers believe that the area suitable for coffee production will decrease by 16% by 2050, especially for arabica coffee.
Studies on the impact of climate change on rice and coffee production that have been conducted previously generally only focus on the impact on production and prices of these commodities. However, both agricultural commodities have an important role in food security and exports, so it is urgent to analyze the impact of climate change on macroeconomic and sectoral performance. Therefore, the objectives of this study are:

1. Analyze the impact of climate change on rice and coffee commodities on Indonesia's macroeconomic performance.
2. Analyzing the impact of climate change on rice and coffee commodities on Indonesia's sectoral performance
3. Analyzing the impact of climate change on rice and coffee commodities on Indonesia's households' welfare

Methodology

The model used to answer the objective of research on the impact of climate change on Indonesia's economic performance uses the latest version of Wayang and INDOF (Warr et al. 1998; Wittwer 1999; Warr 2005; Oktaviani 2010). This model as a reference is built based on the 2016 Indonesian Input-Output Table and the SAM Table which was officially published by the Central Statistics Agency. The basic data disaggregation constructed includes the disaggregation of households, industries, and commodities. Microeconomic behavior is assumed to be in a state of maximizing profit for each producer, as well as maximizing utility for consumers. In the simulations carried out in this study, the final product market, intermediate products, and production factors are assumed to be in equilibrium and determined endogenously in the model. However, variations of these assumptions are possible by modifying the closure.

Model Theoretical Structure

Theoretically, the structure of the model used is relatively conventional with the form of a linear economic model in proportional change, which is often referred to as the Johansen Model. The analytical structure of the model used includes important components, such as:

- Demand for household consumption of agricultural commodities for each type in 10 household groups.
- A factor demand system, based on CES production technology assumptions, which relates to the demand for each primary factor of production.
- There are differences between educated and uneducated workers in sectoral production functions.
- Leontief's assumption for intermediate goods. Each intermediate is assumed to be demanded at a fixed proportion of gross output in each sector.
- Sources of domestic and imported demand in each production activity have integrated the Armington elasticity principle of substitution.

Model Empirical Review

- Industry
  The national model covers 185 sectors with a reporting focus on the rice and rice sectors
- Commodity
  This model includes two types of commodities, namely producer and consumer goods. Producer goods come from domestic and imported sources. All 185 producer goods in principle have the opportunity to be imported.
- Factors of Production
  The mobility of factors of production is critical in the general equilibrium economic model system, where the term mobility is more accurately defined here as activity mobility between industries rather than geography. The greater the mobility factor, the better the model's capacity to simulate the response of an economy related to economic changes.

- Model Scope: Time Dimension
  The model used in this study is operated in a long run mode related to the mobility of production factors.

Equation System

The theoretical structure in the CGE model usually consists of a system of equations that describes the demand for labor, demand for production factors, demand for intermediate inputs, demand for combinations of factor inputs and intermediate inputs, demand for combinations of output, demand for investment goods, household demand, exports and demand. other end, margin demand, selling price, market balance, indirect taxes, GDP receipts and expenditures, trade balance, rate of return on capital, investment and capital accumulation and debt accumulation. The general specifications of the CGE model include 14 blocks, namely:

- labor demand
- primary factor demand
- input demand between
- composite demand for primary factors and intermediate inputs
- Commodity composite of the output of an industry
- demand for investment goods
- household demand
- export and other final request
- margin request
- Price at buyer level
- market balance
- indirect tax
- GDP in terms of income and expenditure
- trade balance and other aggregation

Each production process, each industry can produce several commodities. The sectors use primary factors and intermediate inputs. Any intermediate inputs can be obtained from both the domestic and import markets. The primary factors used are labor, land and capital. Some basic assumptions that must be considered are: (1) separation between input and output (separable), (2) tiered stages and (3) hierarchical structure based on constant elasticity of substitution (transformation). From the production structure, it can be derived directly regarding the demand for primary factors and intermediate inputs. Primary factor demand is determined based on the production function while the intermediate input demand is proportional to a type of output.

Closure of the CGE Model

Closure is the classification of the variables contained in the CGE model into endogenous and exogenous variables. Endogenous variables are variables whose values will be determined (to solve problems), while exogenous variables are variables whose values are determined outside the model. With this grouping, simulation scenarios of the impact of a policy can be carried out through a shock to exogenous variables in accordance with the desired objectives of the simulation for prediction purposes or long-run analysis.

Policy Simulation

Shock simulation of climate change in the long term (2021-2100) defined in the study uses a productivity decrease for coffee andrice commodities. There are three simulations used,

namely: (i) The decline in productivity of rice and coffee based on the median value of the median shock of decreasing productivity in all districts; (ii) The decline in productivity of and rice and coffee based on the minimum value of the median shock of decreasing productivity in all districts; (iii) The decline in productivity of rice and coffee is based on the average value of the median shock of decreasing productivity in all districts. In each simulation, there are two assumptions of future climate projection scenarios that are compared, namely: (a) RCP 4.5 which results in a decrease in air temperature and an increase in rainfall and (b) RCP 8.5 tends to decrease rainfall and increase temperature. In general, it can be identified that the magnitude of the decrease in rice productivity of RCP 8.5 is more significant than that of RCP 4.5.

Table 1. Justification of the Shock

	The Median Value of the median shock all off the districts levels in Indonesia				
Scenario 1		Productivity	2021-2050	2051-2080	2081-2100
	Paddy	4.5	-1.53%	-2.89%	-3.35%
		8.5	-1.95%	-4.75%	-7.50%
	Arabica	4.5	-12.03%	-25.43%	-29.71%
		8.5	-15.12%	-39.51%	-63.18%
	Robusta	4.5	1.09%	0.76%	0.71%
		8.5	0.93%	-0.58%	-2.66%
	The Median Value of all off the districts levels median values in Indonesia				
Scenario 2		Productivity	2021-2050	2051-2080	2081-2100
	Paddy	4.5	-19.72%	-23.00%	-21.20%
		8.5	-20.39%	-45.11%	-34.93%
	Arabica	4.5	-100.00%	-100.00%	-100.00%
		8.5	-100.00%	-100.00%	-100.00%
	Robusta	4.5	-25.39%	-34.33%	-39.14%
		8.5	-46.69%	-51.67%	-68.59%
	The Average value of the median shock all off the districts in Indonesia				
Scenario 3		Productivity	2021-2050	2051-2080	2081-2100
	Paddy	4.5	-1.18%	-2.55%	-3.07%
		8.5	-1.42%	-4.36%	-7.20%
	Arabica	4.5	-13.59%	-25.54%	-30.11%
		8.5	-16.15%	-40.79%	-60.61%
	Robusta	4.5	2.26%	2.00%	2.12%
		8.5	2.30%	0.89%	-1.39%

Source: Authors Calculation

Results and discussion

The Impact of Climate Change on Rice and Coffee Commodities on Indonesia's Macroeconomic Performance

Climate change affects changes in the productivity of rice and coffee commodities and will affect Indonesia's macroeconomic performance in the future. Table 3 shows that macroeconomic performance due to climate change is seen from changes in several macroeconomic indicators, namely the Consumer Price index, real Gross Domestic Product (real GDP), consumption, and trade.

Based on Table 3, the overall simulation scheme reduces Indonesia's real Gross Domestic Product (GDP). From the production side, the decline in real GDP was due to a decrease in rice

and coffee production due to climate change, ranging from -.2-0.51% at RCP 4.5 and 0.3-0.85% at RCP 8.5. When viewed from the expenditure side, the decline in real GDP was due to a decline in household consumption and exports. The decrease in real GDP in simulation 2 was the highest compared to other simulations considering that there was a higher decline in productivity for rice (especially). This indicates the urgency of climate adaptation to address the negative impacts of climate change on Indonesia's national income in the future.

The decline in rice production due to climate change will affect the supply of these commodities in Indonesia. The decrease in supply of the commodity will increase the price of the commodity. The increase in the prices of commodities will cause cost push inflation where inflation. The increase in inflation (Consumer Price Index) due to climate change ranged .01-0.18% at RCP 4.5 and 0.1-0.41% at RCP 8.5. The increase in inflation in simulation 2 is the largest of the other simulations at 0.14-0.41%. The increase in inflation in simulation 2 representing RCP 8.5 scenario is the largest compared to other simulations.

Table 3. Impacts of Climate Changes in Rice and Coffee Sector on Indonesian Macroeconomic Condition

Description			Consumer price index	Real GDP from expenditure side	Export volume index	Real household consumption	Import volume index
Scenario 1	4.5	2021-2050	0.02	-0.03	-0.02	-0.06	0.01
		2051-2080	0.03	-0.06	-0.05	-0.12	0.02
		2081-2100	0.03	-0.07	-0.06	-0.14	0.02
	8.5	2021-2050	0.02	-0.04	-0.03	-0.08	0.01
		2051-2080	0.04	-0.10	-0.08	-0.21	0.02
		2081-2100	0.06	-0.17	-0.14	-0.34	0.03
Scenario 2	4.5	2021-2050	0.16	-0.45	-0.37	-0.90	0.08
		2051-2080	0.18	-0.53	-0.43	-1.06	0.09
		2081-2100	0.16	-0.51	-0.42	-1.01	0.07
	8.5	2021-2050	0.14	-0.51	-0.42	-1.01	0.05
		2051-2080	0.41	-0.95	-0.77	-1.93	0.24
		2081-2100	0.27	-0.81	-0.67	-1.63	0.13
Scenario 3	4.5	2021-2050	0.01	-0.02	-0.02	-0.04	0.01
		2051-2080	0.02	-0.05	-0.04	-0.11	0.01
		2081-2100	0.03	-0.06	-0.05	-0.13	0.02

Description			Consumer price index	Real GDP from expenditure side	Export volume index	Real household consumption	Import volume index
	8.5	2021-2050	0.01	-0.03	-0.02	-0.06	0.01
		2051-2080	0.04	-0.09	-0.08	-0.19	0.02
		2081-2100	0.06	-0.16	-0.13	-0.32	0.03

Source: Authors Calculation

In line with the decline in national income, household real consumption also decreased. The decrease in real household consumption occurred in all What needs attention is the decline in Indonesia's trade performance in the future due to climate change. The decline in rice productivity due to climate change affects Indonesia's competitiveness in the international market. Malahayati et al. (2021) show that Indonesia's current export performance is still dependent on non-oil and gas commodities, especially plantation commodities. The decline in exports occurred in all simulations both in RCP 4.5 and RCP 8.5 scenarios. The decrease in exports of coffee commodities is feared to worsen the trade balance because it is accompanied by an increase in imports. The increase in imports occurred in all simulations, ranging from 0.01 to 0.08 percent (RCP 4.5) and 0.01 and 0.24 percent (RCP 8.5), as it is expected to be driven by reducing domestic coffee supply.

The Impact of Climate Change on Rice and Coffee Commodities on its Output, Price and Export

In theory, the impacts of climate change can be classified into two groups, namely biophysical impacts and socio-economic impacts. Biophysical impacts include psychological effects on the quantity and quality of food crops and plantations, changes in the quality and quantity of land and water, increases in weeds and pests, shifts in the impact of spatial and temporal distribution and increases in sea level and sea salinity. The direct and apparent impact of climate variability occur in decline of rice of yield leading towards decreasing output in each scenario. The magnitude of rice production loss was estimated to be more significant in RCP 8.5 scenario and when simulation 2 was applied. It was estimated that the rice production will go down by 6.90 percent during the period 2021-2050, 14.73 percent 2051-2080, and 11.64 percent during the period 2081-2100. This is similar to the previous studes (Naylor, 2001 and Naylor, 2007) as the temperature changes plays a major factor in influencing year-to-year variation in rice output. Our estimates were significantly higher than that of predicted by Oktaviani et al (2011). Oktaviani et al (2011) also assessed the potential impacts of global climate change by linking IMPACT and Indonesian CGE Model-INDOF and showed that the rice production loss in Indonesia reached 2.94 percent by 2030.

Table 3. Impacts of Climate Changes in Rice Sector on Indonesian Rice and Coffee Output

Output	Period	Sim 1		Sim 2		Sim 3	
		Paddy	Coffee	Paddy	Coffee	Paddy	Coffee
4.5	2021-2050	-0.49	-0.40	-6.54	-12.28	-0.38	-0.18
	2051-2080	-0.94	-1.23	-7.64	-14.65	-0.83	-0.91
	2081-2100	-1.09	-1.48	-7.11	-15.78	-1.00	-1.14
8.5	2021-2050	-0.63	-0.62	-6.90	-17.65	-0.45	-0.31

Output	Period	Sim 1		Sim 2		Sim 3	
		Paddy	Coffee	Paddy	Coffee	Paddy	Coffee
	2051-2080	-1.56	-2.36	-14.73	-19.86	-1.43	-2.04
	2081-2100	-2.47	-4.21	-11.64	-23.71	-2.37	-3.74

Source: Authors Calculation

Meanwhile, the risks of climate variability are enormous in coffee sector both for Robusta and Arabica coffee. Our modeling results showed that the potential loss of production will reach 17.65 percent during the period 2021-2050, 19.86 percent 2051-2080, and 23.71 percent during the period 2081-2100 under the simulation 2 and RCP 8.5 scenario. A systematic literature review conducted by Bilen et al (2023) also supports this finding by showing that most of the literatures analyzing the influence of climate change on coffee production were negative. This is mainly because global climate change reduces suitable areas for coffee cultivation, and rising infestations and distribution of insect pests and diseases that reduce coffee berry quality and yield.

The socio-economic impact apart from the decline in production and productivity as well as a decrease in the share of GDP in the agricultural sector is fluctuations in the prices of agricultural products. The decline in agricultural production on the one hand, while on the other hand the consumption of agricultural commodities is increasing, especially food as a result of an increase in population, pushing the prices of agricultural commodities to increase. Busnita, Oktaviani, and Novianti (2017) also support the argument with their study. This study showed that the Indonesia's temperature changes are not only cause surge in rice prices but also the rice price fluctuation or volatility. Using the ARCH-GARCH methods and VECM (Vector Error Correction Model), this study highlighted that changes of the temperature will cause higher fluctuation in rice prices and eventually will stabilized after 60 months.

Table 4. Impacts of Climate Changes in Rice Sector on Indonesian Export and Import

Indicator	Productivity	Period	Sim 1		Sim 2		Sim 3	
			Paddy	Coffee	Paddy	Coffee	Paddy	Coffee
Export	4.5	2021-2050	-1.19	-0.91	-15.60	-28.20	-0.91	-0.39
		2051-2080	-2.27	-2.80	-18.20	-33.66	-1.99	-2.07
		2081-2100	-2.63	-3.38	-16.85	-36.36	-2.40	-2.58
	8.5	2021-2050	-1.52	-1.40	-16.29	-40.72	-1.10	-0.69
		2051-2080	-3.74	-5.40	-35.40	-45.34	-3.43	-4.67
		2081-2100	-5.92	-9.65	-27.69	-54.54	-5.67	-8.58
Import	4.5	2021-2050	3.97	2.93	51.84	91.12	3.05	1.25
		2051-2080	7.54	9.04	60.50	108.76	6.64	6.66
		2081-2100	8.75	10.89	55.98	117.52	7.99	8.32
	8.5	2021-2050	5.07	4.52	54.09	131.65	3.68	2.22

Indicator	Productivity	Period	Sim 1		Sim 2		Sim 3	
			Paddy	Coffee	Paddy	Coffee	Paddy	Coffee
		2051-2080	12.43	17.45	117.78	146.31	11.40	15.06
		2081-2100	19.67	31.16	92.02	176.24	18.86	27.70

Source: Authors Calculation

The economic assessment of the follow-on impacts of climate-induced productivity changes yielded also impact son imports and exports. For changes in trade, the RCP8.5 scenario has a larger impact than the RCP 4.5 scenario. For rice, consequence of a decrease in rice productivity is that nationally there is a potential decrease in export yields ranging from 2 percent - 35 percent and an increase in import needs reaching a maximum range of 117 percent which will occur in scenario 8.5. What really needs attention is that the decline in rice production will have a spiraling impact, namely increasing the relative prices of rice and rice commodities, thereby reducing their competitiveness for exports. The decline in rice exports is in the range of -0.31 to -35 percent in the RCP 4.5 scenario and –0.5 to -52 percent in the RCP 8.5 scenario. Meanwhile, more significant impacts hit coffee trade as export will expected to go down by 54.54 percent and imports rising up to 176.24 percent in simulation 2. Climate change adaptation actions are urgently needed so that Indonesia can maintain its position as a coffee exporting country.

The Impact of Climate Change on Rice and Coffee Commodities on Indonesia's Household Welfare

Real income distribution is a variable that is used as a proxy for livelihood impacts from climate change policy simulations. The simulation results show that climate change in rice and coffee commodities can represent an income shock as indicated by a decrease in real income for all household groups, both in rural and urban areas. The highest decline in real income occurred in the rural 1 group of agricultural workers, followed by Rural 2 which were agricultural entrepreneurs. Low-income households in urban areas (urban 5) decreased their welfare more significantly than other urban household groups. The comparison of scenarios shows that scenario 8.5 is predicted to have a relatively significant decrease in income, thus indicating the risk of vulnerability related to poverty in both rural and urban areas. The multidimensional consequences of the decline in real income are also related to the potential decline in Indonesia's food security status, considering that the contribution of food products to Indonesian household consumption patterns is very dominant. Food availability continues to play an important role as an important dimension of food security where the supply of food and agricultural commodities is to maintain a stable expansion of food consumption and to offset fluctuations in production and prices.

Table 4. The Impacts of Climate Change on Real Household Consumption

Scenario	Period	rural1	rural2	rural3	rural4	rural5	urban1	urban2	urban3
4.5	2021-2050	-0.03	-0.03	-0.03	-0.03	-0.04	-0.03	-0.03	-0.01
	2051-2080	-0.07	-0.06	-0.06	-0.06	-0.08	-0.05	-0.06	-0.01
	2081-2100	-0.08	-0.07	-0.07	-0.07	-0.09	-0.06	-0.07	-0.01
8.5	2021-2050	-0.04	-0.04	-0.04	-0.04	-0.05	-0.03	-0.04	-0.01
	2051-2080	-0.11	-0.10	-0.10	-0.09	-0.13	-0.09	-0.10	-0.02
	2081-2100	-0.18	-0.17	-0.17	-0.15	-0.21	-0.14	-0.17	-0.03

Scenario	Period	rural1	rural2	rural3	rural4	rural5	urban1	urban2	urban3
4.5	2021-2050	-0.48	-0.45	-0.45	-0.41	-0.56	-0.39	-0.46	-0.08
	2051-2080	-0.56	-0.52	-0.53	-0.48	-0.66	-0.46	-0.53	-0.09
	2081-2100	-0.54	-0.50	-0.51	-0.46	-0.64	-0.44	-0.51	-0.08
8.5	2021-2050	-0.54	-0.50	-0.51	-0.46	-0.64	-0.44	-0.52	-0.08
	2051-2080	-1.02	-0.95	-0.96	-0.88	-1.19	-0.83	-0.96	-0.17
	2081-2100	-0.87	-0.81	-0.81	-0.74	-1.02	-0.70	-0.82	-0.14
4.5	2021-2050	-0.02	-0.02	-0.02	-0.02	-0.03	-0.02	-0.02	0.00
	2051-2080	-0.06	-0.05	-0.05	-0.05	-0.06	-0.05	-0.05	-0.01
	2081-2100	-0.07	-0.06	-0.06	-0.06	-0.08	-0.06	-0.06	-0.01
8.5	2021-2050	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.03	-0.01
	2051-2080	-0.10	-0.09	-0.09	-0.09	-0.12	-0.08	-0.09	-0.02
	2081-2100	-0.17	-0.16	-0.16	-0.14	-0.20	-0.14	-0.16	-0.03

Source: Authors Calculation

Note:

- Rural 1 are agricultural workers.
- Rural 2 is an agricultural entrepreneur.
- Rural 3 is a low class non-agricultural household in rural areas, namely low class free entrepreneurs, administrative staff, mobile traders, free workers in the transportation sector, individual services, and unskilled laborers.
- Rural 4 is non-labor force in rural areas, which includes non-labor force and unclear groups in rural areas.
- Rural 5 is non-agricultural households in the upper class, including upper class independent entrepreneurs, non-agricultural entrepreneurs, managers, military, professionals, technicians, teachers, administrative workers and upper class salespeople.
- Urban 1 is a non-agricultural household of the lower class in urban areas, which includes low-income free entrepreneurs, administrative staff, mobile traders, free workers in the transportation sector, individual services and unskilled laborers.
- Urban 2 is non-labor force in urban areas, including non-labor force and unclear groups.
- Urban 3 is non-agricultural households in the upper class, such as upper class independent entrepreneurs, non-agricultural entrepreneurs, managers, military, professionals, technicians, teachers, managerial workers, and upper class salespeople.

Conclusion

1. Climate change that reduces rice and rice productivity affects Indonesia's macroeconomic performance. Climate change will reduce real GDP, real household consumption and exports. On the other hand, climate change will increase Indonesia's imports. Changes in macroeconomic performance in all scenarios of RCP 8.5 are worse than scenario 4.5.
2. Climate change poses a negative risk to the quantity and quality of rice and coffee output and has a spiraling impact on increasing domestic prices. An increase in domestic prices has the potential to reduce Indonesia's trade competitiveness, especially as a major producer and exporter of coffee due to an increase in relative prices.
3. Climate change in rice commodities can represent an income shock as indicated by a decrease in real income for all household groups, both in rural and urban areas. The highest decline in real income occurred in the rural 1 group of agricultural workers, followed by Rural 2 which were agricultural entrepreneurs. Low-income households in urban areas (urban 5) decreased their welfare more significantly than other urban household groups.

Recommendation

1. Adaptation climate policies on rice and rice commodities requires multi approach to enhance the resilience of both production systems to climate change, safeguarding livelihoods, food security, and sustainability. Government and related stakeholders should develop heat-tolerant and drought-resistant varieties of rice and coffee, strengthen extension officer to provide training on climate smart agricultural practices, and improved infrastructure (irrigation, post-harvest facilities) to enhance the resilient of rice and coffee production. Production stability is very much needed to maintain Indonesia's position as one of the largest coffee exporters in the world.
2. Government should develop financial support and risk management towards climate change, such as providing financial incentives (subsidies and low-interest loan) to encourage rice and coffee farmers to invest in climate adaptation measures, establish crop insurance to protect and stabilize farmers income, and strengthen social safety nets.

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