Munich Personal RePEc Archive

A General Assessment of Climate Change - Loss of Agricultural Productivity in Indonesia

RESTU ANANDA, RIMA and Widodo, Tri

Master and Doctoral Program, Economics Department, FEB
Gadjad Mada University

7 January 2019

Online at https://mpra.ub.uni-muenchen.de/91316/
MPRA Paper No. 91316, posted 09 Jan 2019 13:56 UTC

A General Assessment of Climate Change - Loss of Agricultural Productivity in Indonesia

By
RIMA RESTU ANANDA
And
Tri Widodo

A General Assessment of Climate Change - Loss of Agricultural Productivity in Indonesia

Abstract:

The changes of frequency and complexity of extreme climate events and in the variability of weather patterns will have significant impacts for stability of agricultural system. Climate change and variability are phenomena of climate anomalies that are of great concern, especially due to the agricultural sector. In Indonesia, in 30 years there have been several extreme conditions which are marked by the frequency of increasingly high climate variability. This paper investigate the impact of climate change on change of value GDP, change of wealth, Government Household Demand, Private Household Demand and real wage in Indonesia by using the dynamic Computable General Equilibrium (CGE) model. This study used GTAP 9 with base year 2011. The GTAP database covers 140 regional units and 57 sectors that aggregated into eleven regions and eight sectors. There are three scenarios of climate change used in this paper that were the highest, medium and the lowest. The results shows that both GDP and wealth have a negative impact due to the scenarios. The greater of climate change is, the greater the decrease of values of GDP, Wealth, Market Price, Government Household Demand, Private Household Demand towards the scenarios of climate change in Indonesia are. The results indicate an urgent need to mainstream adaption strategies to lessen the negative impacts of any climate change-induced loss of agricultural productivity in Indonesia.

Keyword: Climate change, agricultural productivity, impact assessment, Indonesia, GTAP.

I. *Introduction*

Climate change is a condition that is labelled by changes in the world's climate design which result in hesistant weather conditions. Climate is changed because the changes in climate indicator, such as air temperatures and rainfalls that happen over a long period of time, frequent storms, extreme air temperatures, and wind directions that change drastically (Ratnaningayu, 2013; Ministry of Environment, 2004).

Climate change and variability are phenomena of climate anomalies that are of great concern, especially due to the agricultural sector. The FAO (2005) investigations show that the climate change and variability affect 11% of agricultural land in developing countries that can reduce food production and reduce Gross Domestic Product (GDP) to 16%. Meanwhile, climate variability and change lead the production of food crops (cereals) in the Southeast Asia region reduce between 2.5% and 7.8% (Fischer et al, 2002). Variability and climate change with all its effects have the potential to cause loss of food crop production, 20.6% for rice, 13.6% corn, and 12.4% soybean (Handoko et al. 2008). While food needs, especially rice, continue to increase in line with population growth. It is estimated that in 2025 the population will reach 262 million people with consumption of 134 kg of rice per capita, thus the national rice demand reaches 35.1 million tons or 65.9 million tons of GKG (Budianto, 2002).

The agricultural sector is very vulnerable to the climate changed because it impacts the cropping patterns, planting time, production, and quality of yield (Nurdin, 2011). Climate is closely related to climate change and global warming can reduce agricultural production between 5-20 percent (Suberjo, 2009).

Indonesia is an agricultural country where agriculture have an significant role in the national economy. This can be shown from the many people or labor who live or work in the agricultural sector and national products derived from agriculture (Mubyarto, 1989). In Indonesia, in 30 years there have been several extreme conditions which are marked by the frequency of increasingly high climate variability. Climate change has a negative influence on agricultural production (Utami et al, 2011). The direct impact, for example, decreased agricultural productivity due to increased air temperature and changes in rainfall patterns. Indirect effects include changes in irigation maintanance as a result of changes in crop demands and drains as well as shift types of pests and disease that affected food crops and stockbreeding.

To this end, the main objective of this paper is to examine the economy-wide impacts of climate change–induced productivity loss in Indonesian crops. The rest of the paper is organized as follows: Section 2 provides a brief literature review on climate change and agricultural productivity in Nepal; Section 3 outlines the methodology, including the empirical model and framework; Section 4 presents the simulation results; and Section 5 discusses policy implications and offers some concluding remarks.

Empiric Studies

Ample evidence proves that the climate in Indonesia has change. Boer, Buono, and Rakhman (2008) said that the rainfall from 26 stations for East Java for 20-40 years were significantly declining trend in seasonal rainfall in East Java. But in fact, rainfall in most areas show increasing trends. As a result, the increased rainfall resulting in increased flooding.

Thus, climate change is forecasted to have a significant impact on agricultural production in Indonesia, especially food crops. Boer (2009) found that climate change reduce corn yields by more that 40 percent and rice yields by 20 percent. Rice yields are delicate to the rising of minimum temperatures in the dry season (Peng et al., 2004).

Nelson and Shively (2014), Miller and Robertson (2014) and Hertel et al. (2010) have been investigate the effects of climate change on countries and regions in the world by using the CGE Models. Meanwhile, Bandara and Cai (2014), Cai et al. (2016) and Ahmed and Suphachalasai (2014) have also been some research to investigate the impact climate changing at South Asian. Zhai, Lin, and Byambadorj (2009) tempted the potential impacts of the climate change on China's agriculture production and trade as its macroeconomy changes in agricultural productivity. The result suggest that declining in the agricultural share of GDP, the impact of climate change on China's macroeconomy should be anticipated. If future growth in China's agricultural productivity is slower, subordination on world agricultural markets will be higher, leading to more welfare and output losses worsening terms of trade.

In general, the impact on agricultural production show that overall impacts will be less than those found by natural scientists. The reduction of agricultural production from the direct impact of climate change increase the crops price and raise farmer's incentive, which will need labor and capital into agricultural production and therefore partially mitigate either negative or positive effects of climate change (Zhai et al. 2009; Wang et al. 2009b; Li et al. 2011).

Climate change also have socio-economic impact that can be seen from decline in yields and production; reducing in marginal GDP; fluctutation in market world's prices; geographical distribution of trade regimes changes; increasing of people that hunger and food scarcity (Kusumasari, 2016).

Methodology: Global Trade Analysis Program* (GTAP) *Method

GTAP (Global Trade Analysis Project) is a global network of researchers and policy makers conducting quantitative analysis of international policy issues. GTAP's goal is to improve the quality of quantitative analysis of global economic issues within an economy-wide framework (GTAP, 2018). The GTAP Project maintains a global database that CGE modelers rely on. The database is built based on data contributions from all CGE modelers, which GTAP is a consistent global data base (Burfisher, 2011). The GTAP Data Base has been on supporting trade policy analysis, the pertaining to greenhouse gas emissions and land usage of related to climate change as other environmental issues (Aguiar *et al., 2016*).

The GTAP Data Base available globally consistent that consist of consumption, production datas, and international trade energy data and CO_2 emission for 140 regions and 57 commodities for 2204, 2007, and 2011 benchmark years.

Source: GTAP 9 Data Base, official website.

The GTAP Data Base can be used with the GTAP Model and RunGTAP software. First, the user must aggregate the data (regions, commodities and endowments) using the GTAPAgg (or FlexAgg) program provided with the data base to the desired level and then use with the GTAP or GTAPinGams model/s to analyze the impact of global policies (trade, environmental, migration policies are commonly examined).

Data

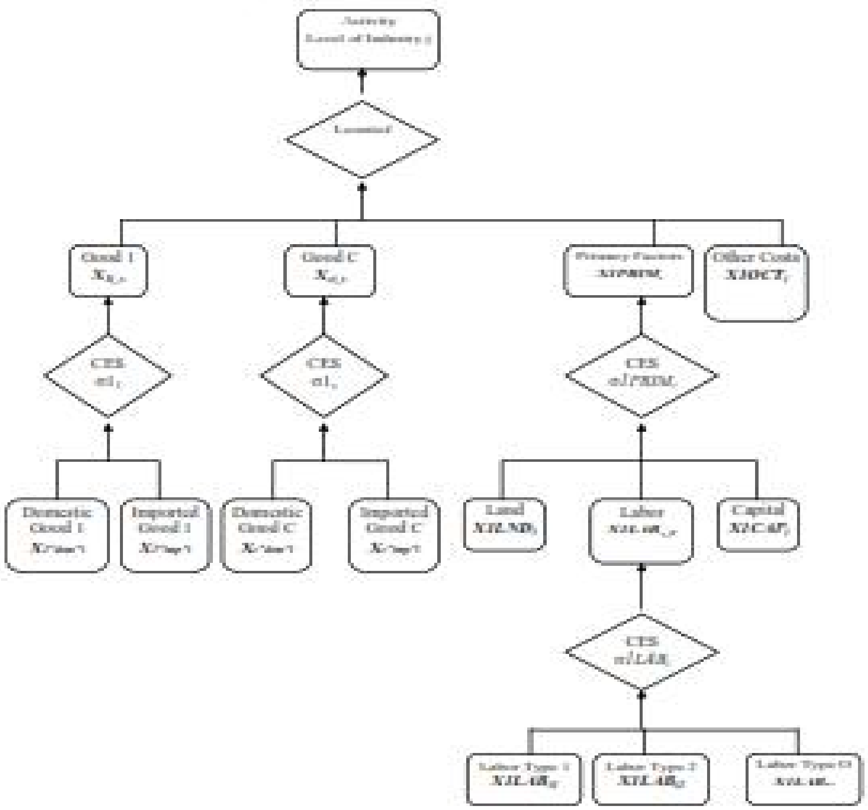
This study using Global Trade Analysis Project (GTAP) Database version 9A from Center for Global Trade Analysis, Purdue University. The GTAP database covers 140 regional units and 57 sectors (Aguiar, *et al.* 2016) with reference year 2004, 2007, and 2011. The latest reference year 2011 was used in model calibration.

Indonesia CGE Model for Climate Change

The structure of the Indonesian CGE Model for Climate Change is conventional and belongs to the class of general equilibrium models that are linear in proportional changes, sometimes referred to as Johansen Model (Oktaviani et al., 2011). This structure have assumptions about firm behavior and market structure, determines the demands for labor, other primary factors, and intermediate inputs and supply of commodities by the industry. These market and behavioral assumptions are as follows:

1. Producers and consumers are price takers in both input and output markets.

2. Producers seek to maximize profit by choosing input levels subject to the depicted production technology and therefore choose the least-cost combination of inputs for any given of output.



Sources: Horridge, Parmenter, and Pearson (1999).

Aggregation

Region Aggregation Mapping

The countries that used in this study are grouped according to countries that already available in GTAP 9. The region aggregation of this research is Indonesia, Africa, America, Asia, Australia, European Union, Middle East, New Caledonia, United Kingdom and Rest of The World (ROW) as it supposed below.

Table. 1 Region Aggregation

Regions	Member
East Asia	Chn hkg jpn kor mng twn xea brn
EU_28	Aut bel cyp cze dnk est fin fra deu grc hun irl ita lva ltu lux mlt nld pol prt svk svn esp swe gbr bgr hrv rou
Indonesia	Indonesia
Latin Amer	Arg bol bra chl col ecu pry per ury ven xsm cri gtm hnd nic pan slv xca dom jam pri tto xcb
MENA	Bhr irn isr jor kwt omn qat sau tur are xws egy mar tun xnf
NAmerica	Can usa mex xna
Oceania	Aul nzl xoc
ROW	Che nor xef alb blr rus ukr xee xer kaz kgz xsu arm aze geo xtw
SEAsia	Khm lao mys phl sgp tha vnm xse
South Asia	Bgd ind npl pak lka xsa
SSA	Ben bfa cmr civ gha gin nga sent go xwf xcf xac eth ken mdg mwi mus moz rwa tza uga zmb zwe xec bwa nam zaf xsc

Source: Author's specification from GTAP 9 Database (2018).

Sectoral Aggregation Mapping

This research followed default GTAP database sector aggregation mapping with some differences. The sectoral aggregation is disaggregationing "GrainsCrops" sector to provide more detailed analysis. GrainsCorps that consist of rice, wheat, cereal grains and other crops is the focus of this research.

Table 2. Sectoral Aggregation

Aggregation Name	Group Description	GTAP Sector Code	Disaggregated Sectors
Paddy Rice	Paddy Rice	Pdr	Paddy Rice
Wheat	Wheat	Wht	Wheat
Cereal Grains	Cereal Grains	Gro	Cereal Grains
OtherCrops	Horticulture products, farm crops	v_f osd c_b pfb ocr	Vegetables, fruit, nuts Oil seeds Sugar cane, sugar beet Plant-based fibers Crops n.e.c
MeatLstk	Meat, animal products from farms	Ctl oap	Cattle, sheep, goats, gorses Animal products, n.e.c

		rmk wol cmt omt	Raw milk Wool, silk-worm cocoons Meat, cattle, sheep, goats, horse Meat products, n.e.c
Extraction	Extraction and mining products	Frs fsh coa omn	Forestry Fishing Coal Minerals, n.e.c
OilGas	Oil and gas	Oil Gas	Oil Gas
ProcFood	Processed food products	Vol mil pcr sgr ofd b_t	Vegetable oils and fats Dairy products Processed rice Sugar Food products, n.e.c Beverages and tobacco products
TextWapp	Textile and apparel products	Tex Wap	Textile Wearing apparel
BasicInd	Basic manufacturing producing raw or primary materials	Lea lum ppp p_c crp nmm	Leather products Wood products Paper products, publishing Petroleum, coal products Chemical, rubber, plastic products Mineral products, n.e.c
MetalInd	Metal manufacturing	i_s nfm fmp	Ferrous metals Metals n.e.c Metal products
HighInd	High-tech manufacturing	Mvh otn ele ome omf	Motor vehicle and parts Transport equipment n.e.c Electronic equipment Machinery and equipment n.e.c Manufactures n.e.c
Util_Cons	Utility and construction sector	Ely gdt wtr cns	Electricity Gas manufacture, distribution Water Construction
TransComm	Transport and communication sector	Trd otp wtp atp cmn	Trade Transport n.e.c Sea transport Air transport Communication
OthServices	Other services sector	Ofi Isr obs ros osg dwe	Financial services n.e.c Insurance Business services n.e.c Recreation and other services Public administration/defense/health/education Dwellings

Source: Author's specification from GTAP 9 Database (2018).

Factors of Production Aggregation Mapping

For factor production were aggregated into "Land", "Skilled Labor", "Unskilled Labor", "Capital", and "Natural Resources" category. Land and natural resources were set to have limited mobility across sectors. The value of *ETRAE* for capital goods is assumed to be similar with those of land (Burfisher, 2011).

Table. 3 Factors of Production Aggregation

Factor of Production	Aggregation Group	Factor Mobility
Land	"Land"	Sluggish (*ETRAE = -1)*
Technicians, Associates, Professionals Officials and Managers	Skilled Labor "SkLabor"	Mobile
Agricultural and Unskilled Clerks Service/Shop Workers	Unskilled Labor "UnSkLabor"	Mobile
Capital	"Capital"	Sluggish (*ETRAE = -1)*
Natural Resources	Natural Resources "NatRes"	Sluggish (*ETRAE = - 0.001)*

Source: Author's specification from GTAP 9 Database (2018).

Simulation Scenarios and Magnitude of Shocks

Simulation

To analyze the economic impact of the climate change on Indonesia's agricultural sector, it is necessary to adopt agricultural productivity shock (change %) that will be applied in a country. Application of scenarios based on Chalise *et al*. (2018) in Nepal based on the analysis and the existing phenomenon. Since Nepal is predicted to be one of most vulnerable country to climate change and agricultural productivity is significantly affected as predicted, this could have negative effects on the Nepalese economy due to the crucial role of agriculture in household income and consumption. Based on this, this study would like to see the economic impact of climate change to Indonesia agricultural sector depend on the agricultural productivity shock. For simplicity, This study assume that climate change only affected land productivity based on Bandara and Cai (2014). So, the simulations used in this research are:

1. Highest impact of climate change (S1) for paddy rice is about 15,20%, wheat is about 17,10%, cereal grains is about 22,70% and other agricultural sectors is about 17,30%.
2. Medium impact of climate change (S2) for paddy rice is about 10,81%, wheat is about 14,16%, cereal grains is about 19,08% and other agricultural sectors is about 10,17%.
3. Lowest impact of climate change (S3) for paddy rice is about 1,20%, wheat is about 2,30%, cereal grains is about 6,90% and other agricultural sectors is about 4,80%.

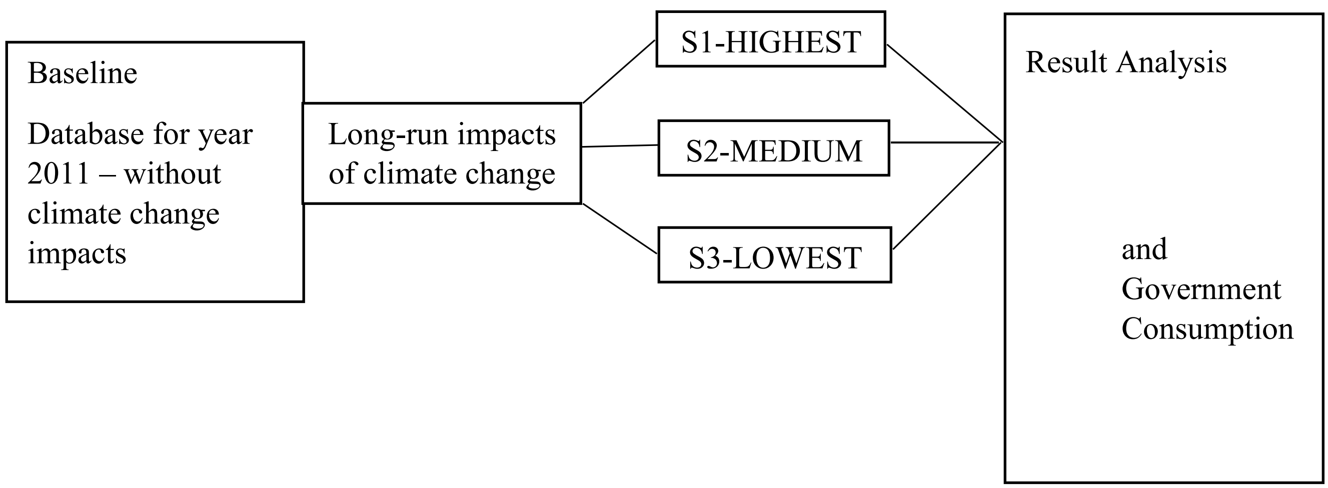
Table 4. Simulation Scenarios

	Simulation 1	Simulation 2	Simulation 3
Paddy Rice	-15.20%	-10.81%	-1.20%
Wheat	-17.10%	-14.16%	-2.30%
Cereal Grains	-22.70%	-19.08%	-6.90%
Other Agricultural	-17.30%	-10.17%	-4.80%

Sources: Chalise et al, (2018).

The author would see the effect of change in values of Wealth, GDP, Government and Private Demand, Real Wage, Household Consumption and Market Prices in different scenarios.

Figure 1. Conceptual Framework of The Experiment



Sources: Chalise et al, 2018.

Simulation Results and Analysis

The results is based on the simulations of climate change impacts on Indonesian Agriculture that were analyzed in two different stages, focusing on changes in macroeconomy variables and the effects on diverse household groups. The simulated results are reported in the form of percentage changes from the baseline status. As shown in Diagram 1, the results for every variable are compared for three distinct climate change scenarios: S1 represents the highest, S2 a medium and S3 the lowest decrease in agricultural productivity.

Many analysts use the impact on GDP to examine the effects of climate change on crop productivity. The use of real GDP in term of expecting changes in Indonesia economy is necessary because of a great share to national GDP. The simulation results represent the projected impact of climate change on agricultural productivity affects real GDP and wealth negatively which is means negative growth of agricultural sectors.

By comparing each commodity in every simulation, cereal grains gets the highest impact on both change of wealth and value change of GDP. From all simulation in change of wealth, cereal grains hits the highest decrease of change of wealth as about 22% and the lowest is paddy rice is about 6%. The highest decrease of value change of GDP is also cereal grains is about 24,5% and the lowest is paddy rice as about 6%. In short, climate change affects agriculture productivity could cause a decrease in wealth about 6% to 22% and change value of GDP about 6% to 24,5%.

Table 1. EV and Value Change of GDP in Indonesia

		EV			VGDP	
	Sim. 1	**Sim. 2**	**Sim. 3**	**Sim. 1**	**Sim. 2**	**Sim. 3**
Paddy Rice	-8408.92	-5527.27	-523.59	-0.901076	-0.605389	-0.060532
Wheat	-9800.62	-7685.89	-1020.98	-1.041257	-0.858456	-0.117282
Cereal Grains	-14505	-11355.4	-3300.19	-1.508992	-1.196584	-0.369245
Other Crops	-9952.68	-5142.4	-2217.76	-1.056499	-0.565147	-0.251108

Sources: GTAP, author, 2018.

In Table 2, it appears that the climate change on agriculture in Indonesia will lead to a decrease in demand Government and Private Household for paddy rice, wheat, cereal grains and other crops. The smaller change of climate change, the smaller change of demand for paddy rice, whet, cereal grains and other crops. From the results of the simulation below, cereal grains is commodity that gets the greater impact of the climate change. When the climate change being greater time by time, the demand of private and government household will decrease. Cereal grains still the commodity that gets the greatest impact than other commodity, it is about 25% for private household and 28% for government household demand, followed by other crops is about 24% and 25% for private and government demand, wheat is about 6% and 7,5% for private and government demand and the last is paddy rice around 6% and 7,5% for private and government demand.

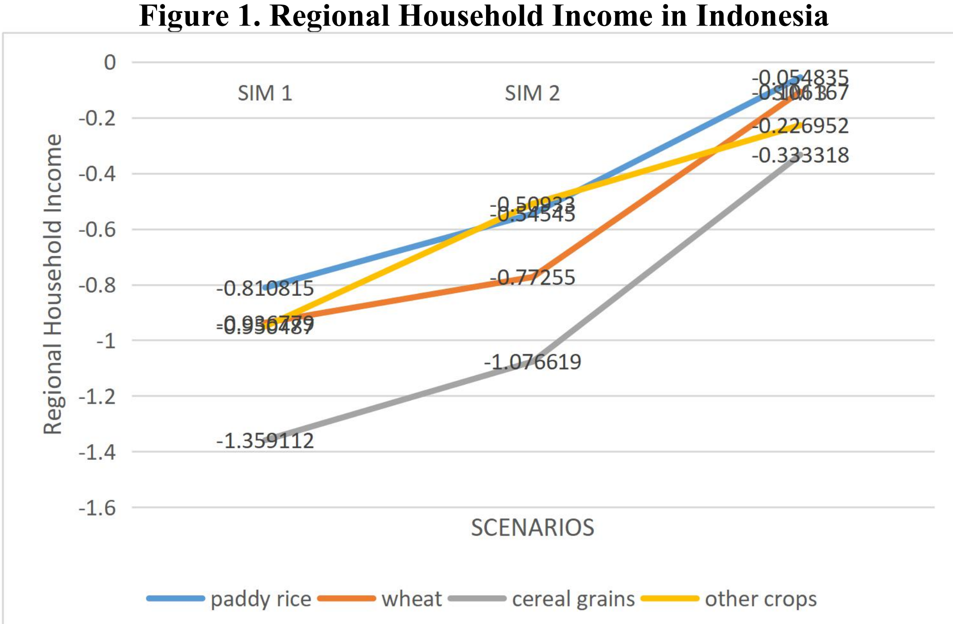
Table 2. Government and Private Household Demand in Indonesia

	Qp			Qg		
	Sim. 1	**Sim. 2**	**Sim. 3**	**Sim. 1**	**Sim. 2**	**Sim. 3**
Paddy Rice67,5	-4.2	-2.84	-0.28	-21.08	-14.81	-1.58
Wheat1112,5	-2.96	-2.4	-0.35	-19.08	-15.61	-2.38
Cereal Grains	-5.02	-4.04	-1.27	-22.23	-18.38	-6.22
Other Crops2426	-4.38	-2.37	-1.05	-22.36	-12.76	-5.86

Sources: GTAP, author, 2018.

Figure 1, it appears that the effect of climate change from the simulations will lead to a decrease in regional household income for paddy rice, cereal grains, wheat and other crops. The greater climate change, the more regional income household will decrease. From the figure 1, paddy rice is the commodity which had the highest decreasing that is about 15% and followed by Other Crops is about 12,7%, wheat is about 3,2% and the last is cereal grains. But, there is something interesting in this simulation results that cereal grains is different from others. While the other commodities lead to decrease, cereal grains is the opposite. Cereal grains gains the real wage of household about 2%.

Figure 1. Regional Household Income in Indonesia



Sources: GTAP 9A, author, 2018.

In line with discussion before, the climate change also affect the commodities market price in Indonesia. In Table 3, climate change lead the prce of paddy rice about 17%, Otherscrop about 15,9%, Wheat is about 4,45% but Creal Grains is difference. The effect of climate change makes price of Cereal Grains is decreasing about 0.045%. The increasing price of paddy rice, wheat and others crop caused by decreasing of the supply of the commodities, so the demand will increase followed by price of commodities.

Table 3. Market Price in Indonesia

Market Price (%)	Paddy rice	Wheat	Cereal Grains	Other Crops
Land	17.4337847	5.055291	0.8263655	16.86539141
UnSkLab	15.3845978	3.480097	-1.803172343	13.40477105
SkLab	15.7002001	3.71554	-1.455783894	13.9275531
Capital	15.7371567	3.743029	-1.412855792	13.9890402
NatRes	15.6015107	3.649579	-1.509177663	13.77187278
PaddyRice	**17.0153871**	4.727934	0.243157452	16.15110893
Wheat	16.657029	**4.456517**	-0.173359115	15.54872185
CerealGrains	16.7579665	4.53599	**-0.045668358**	15.72011502
OthersCrop	16.8801766	4.625711	0.079936454	**15.92416116**

Sources:GTAP 9, author, 2018.

Besides the commodities, factor production, likes Land, UnSkLab, SkLab, Capital and Natural Resources, prices had changes because of the extreme of climate change. Based on the simulation, prices Land of paddy rice has increase 17,4%, 5% for wheat, 0,8% for cereal grains and 16,8% for other crops. The prices of other factor productions like unskill labor, capital, natural resources and skill labor also lead to a increasing about 3% to 15% for paddy rice, wheat and others crop. But, the estimation result for cereal grains is different from others. The estimation result from the Table 3 shows that, prices of cereal grains for unskill labor, skill labor, capital and natural resources decrease for every commodity, the decreasing of all prices is about 1,5% to 1,9%. From this simulation result, it shows that climate change not have a great impact in cereal grains even in the highest climate change simulation. So, the result simulation of cereal grains is different from the other commodities like paddy rice, wheat and others crop.

Policy Implication and Conclusions

Using a CGE model of the Indonesian economy, this paper has explored the macro and micro economic effects of climate change impacts on Indonesian agriculture. The simulation results of this study had revealed that Indonesian agriculture will be seriously impacted by climate change-induced productivity loss. GDP is supposed to decline sharply due to contributes a large proportion contribution to GDP. The results of this study are highly consistent with the result of previous studies. The result above show that a climate-induced reduction in crops production is indicated to exert an upward pressure on food prices, which will result in food security problems in Indonesia. The prices of rice, wheat, and cereal grains are expected to rise sharply.

To conclude, future research is recommended to address the limitation of this paper. Many researches to investigate the factors responsible for productivity loss due to climate change and the adaptation practices Indonesia is required. The future research should have been better than this, measuring the impacts of climate change would require a much expanded modelling framework.

REFERENCES

Aguiar, A., Narayanan, B., McDougall, R., 2016. Overv. GTAP 9 Data Base. 2016 1 (1), 28, Bandara, J.S., Cai, Y., 2014. The impact of climate change on food crop productivity, food prices and food security in South Asia. Econ. Anal. Policy 44 (4), 451–465.

Ahmed, M., Suphachalasai, S., 2014. Assessing the costs of climate change and adaptation in South Asia

Boer, R., A. Buono, A. Rakhman.2008. *Analysis of Historical Change of Indonesian Climate Change*. Technical reports for the 2 National Communication Ministry of Environment. Republic of Indonesia, Jakarta.

Boer, R. 2009. *Strategi Menghadapi Perubahan Iklim untuk Sektor Pangan*. Centre for Climate Risk and Opportunity Management in Southeast Asia Pacific (*CCROM* - SEAP), Bogor, Indonesia: Bogor Agricultural University,

________. 2010. *Climate Change and Agricultural Development: Case Study in Indonesia*. Paper commissioned by International Food Policy Research Institute. Unpublished Report.

Budianto J. 2002. Tantangan dan peluang penelitian padi dalam perspektif agribisnis. Dalam: B. Suprihatno *et al*. (Eds.). Kebijakan perberasan dan inovasi teknologi. Puslitbang Tanaman Pangan. Bogor. p. 1-17.

Cai, Y., Bandara, J.S., Newth, D., 2016. A framework for integrated assessment of food production economics in South Asia under climate change. Environ. Model. Softw. 75, 459–497.

FAO. 2005. “Impact of Climate Change and Diseases on Food Security and Proverty Reduction”. Special event background document for the 31st session of the committee on world food security. Rome, 23-26 May 2005.

Handoko I, Sugiarto Y, Syaukat Y. 2008. Keterkaitan Perubahan Iklim dan Produksi Pangan Strategis. Telaah kebijakan independen bidang perdagangan dan pembangunan oleh Kemitraan/Partnership Indonesia. SEAMEO BIOTROP. Bogor.

Hertel, T.W., Burke, M.B., Lobell, D.B., 2010. The poverty implications of climateinduced crop yield changes by 2030. Glob. Environ. Change 20 (4), 577–585.

Horridge, J.R., B.R. Parmenter and K.R. Pearson. 1999. ORANI G: General Equilibrium Model of the Australian Economy. Course in Pratical GE Modeling. Center of Policy Studies and IMPACT Project. Monash University, 5thn July-9 July 1999. , Melbourne: Monash University.

Mubyarto. (1989). Pengantar Ekonomi Pertanian. Jakarta: LP3ES.

Müller, C., Robertson, R.D., 2014. Projecting future crop productivity for global economic modeling. Agric. Econ. 45 (1), 37–50.

Nurdin. (2011). Antisipasi Perubahan Iklim untuk Keberlanjutan Ketahanan Pangan. Sulawesi Utara: Universitas Negeri Gorontalo.

Nelson, G.C., Shively, G.E., 2014. Modeling climate change and agriculture: an introduction to the special issue. Agric. Econ. 45 (1), 1–2.

Li X, Takahashi T, Suzuki N, Kaiser M H. 2011. The impact of climate change on maize yield in the United States and China. Agricultural Systems, 104, 348-353

Peng, S., J. Huang, J. E. Sheehy, R. C. Laza, R. M. Visperas, X. Zhong, G. S. Centeno, et al. 2004. Rice Yields Decline with Higher Night Temperature from Global Warming. *Proceedings of the National Academy of Sciences of the United States of America* 101 (27): 9971–9975.

Suberjo, (2009). *Adaptasi pertanian dalam pemanasan global*. The University Of Tokyo. Online: http://subejo.staff.ugm.ac.id/?p=108.

Utami, Jamhari, dan Suhatmini Hardyastuti. (2011). El Nino, La Nina dan Penawaran Pangan di Jawa, Indonesia. *Jurnal Ekonomi Pembangunan*. Vol. 12: 2, hlm. 257-271.

Wang J X, Huang J K, Yang J. 2009b. Water security and agricultural development in 3H region. In: Climate Change. Report Submitted to the World Bank, China.

Zhai F, Lin D, Byambadorj E. 2009. Impacts of climate change on China's agriculture: A analysis by CGE model. ADB Report.