

Irrigation as a Climate Change Mitigation Option in Cambodia

Sokuntheavy Hong and Jun Furuya

Abstract—The paper aims at predicting the impacts of government's irrigation investment on the fluctuation of rice consumption and rice price under moderate climate change and socio-economic scenarios by using supply and demand model of agricultural products. The simulation results show that under the increasing irrigation stock scenario, people would have more widely availability of rice to consume and the price of rice is predicted to be more affordable comparing to the baseline scenario of which irrigation investment is not increased. Therefore, the government's investment in irrigation is crucial for people to have more access to rice and for reducing rice fluctuation as one of the important mitigation measures in Cambodia.

Index Terms—Government's irrigation stock, moderate climate change scenario, per capita consumption of rice, rice farm price.

I. INTRODUCTION

The vision of agricultural development in Cambodia as indicated in the policy paper on the promotion of paddy production and rice export of Cambodia is production enhancement, diversification and agricultural commercialization. To achieve this vision, one of the main and foremost measures to be undertaken is infrastructure construction and improvement, including irrigation as in [1]. Nevertheless, the core national strategic frameworks of the countries such as Rectangular strategies and National Strategic Development Plan, which are the approaches to support the vision of Millennium Development Goal of improving food security and nutrition, mainly focus on only land intensification to improve agricultural productivity and not on expansion of cultivated land according to Reference [2]. Rice yields have been increasing from 1.8 tons (t)/ha in 1998 to 2.6 t/ha in 2007 and the production has almost doubled from 3.5 million tons in 1998 to 6.7 million tons in 2007. The rapid increase in rice production was reportedly due to the improved production technology as well as the increasing expansion of irrigated areas. Moreover, using Ricardian approach to analyze the economic impact of climate change on rice production, Reference [3] concluded that net revenue from irrigated farm is less sensitive to changes of temperature and precipitation than that from dry land farm. Rice production is closely related to climatic condition, especially rainfall. It is said that the availability of water supply is the main factor to boost rice production. In

Cambodia, there is a huge potential irrigated land, which hasn't been irrigated yet according to Reference [4]. Reference [5] said that irrigation expansion is an important factor for agricultural growth. However, irrigation development and management is not the main and prompting focus of agricultural sector by the government of Cambodia although Cambodia Climate Change Strategic Plan 2014-2023 has been launched to address climate change issue based on Reference [6]. The objective of the study is to analyze how much government's investment on irrigation influences consumption of rice and rice price in Cambodia as one of climate change mitigation measures in Cambodia.

II. DATA AND METHODOLOGY

A. Empirical Model

Yields are determined by climatic conditions and inputs. Reference [7] used supply and demand model in their study to predict the equilibrium rice price and per capita consumption of rice under climate change scenarios. However, input prices were not incorporated into yield function in their study. This study used nutrition in fertilizer as a proxy variable to fertilizer variable in yield function of dry season rice to make a more reliable estimation. The nutrient in fertilizer would more significantly affect yield in dry season than that in wet season since rainfall in wet season would wash the nutrition from the soil to crops. Moreover, this study integrated government's irrigation stock in area function of dry season rice to predict the effect of irrigation investment on equilibrium rice price and consumption of rice using a larger number of observation data (year 1995 through year 2012). Reference [8] developed their model incorporating import function. However, Cambodia had become rice exporter after 2003. In the study of [7], the export function was used in their model, whereas this study used net export function, which yields a more reasonable result.

Yield functions of wet season rice:

$$YW_t = \alpha_{YW} + b_{YW1} \log T + b_{YW2} TEMP_{SEPT} + b_{YW3} RAIN_{SEPT} + b_{YW4} SOLAR_{SEPT} \quad (1)$$

Yield functions of dry season rice:

$$YD_t = \alpha_{YD} + b_{YD1} \log T + b_{YD2} TEMP_{MARCH} + b_{YD3} SOLAR_{MARCH} + FN_t \quad (2)$$

Area functions are the functions of lagged planted areas and lagged rice farm price based on adaptive expectation model. Reference [9] used irrigation cost variable to estimate stock of irrigated land of maize in their model, mentioning that irrigation cost positively influences irrigated land. This

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study incorporates government's irrigation stock in area function of dry season rice since wet season rice production depends tremendously on rainfall.

Area functions of wet and dry season rice can be written as follows:

Area functions of wet season rice:

$$AW_t = a_{AD} + b_{AW1}AW_{t-1} + b_{AW2}RFP_{t-1}/(CPI_{t-1}/100) + b_{AW3}RAIN9_{t-1} \quad (3)$$

Area functions of dry season rice:

$$AD_t = a_{AD} + b_{AD1} \log T + b_{AD2}AD_{t-1} + b_{AD3}RFP_{t-1}/(CPI_{t-1}/100) + b_{AD4}GS_{t-1} \quad (4)$$

Identity of paddy production of wet season rice:

(5)

Identity of paddy production of dry season rice:

$$QD_t = YD_t AD_t \quad (6)$$

Total productions of rice (paddy and milled) are identities in the model, derived from the following equations.

Identity of total production of rice (paddy equivalent):

(7)

Identity of production of rice (milled equivalent):

(8)

Cambodia became a net rice exporter after 2003, so the net export of rice can be modeled as following.

Net export of rice:

$$NEX_t = a_{NEX1} + b_{NEX2}(WP_t * EXR_t)/(CPI_t/100) + b_{NEX3}(RFP_t/(CPI_t/100)) \quad (9)$$

Identity of net export of rice:

$$NEX_t = EXP_t - IMP_t \quad (10)$$

Stock change functions of rice are influenced by the changes in production of rice and rice price at the ending and the beginning of the year. However, due to the small number of observations, only changes in production of rice at the ending and the beginning of the year was incorporated in stock change functions given as below.

Stock change functions of rice:

$$STC_t = a_{STC} + b_{STC1}(Q_t - Q_{t-1}) \quad (11)$$

Domestic supply of rice can be derived from the sum of total production and imported amount of rice minus the exported amount, stock change and feed, seed and waste. The identity of supply of rice can be written as follows.

Supply of rice:

$$QS_t = Q_t - NEX_t - STC_t - (Feed_t + Seed_t + Waste_t + Other_t) \quad (12)$$

The consumption of rice depends on consumers' income, rice price and price of substitute goods. In this study, maize is assumed to be a substitute goods to rice, so the demand equation can be written as following.

Demand functions of rice:

$$\begin{aligned} \log QC_t &= \log \frac{QS_t}{POP_t} \\ &= a_{QC} + b_{QC1} \log [RFP_t / (CPI_t / 100)] \\ &\quad + b_{QC2} \log [MFP_t / (CPI_t / 100)] \\ &\quad + b_{QC3} \log (GDP_t / POP_t) \end{aligned} \quad (13)$$

where YW_t and YD_t are yields of wet season rice and dry season rice at time t ; T is time trend; $TEMP_{SEPT_t}$ is temperature in September at time t ; $RAIN_{SEPT_t}$ is rainfall in September at time t ; $SOLAR_{SEPT_t}$ is solar radiation in September at time t ; $TEMP_{MART}$ is the temperature in March; $SOLAR_{MART_t}$ is solar radiation in March; FN_t refers to nutrient in fertilizer; AW_t and AW_{t-1} are planted area of wet season rice at time t and a year before respectively; AD_t and AD_{t-1} are planted area of dry season rice at time t and a year before accordingly; GS_{t-1} is government irrigation stock one year before time t ; RFP_t and RFP_{t-1} are rice farm price at time t and one year before time t . QW_t is production of wet season rice, while QD_t is production of dry season rice and QT_t and Q_t are the total paddy production of rice and total milled rice at time t ; Q_{t-1} denotes total production of milled rice one year before time t . NEX_t : net export of rice; EXP_t : export of rice at time t ; IMP_t is import of rice; WP_t : world rice price (Thai white rice 5% broken); EXR_t : exchange rate; CPI_t : consumer price index; STC_t refers to stock change of rice. QS_t is a total supply and QC_t is per capita consumption of rice; MFP_t : maize farm price; POP_t refers to population; $Feed$, $Seed$, $Waste$ and $Other$ represent the amount of rice used for feeding livestock, for seed, losses during transportation and storage and other usages respectively.

Supply and demand model of rice was employed to find equilibrium rice price in the future and the other endogenous variables considering the factors affecting demand part and supply part in the model.

After performing the estimations of each function, the supply and demand model of agricultural product was used to estimate the equilibrium price and consumption of rice in the future. The results compare rice consumption and price with and without the presence of irrigation investment and predict how irrigation investment influences rice consumption and price under moderate climate change scenario (RCP6.0) and moderate socio-economic scenario (SSP2) from year 2013 through year 2030.

Endogenous variables in the models are YW , YD , AW , AD , QW , QD , Q , NEX , STC , QC , RFP , while exogenous variables include FN , CPI , EXR , WP , GDP , POP , GS and historical climatic variables comprising $TEMP9$, $RAIN9$, $SOLAR9$, $TEMP3$ and $SOLAR3$.

B. Representative Concentration Pathways and Shared Socio-economic Pathways (RCPs and SSPs)

Climate change scenario RCP6.0 and socio-economic scenario SSP2 were integrated to make a reasonable scenario for prediction for this study. According to [10], RCP6.0 is one of the newly developed climate change scenarios RCP6.0, representing a medium baseline or a high mitigation scenario, stabilizing without overshoot pathway to 6.0 W/m^2 ($\sim 850 \text{ ppm CO}_2 \text{ eq}$) at stabilization after 2100. SSP2 denotes the medium assumptions about population growth, economic and technology development. This scenario assumes that all countries keep urbanizing according to their own experiences

and situations.

C. Data

All variables in the study are time series data from year 1995 through 2012. Irrigation investment data was collected from the Ministry of Planning, Department of Statistics of Cambodia. The data of rice farm price, maize farm price, imports, exports, stock variation, feed, seed, waste and other usages were collected from FAO-STAT. nutrient in fertilizer, CPI, GDP, population, exchange rate, world rice price and nutrients in fertilizers are the data from World Bank. Data on yields of wet and dry season rice and areas of wet and dry season rice were disseminated by Ministry of Agriculture, Forestry and Fisheries, Department of Planning and Statistics of Cambodia. Historical climatic data was taken from Data Distribution Center of IPCC and forecasted climatic data under RCP6.0 scenario from year 2013 to 2030 is the value of MIROC 5 (Model for Interdisciplinary Research on Climate), which is a GCM (General Circulation Model) of the University of Tokyo, NIES (National Institute for Environmental Studies) and JAMSTEC (Japan Agency for Marine-Earth Science and Technology). The forecasted exogenous variables of GDP and population data are shared socio-economic pathways (SSPs) of IIASA (International Institute for Applied Systems Analysis).

Fig. 1 through 5 display forecasted climatic data under RCP6.0 climate change scenario, whereas Fig. 6 and Fig. 7 show the forecasted socio-economic data under SSP2 scenario. The combination of these two scenarios were used for making prediction to the year 2030.

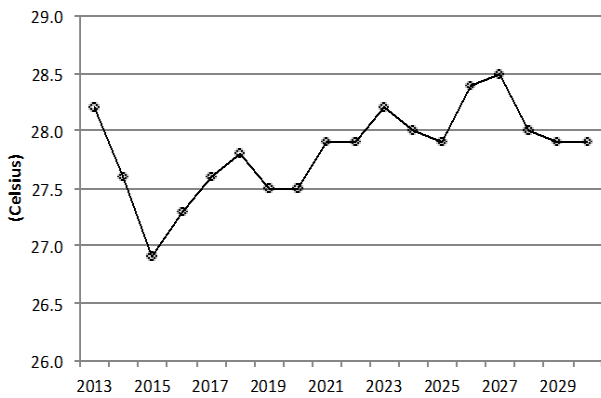


Fig. 1. Forecasted temperature in September.

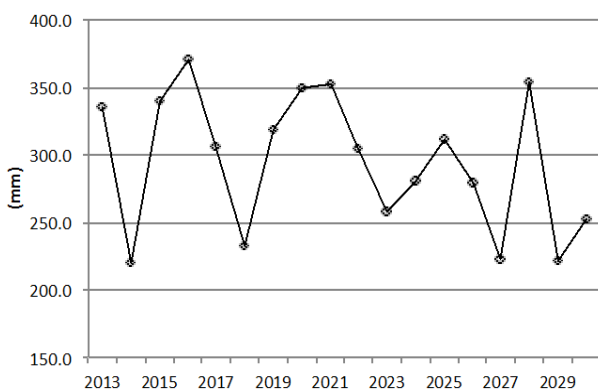


Fig. 2. Forecasted rainfall in September.

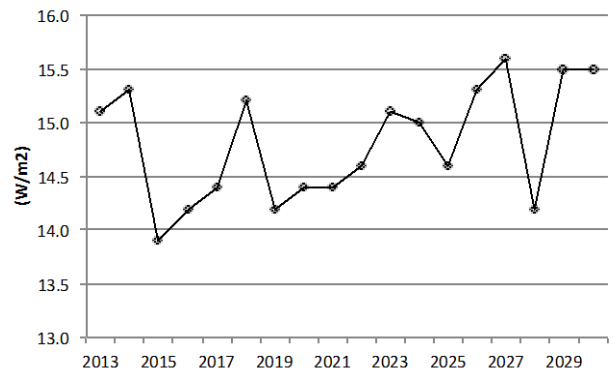


Fig. 3. Forecasted solar radiation in September.

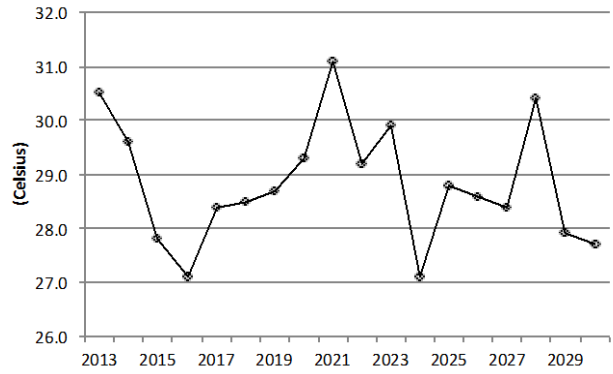


Fig. 4. Forecasted temperature in March.

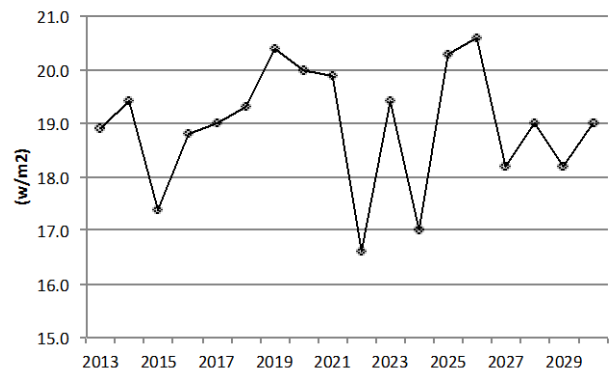


Fig. 5. Forecasted solar radiation in March.

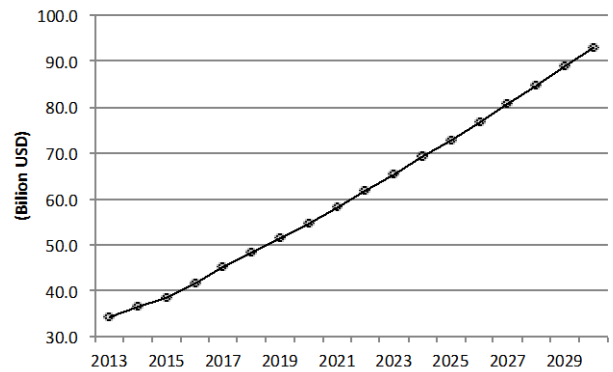


Fig. 6. Forecasted GDP.

D. Assumption of Simulation

The simulation was conducted on supply and demand model under the scenario of which the government irrigation stock keep increasing, while facing 10% depreciation each year (GS) and that of which the government irrigation stock stays constant and has 10% depreciation every year (GS0). These assumptions can be expressed in the following

equations.

$$GS_t = GS_{t-1} + IrrI - (10\% * GS_{t-1})$$

$$GSO_t = GS_{t-1} - (10\% * GS_{t-1})$$

where *GS* represents the government irrigation stock with irrigation investment every year, while *GSO* refers that without irrigation investment. Both are assumed to have 10% depreciation every year. *IrrI* refers to investment in irrigation and *GS_{t-1}* is one year lagged government irrigation stock.

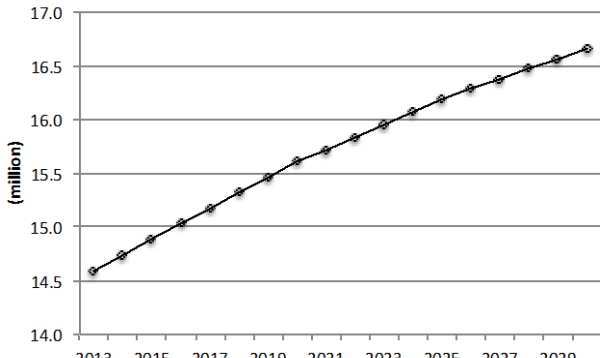


Fig. 7(a). Forecasted population.

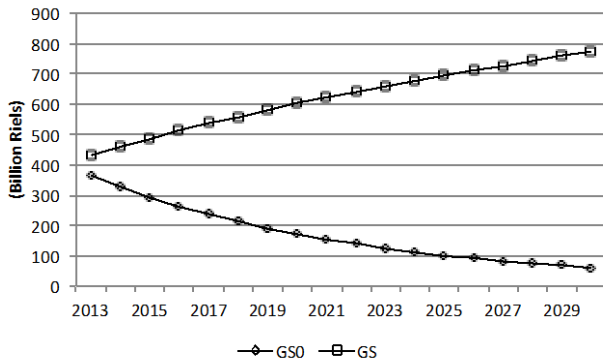


Fig. 7(b). Forecasted government irrigation stock without irrigation investment and forecasted government irrigation stock with irrigation investment.

III. RESULTS

A. Estimation Results

TABLE I: YIELD OF WET SEASON RICE

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	-11.85	3.74	-3.17	
Log TREND	1.75***	0.23	7.53	
TEMP9	0.25 ⁺	0.14	1.82	3.26
RAIN9	0.003*	0.001	2.87	0.43
SOLAR9	0.06	0.04	1.61	0.40
Dummy				
D97	0.86*	0.34	2.50	
D9900	0.44*	0.19	2.34	

Adj-R²: 0.88; DW: 2.06

Signif. codes: 0.001***0.01**0.05*0.1⁺

The results show goodness of fit for all estimation functions ranging from 0.88 to 0.98 except stock change function because Cambodia had become a net rice exporter quickly after 2003. The auto correlation test was also conducted using Durbin Watson. The Durbin Watson values of the estimation functions ranges from 1.70 to 2.69 except dry season area which shows 2.85 of Durbin Watson value. The estimation results of each function can be found in table

1 through Table VII.

TABLE II: YIELD OF DRY SEASON RICE

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	2.88	3.17	0.91	
Log TREND	0.53	0.95	0.55	
TEMP3	-0.08	0.06	-1.26	-0.61
SOLAR3	0.018	0.014	1.29	0.09
FN	0.004	0.003	1.20	0.26
Dummy				
D014	-0.35**	0.086	-4.05	
D08	0.18	0.24	0.77	
SHIFT09	0.67	0.51	1.33	

Adj-R²: 0.95; DW (Durbin Watson): 2.11

According to the estimation result, if nutrient in fertilizer is increased by 10%, yield of dry season would increase by 2.6%. 10% increase in irrigation stock would make area of dry season rice 0.9% larger than before.

TABLE III: AREA OF WET SEASON RICE

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	-44417	118515	-0.37	
Log TREND	408566***	76955	5.31	
Lag AW9	0.35**	0.11	3.28	0.35
Lag RFP	0.27*	0.11	2.56	0.07
Lag RAIN9	304.8 ⁺	186.4	1.64	0.04
Dummy				
D97	-107670*	40237	-2.68	
D00	147413***	34777	4.24	
D02	-166113***	32420	-5.12	
SHIFT11	84960*	37887	2.24	

Adj-R²: 0.98; DW: 1.70

TABLE IV: AREA OF DRY SEASON RICE

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	108091 ⁺	59139	1.83	
Log AD	0.42*	0.21	2.03	0.40
Lag RFP	0.13 ⁺	0.08	1.58	0.22
Lag GS	0.39*	0.15	2.51	0.09
Dummy				
D969	-52882*	21762	-2.43	
D09	-27702 ⁺	16358	-1.69	
D10	-29962 ⁺	16050	-1.87	

Adj-R²: 0.97; DW: 2.85

TABLE V: NET EXPORT OF RICE

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	-106216***	15630	-6.80	
Rice product	0.022***	0.005	4.88	-6.40
World rice	0.003 ⁺	0.002	1.53	-1.53
Price				
Rice farm	-0.071	0.053	-1.34	2.91
Price				
Dummy				
D967	46576**	11389	4.09	
D07	-20850 ⁺	11921	-1.75	
SHIFT11	193692***	11948	16.21	

Adj-R²: 0.98; DW: 2.19

TABLE VI: STOCK CHANGE OF RICE

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	215460***	52167	4.13	
Changes in rice products	0.51*	0.20	2.57	0.48
Dummy				
D04	423277*	178530	2.37	
D05	-541921 ⁺	261472	-2.07	
SHIFT08	-284930**	87776	-3.25	

Adj-R²: 0.40; DW: 2.13

TABLE VII: DEMAND OF RICE

Coefficient	Estimates	Std. error	t-value	Elasticity
Intercept	5.83**	1.81	3.23	
Log RFP	-0.22 ⁺	0.16	-1.39	-0.22
Log MFP	0.15*	0.07	2.19	0.15
Log GDP per capita	0.18 ⁺	0.12	1.49	0.18
Dummy				
D968	0.11	0.09	1.26	
D02	0.12 ⁺	0.06	1.83	
D07	-0.06	0.05	-1.23	
D09	0.05	0.05	1.05	
D10	0.24***	0.04	5.61	

Adj-R²: 0.91; DW: 2.69

B. Simulation Results

The simulation result of area of dry season rice shows that with increasing irrigation investment in place, the area of dry season would be almost doubled. Statistically, the average irrigated paddy area in dry season would be 0.78 million ha comparing to that under no investment in irrigation stock scenario (0.44 million ha) over 10-year period from 2020 through 2030 as indicated in Fig. 11. Furthermore, the result also shows that per capita consumption would be high if the investment in irrigation stock is increased. In particular, the per capita consumption would be 289kg if the government increases investment in irrigation stock in the future. On the other hand, it would be only 243kg if such investment is not in place (Fig. 15). As a result, the price of rice would be lower under increasing irrigation investment scenario. As shown in Fig. 16, rice price would be only 1.24 million riels, which is much lower, if we compare with the one with no irrigation investment (1.95 million riels). Fig. 8-Fig. 14 show the simulation results of yield of wet season rice, yield of dry season rice, area of wet season rice, production of wet season rice, production of dry season rice and total production of rice respectively.

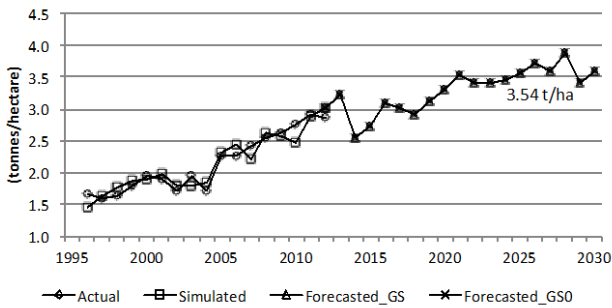


Fig. 8. Yield of wet season rice.

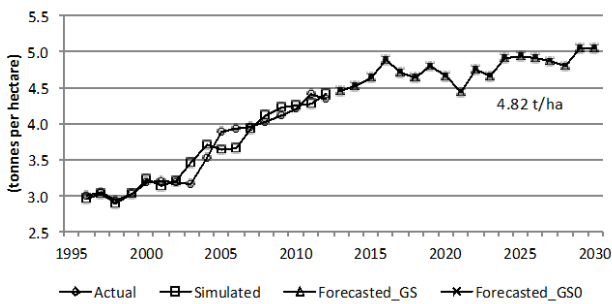


Fig. 9. Yield of dry season rice.

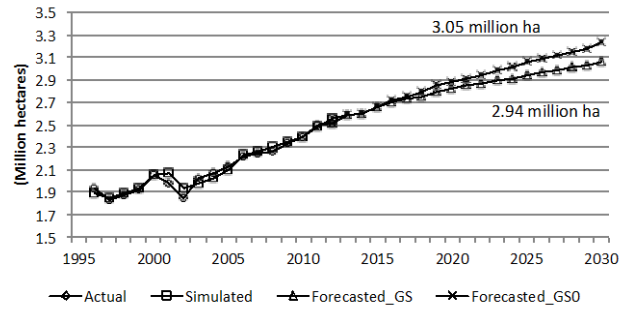


Fig. 10. Area of wet season rice.

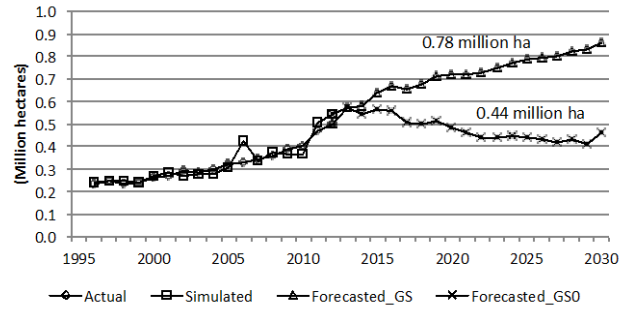


Fig. 11. Area of dry season rice.

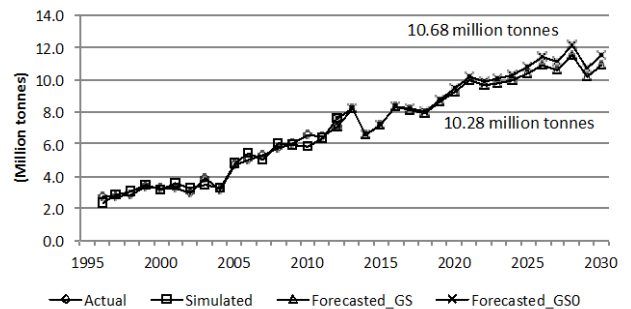


Fig. 12. Production of wet season rice.

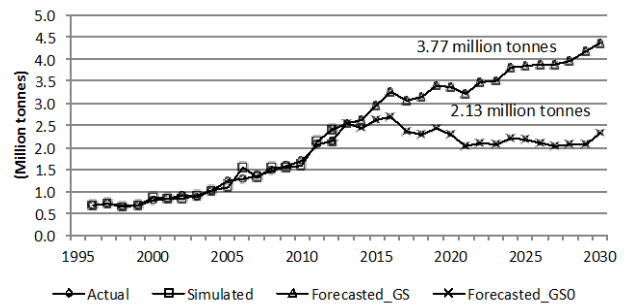


Fig. 13. Production of dry season rice.

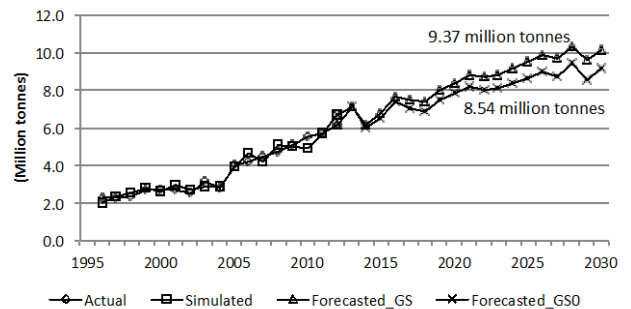


Fig. 14. Total production of milled rice.

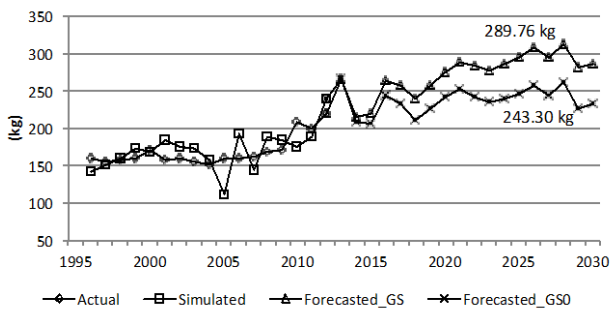


Fig. 15. Per capita consumption of rice.

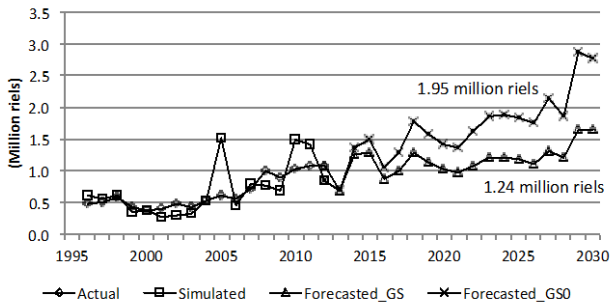


Fig. 16. Rice farm price (1USD=4,000 riels in 2004).

IV. CONCLUSION

Irrigation stock was incorporated into area function of dry season rice in order to predict its impact on rice price fluctuation, which was found to be soaring as the effects of climate change. The simulation result shows that the investment in irrigation significantly contributes to stabilization of rice price under moderate climate change and socioeconomic scenario. The increase in area of dry season rice contributes to the increase in total production of rice, which means more rice would be available for local consumption and export. As a result, rice price soaring due to climate change would be minimized. It can be concluded that Cambodian government's investment in irrigation plays an important role in mitigating climate change in Cambodia. The agricultural policy in Cambodia is suggested to focus mainly on rehabilitating and establishing more irrigation systems since water is the main factor for growing rice.

The limitation of the research is the limited availability of observation data due to war.

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