Impact of Climate Change on Rice Production in the Red River and Mekong River Delta of Vietnam

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Summary: Rice is the most important crop with 43.2 million tons of productivity and 8.1 million of milled rice for exportation a year. The Red River Delta and Mekong River Delta regions are the biggest rice production (accounted for 68.4% of country rice cultivated areas and 71.3% of rice quantity in comparison with national rice production). Hence, any change in rice production in these regions, food security in Vietnam will be threatened seriously. Due to locating in low land, these areas are considered as worst affected by the impacts of climate change, especially by sea level raise. This study used relative minimum dataset to rice cultivation to run DSSAT and economic tools to asses impacts of climate change on rice production in Vietnam up to 2020, 2030, 2050. The result shows that rice yield is forecasted to reduce by 0.65 ton per hectare (11.8%) in spring season and 0.1 ton per hectare (3.6%) in summer rice in RRD; 0.43 tons per hectare (6.3%) in spring and 0.33 ton per hectare (7.3%) in wet season in MRD for average scenario (B1). In this case, Vietnam will be no longer rice exportation and food security country if no integrated solutions are conducted to protect rice yield and adopt to climate change in RRD and MRD.

Keywords: Climate change, impact, rice cultivation, Red River and Mekong River Delta, Vietnam

1. INTRODUCTION

Vietnam is among the few countries that will be worst affected by the impacts of climate change (Nguyen 2009). In fact, the country has already witnessed a lot of manifestations of climate change in the recent past, including temperature increase, sea level rise, and more damages from hydro-climatic disasters such as cyclones and flash floods (Cruz et al. 2007). These are primarily attributed to the country's tropical location, long coastal line, mega river deltas, and the economy's heavy reliance on water and agriculture.

Agriculture and water lies at the very heart of Vietnam's rural development strategy. The agriculture sector, including crops, livestock, fisheries and aquaculture accounts for more than 20% of national GDP, 65% of employment and 30% of exports. Its performance has considerable influence on the economic growth and the status of poverty and malnutrition in the country.

In the agricutltural sector, rice is the most important crop with 43.2 million tons of productiion and 8.1 million tons of milled rice for exportation annually. The Red River Delta (RRD) and Mekong River Delta (MRD) are the most important agricultural regions in Vietnam. In RRD and MRD, rice is the most important crop and accounted for 68.4% of country rice cultivated areas and 71.3% of rice quantity in comparison with national rice quantity. Hence, any change in rice production in RRD and MRD will be threatened to food security and rice exportation by Vietnam. MONRE (2012) indicated that Vietnam locates in the most seriously affected by global warming and climate change. The national scenario of climate change and sea level rise (SLR) indicated that temperature will increase by 1.2-3.60C, rainfall will increase by 1-10% depending on season and location; sea level will rise by 69-100cm in 2100. Beside with high presures of population, industrilization and urbanization, climate change has brought big challenge to sustain rice production in RRD and MRD in particular and Vietnam in general. This study aims to gather related data, evaluate and predict on what change in rice production in Vietnam and recommends integrated solutions to protect rice production and food security subject to climate change.

2. MATERIALS AND METHODS

2.1 Data collection

Various data are collected and used for calculating change in rice production due to climate change in the RRD and MRD.

- *General statistical data:* The current and master plan of rice production was collected from National General Statistic Office (GSO 2012), national strategies of agricultural production (MARD 2009) and national restructure of agricltural sustainable development (GoVN 2013).

- *Weather and climate data:* Land losses due to SLR were collected from national scenario of climate change and sea level rise (MONRE 2012). And eather data (daily maxium temperature, minimum temperature, daily rainfall, solar radition, relative humidity, wind speed (Richardson 1981; Geng 1988) was collected from local stations and constructed in the crop model.

- *Soil data:* Minimum data set includes upper and lower horiszon depths; percentage of sand, silt, clay content; bulk density; organic carbon (OC); pH in water; alunimium staturation; and root abundance. Information was collected from selected provinces in RRD and MRD (Jones et al. 2003);

- *Social and economic factor:* Farmers' education, econimic income, labor and human resources were collected from field survey;

- Crop data was collected through survey in the field and cablirated experiment including sowing date, planting density, planting depth, rice varieties, irrigation, fertilizer pracitices, harvested date, rice yield,… Soil and crop data/information was also collected from field experiments in selected provinces to cablibriate the coeffcients and select the optimal inputs to revise the prediction through crop models. The study addressed RRD and MRD regionss. In RRD region, 4/12 provinces (including Vinh Phuc, Hai Duong, Thai Binh and Ninh Binh provinces) and 4/13 provinces in MRD (including Dong Thap, Kien Giang, Hau Giang and Soc Trang provinces) were selected for survey and calibrated experiment. These selected provinces are typical rice production and can be representative for all regions (Figure 1).

a) Red River Delta **b) Mekong River Delta**

Figure 1. Red River Delta and Mekong River Delta Region Maps

2.2 Crop modeling

DSSAT software (verson 3.5) was applied to determine the change in rice yield subject to site weather climatic dataset, soil characteristics, crop information which are collected from field survey and experiment records. Due to applying DSSAT, hence, this paper have not deeply mention on the theoretical relationship between rice yield and weathers.

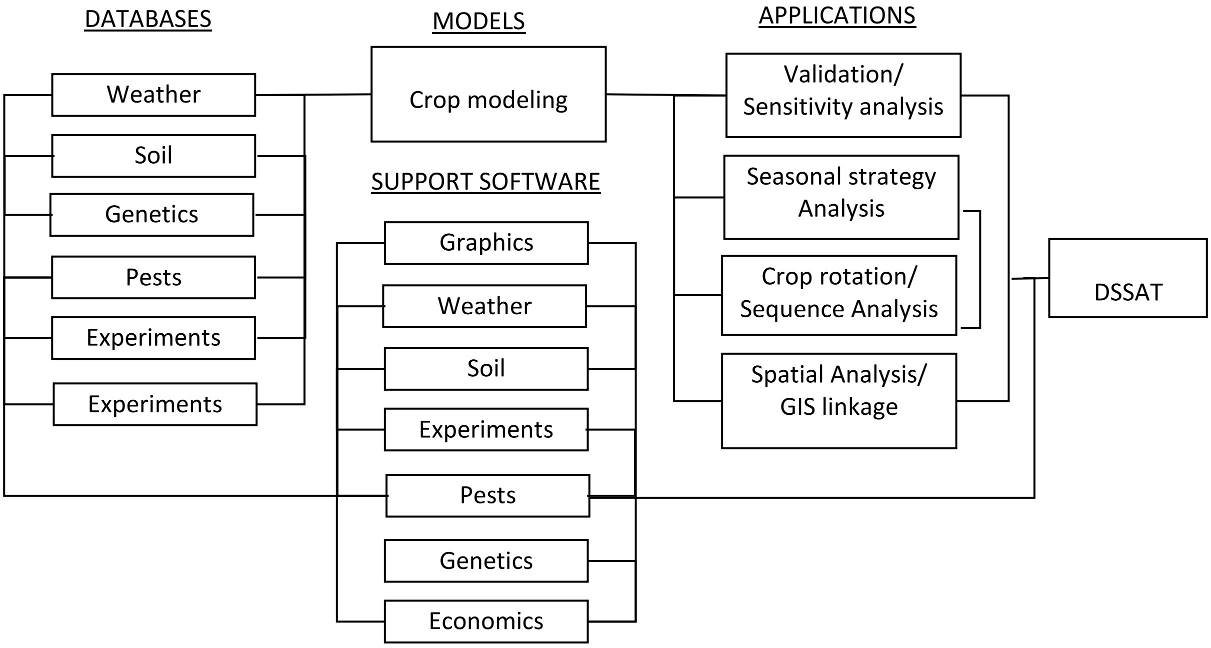

Figure 2. Database, support software and application for DSSAT model
Source: Jones et al. 2003.

2.3 Calculation and limitation

Impact of change in rice yield was estimated based on the change in rice yield, cultivated areas. Because it was not easy to determine planing price, future discount rate was applied to determine impact of climate change on rice production given different scenario of climate change and sea level rise in range of 5%, 7% and 10%. Experiment was also conducted to calibrate significance of predicted change in rice productivity.

This study focuses on the assessing impacts of climate variables to change in rice yield for different scenarios of climate change and sea level rise. Based on collected data, impacts of extreme climate (typhoon, natural disasters, irregular hot and cold) and i sea level rise (water spread and submerge, etc) were estimated.

3. RESULTS

3.1 Change in climate and rice yield

Vietnam released the first scenario of climate change and sea level rise (SLR) in 2009 (MONRE 2009) and revised in 2012 (MONRE 2012). In the updated version, scenrios of climate change and SLR is more detailed and downscaled to sub-ecological zone over country with three scenarios (low, B1; medium, B2; high, A2). Given medium scenario (B2), temperature will increase from 2.0 to 2.8 degree celcius; rainfall will increase less than 2% in winter, and more 6% in the raining season; SLR will increase from 62cm to 82cm in 2100. Temperature, rainfall will be distributed indequately, winter in some areas will be colders, raining season have more rainfall but dry season was less water.

Rice crop was very sensitive to any change in climate and ecological condition, hence, rice cultivation was condidered as most vulnerable to climate change (Bouman et al. 2006; Zhang and Liu 2008). Based on different scenarios of climate change, the trend of rice yield in bussines as ussual (BAU) seem to reduce in perido 2020-2040 and lightly increase in 2050. It can be seen that rice yield in spring season in the RRD seem to reduce to 2020, then slight increase in 2040 and continously reduced in 2050, especially high emisson scenario (A2) (Figure 3a); rice yield in wet season was forcasted slighter change in the RRD for all emission scenarios (Figure 3b).

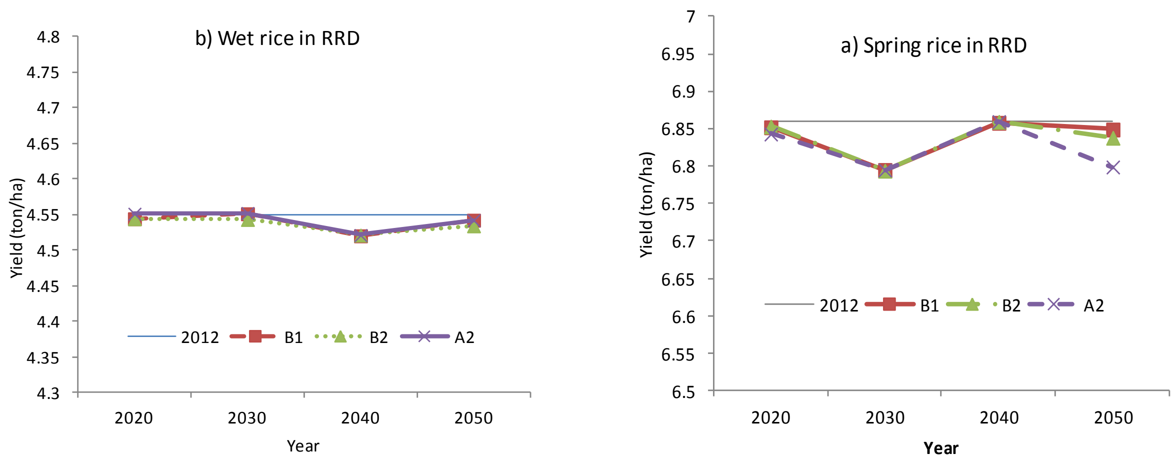

Figure 3. Trend of change in rice yield for different scenario in Red River Delta Region

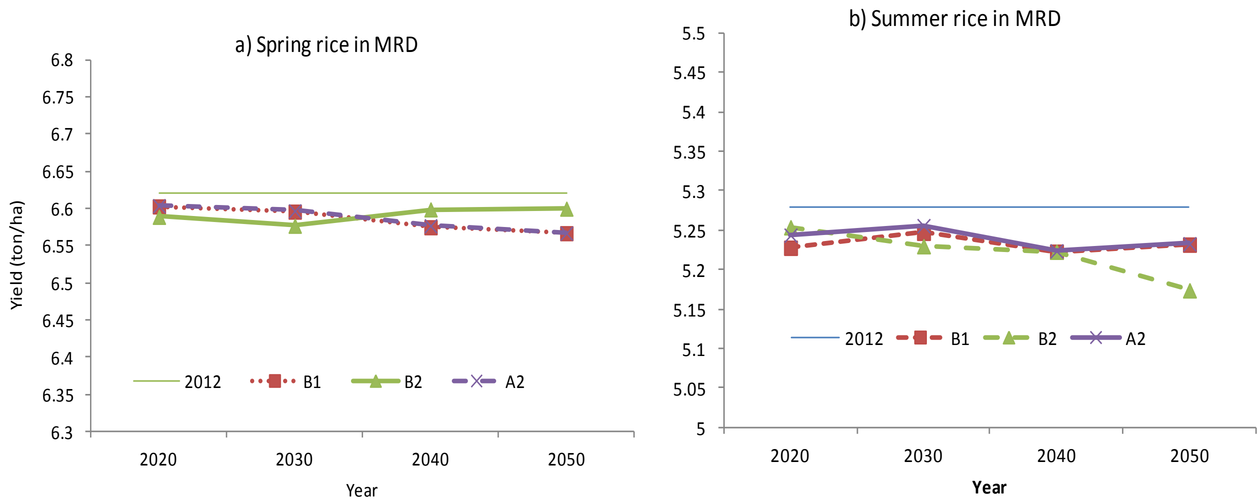

Figure 4. Trend of change in rice yield for different scenario in Mekong River Delta Region

In normal cultivated condition, rice yield in spring season will be reduced in B1, A2 and slightlu increased in B2, especially in the period of 2040-2050 in MRD (Figure 4a). In summer season, rice yield in the MRD continously reduce upto 2050 in B2 scenarios while the other scenarios, it is forcasted to reduce but less than B2 (Figure 4b). Hence, local provinces need to be revised and update scenarios and re-plan rice production to cope with impacts of climate change on rice production.

3.2 Change in rice quantity

Although rice production is facing challenges from climate change, industrialization and urbanization, cultivated areas have been increased over time from 6.04 million hectare in 1990 to 7.71 million ha in 2012 (increased by 28.3%). However, rice season has transformed significantly, spring rice and summer rice seem to increase sharply during 1990-2012. Spring rice has transformed from winter-spring rice in the RRD; its cultivated area has increased from 2.07 million hectare in 1990 to 3.1 million hectares in 2012 (increased by 49.71%). Summer rice has increased by 1.34 times from 1.98 million hectare in 1995 to 2.66 million hectares in 2012 in the MRD. Hence, rice cultivated season has transformed in RRD and MRD. It is significant to climate change, transformed spring rice in RRD to avoid chilly cold in the north and concentrated summer rice is to reduce vulnerability to late flood season in MRD (Dinh Vu Thanh and Nguyen Van Viet 2012). Based on medium scenario (B1), change in rice yield was estimated for three rice cultivated seasons and three time phases (2020, 2030, 2050) in normal cultivated condition (existing input and soil quality application)..

- *Change in rice quantity in the RRD:* Table 1 shows that rice quantity in the RRD will be changed slightly. In 2030, rice quantity is predicted to reduce by 376.79 thousand tons (-5.39%) in which reduction from spring rice accounted for 98.4% of total reduction on rice in RRD in comparison with 2012. In spring season in RRD, temperature is forecasted significant increase but rainfall is predicted reduction, hence, it can be seen that water scarcity will be paid attention by local authorities in the RRD.

- *Change in rice quantity in MRD:* Due to account for high proportion, rice quantity is predicted seriously by climate change in MRD. Table 1 shows that rice quantity in RRD will reduce by 1.06 million tons in 2020 (-4.59%); 1.21 million tons in 2030 (-5.22%); and 1.57 million tons in 2050 (-6.77%) in comparison with 2012. Large third rice areas (wet season) has been transformed to summer rice; however, summer rice is affected more seriously by climate change (accounted for 53.99%, 43.88% and 78.92% of total rice reduction in 2020, 2030 and 2050, respectively). Hence, the government should consider this issue and develop suitable program to cope with impacts of climate change for rice production in MRD.

- *Impact of change in rice quantity in RRD and MRD to national food security and rice exportation:* Total rice is predicated to reduced by 1.13 million tons (-5.62%) in 2030, -1.59 million tons (-8.73%) in 2030 and -1.75 million tons (-8.61%) in 2050. Annually, Vietnam was also considered as top rice exportation with more than 8.13 million tons of milled rice in 2012. As given above, land for rice production is competing very critically to other purposes, especially in land demand of industrialization and urbanization, hence, rice production face the big challenges to ensure food security and rice exportation and request some active policies to cope with impacts of climate change.

Table 1. Change in rice quantity in RRD and MRD up to 2050

Year	Reduced in quantity (1000 tons)			
	Spring rice	Summer rice	Wet rice	Total rice
Red River Delta Region				
2020	-39.35	-	-34.43	-73.79
2030	-371.05	-	-5.74	-376.79
2050	-123.68	-	-51.65	-175.34
Mekong River Delta Region				
2020	-489.89	-575.28	-	-1,065.17
2030	-679.53	-531.02	-	-1,210.55
2050	-331.86	-1,239.06	-	-1,570.92
Total change				
2020	-529.25	-575.28	-34.43	-1,138.96
2030	-1,050.58	-531.02	-5.74	-1,587.34
2050	-455.55	-1,239.06	-51.65	-1,746.25
% change				
2020	-2.61	-2.84	-0.17	-5.62
2030	-5.18	-2.62	-0.03	-7.83
2050	-2.25	-6.11	-0.25	-8.61

3.3.3 Change in value of rice

Based on the discounted rate at 10%, 12% and 15%, reduced in rice quantity will lead to losses in economic value. In comparison with 2012, up to 2050, RRD will loses 284.34 million US$ (at 5%); 560.84 million US$ (at 7%) and 1.52 billion US$ (at 10%) in agricultural GDP due to impacts of climate change in rice cultivation. Similarly, rice GDP in MRD is threatened to reduce by 2.55 billion US$ (at 5% discount rate); 5.38 billion US$ (at 7%) and 14.57 billion US$ (at 10%). Total GDP from rice production MRD and RRD will lose 2.83 billion US$ (5% discount rate), 5.94 billion US$ (at 7%) and 16.08 billion US$ (at 10%). Hence, it can be seen that value loses due to impacts of climate change on rice production.

Table 2. Sensitivity on value of change in rice quantity in RRD and MRD up to 2050

Year	Reduced on value of rice (million US$)		
	5%	7%	10%
Red River Delta Region			
2020	-27.69	-31.01	-36.60
2030	-230.30	-311.46	-484.78
2050	-284.34	-560.84	-1,517.62
Mekong River Delta Region			
2020	-399.68	-513.13	-622.71
2030	-739.90	-1,147.17	-1,835.61
2050	-2,547.57	-5,383.83	-14,568.40
Total change in value			
2020	-427.37	-544.13	-659.32
2030	-970.19	-1,458.63	-2,320.39
2050	-2,831.91	-5,944.67	-16,086.02

4. DISCUSSION

DSSAT can be applied to determine the change in rice yield change due to climate change in the RRD and MRD. Calibrated experiment is also considered as good as to revise significance of prediction through the DSSAT model. Three different intensive inputs were used for calibrated experiments, bias of rice yield among crop modeling and experiment varied from 2.32% to 15.33% for spring rice, 3.69-28.81% for wet rice season in RRD. The bias of rice yield from calibrated experiment was estimated about 4.92% to 16.24% for the spring rice and 4.58% to 15.71% for the summer rice in MRD. According to the calibrated experimental results, medium intensive inputs use is significant applying for crop information to estimate impacts of climate change because of low percentage of bias. However, field survey from selected provinces in both RRD and MRD has used much intensive input use and much higher than technical advices and big challenges for local authorities to convince farmers to reduce level of input use, hence, change in rice quantity from farmer practice may be more bias. Hence, scale and time length of calibrated experiments will be necessary to revise and enhance significance of forecast through DSSAT.

Naturally, researchers, policy-makers and farmers thought about negative to mention on impacts of climate change on agricultural production in general and rice production in particular. However, increased temperature and reduced drizzling rain in the winter and spring seasons decrease some insect and disease incidents not only for rice but also for other crops. Hence, what is real impact of climate change, it could be both negative and positive. Thus it is imperative to reduce negative impacts and strengthen positive impacts to adopt to climate change in rice production. In addition, serious negative impacts of climate change for rice cultivation but rather grow rice, farmers moved/transferred to shrimp and fish with higher benefits, how to assess impacts of climate change in this cases. For example, farmers in MRD transformed 120,000 hectare from unstable third rice to shrimp, benefit losses was about 3,385 billion VND but its benefit gain from shrimp was about 6,625 billion VND in 2010 (Tran Van The et al, 2010).

5. CONCLUSION

In normal cultivated condition, trend of rice yield in all season and both RRD and MRD will reduce up to 2020, 2030, 2040 and 2050 for all given scenarios of climate change and sea level rise (B1, B2, A2).

Given medium scenario (B2), reduction of rice quantity varied from 73.79 thousand tons to 376.79 thousand tons in prediction. Spring rice was more affected by climate change than wet rice in RRD. And in MRD, rice quantity will reduce from 1.06 million ton to 1.57 million ton during 2020-2050 in prediction. Summer rice will be more vulnerable to climate change than spring rice. Hence, adaptive strategies need to set prior to protect rice production, especially summer rice in MRD and spring season in RRD.

Given B2, rice quantity in Vietnam will reduce by 5.62% (1.14 million tons) in 2020; 7.83% (1.59 million tons) in 2030 and 8.61% (1.75 million tons) in 2050). Hence, Vietnam government needs to replan landuse strategies for rice and technically support farmers to protect cultivated areas and improve benefit from rice production, reconsider rice exportation to supplement to domestic consumtion.

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