Assessment of Climate Change Impact on Rice Yield

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ABSTRACT

As a general understanding with higher CO_2 and increased daily temperature and sunlight radiation, there will be better condition for photosynthesis, promising better crop yield. But, tropical climate with already higher daily temperature causes miserable situation when it increases further. Climate change effect will further troublesome the rainfall schedule in the region in terms of arrival of monsoon, amount and overall pattern of precipitation distribution.

The regional climate change model PRECIS is successful in predicting future weather situations locally. The rainfall pattern is disrupted with change in environmental situation. PRECIS model has taken wholesome approach for the regional parameters successfully predicting future weather scenarios. DSSAT model was used to simulate future rice yield, of Northeast of Thailand, with predicted weather data for year 2029 and 2059 for PRECIS model. As it was found, with current crop management practices, the expected yield level could be somewhat maintained by just varying the planting data by a week or two with changed weather situation. The farmers should be educated for using up-to-date information on weather condition to decide cropping pattern and crop management practices. As expected, well-fertilizer crop ensured better yield compare to the crop with no fertilizer application. The simulation with rise in temperature showed a gloomy face with lower rice yield. The issue of rice yield with environmental temperature has to be analyzed in details with specifically designed field experiments.

Keywords: Climate change, rain-fed rice, PRECIS, DSSAT

1. INTRODUCTION

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its property, and that persists for an extended period, typically decades or longer. Climate change is one of the most dreadful environmental challenges for human kind in today's context and it will persist in many years to come. Eleven of the last twelve years (1995-2006) rank among the twelve warmest years in the instrumental record of global surface temperature (since 1850, IPCC Report, 2007). The report further said that the average global temperature is very likely to increase between 1.8 ^{0}C and 4.0 ^{0}C by the year 2100.

Agriculture is an important sector, which is affected by the current climatic variations. In 2002, rice was the source of more than 500 calories per person per day for over 3 billion people (FAOSTAT, 2006). Furthermore, rice cultivation is the principal activity and source of income for more than 100 million households in developing countries in Asia, Africa and Latin America. The food security of more than half of the world population depends on ability of the world to supply and distribute rice. From IRRI (2006) it is said that for every 75 ppm increase in CO_2 concentration, rice yields will increase by 0.5 ton per hectare, but yield will decrease by 0.6 ton per hectare for every 1 ^{0}C increase in temperature.

Climate change is basically triggered by, both, natural as well as man made causes. The natural causes can be long-term variation within the earth's climate like glaciation, ocean variability, or may be short-term variability in climatic parameters. Similarly, green house gases, plate tectonics, solar variations, orbital variations, volcanism are some of the non-climatic factors affecting climate change. The man-made causes may consists of burning of fossil fuels, aerosols from these fossil fuels, excessive emissions from vehicles, carbon dioxide emissions from cement business and different land use patterns along with contribution from livestock domesticated. Carbon dioxide (CO_2) is the most important anthropogenic GHG. Its annual emissions grew by about 80% between 1970 and 2004 (IPCC, 2007). Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution (Figure 1).

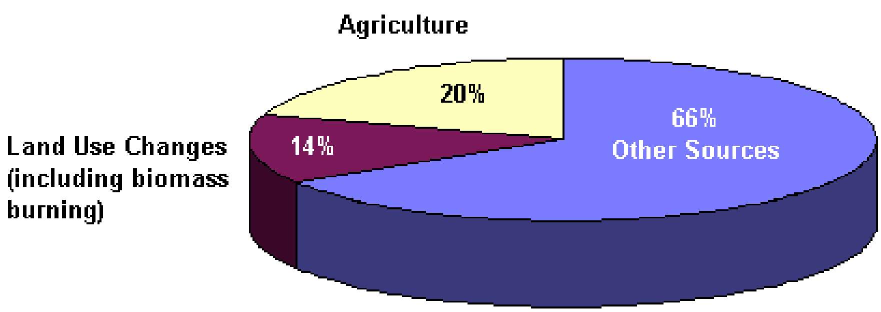


Figure 1: Contributions of agriculture to global warming (IPCC, 1995)

Research has confirmed that global warming will make rice crops less productive with increasing temperatures decreasing yields (IRRI 2006).

2. OBJECTIVES

The primary objective of the project is to predict future changes in climatic condition and its influence on agriculture production especially rain-fed rice farming in Northeast region of Thailand.

3. METHODOLOGY

3.1 The Study Area

The study area is located in northeast of Thailand region (Figure 2). In northeast Thailand, agriculture is usually rain-fed of which the productivity is very low and unstable due to poor soil fertility and unstable rainfall. Besides, the culture of rearing fishes in rice fields is much more common in North-East Thailand.

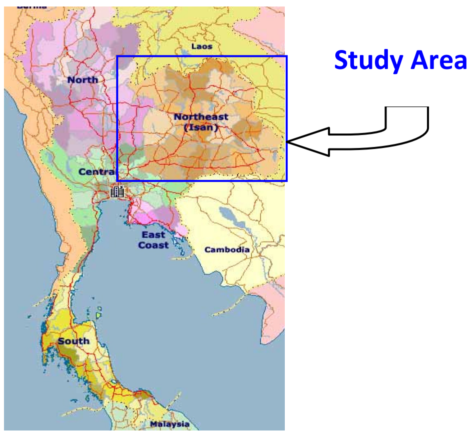


Figure 2: The study area

3.2 Climate Change Models

CCAM model

The Conformal Cubic Atmospheric Model (**CCAM**), which is the second-generation regional climate model developed specifically for Australasian region and developed by CSIRO Division of Atmospheric Research in Australia, was used and the output resolution was set at 0.1 degree (approximately 10 km). The model uses the principle of stretched coordinate of a global model instead of uniform latitude-longitude gridding system and runs for 18 vertical levels including the stratosphere. CCAM has also been evaluated in several international model inter-comparison exercises to be among the best climate model for Asian region. The condition used for the simulation of climate change scenarios was the increasing of atmospheric CO_2 concentration from 360ppm, which was used as baseline in the analysis, to 540 ppm and 720 ppm.

PRECIS model

PRECIS (Providing REgional Climates for Impacts Studies) model was developed at the Hadley Centre at the UK Met Office. It is a regional climate modelling system designed to run on a Linux based PC. PRECIS can be easily applied to any area of the globe to generate detailed climate change projections. PRECIS was developed in order to help generate high-resolution climate change information for as many regions of the world as possible. The intention is to make PRECIS freely available to groups of developing countries in order that they may develop climate change scenarios at national centres of excellence, simultaneously building capacity and drawing on local climatological expertise.

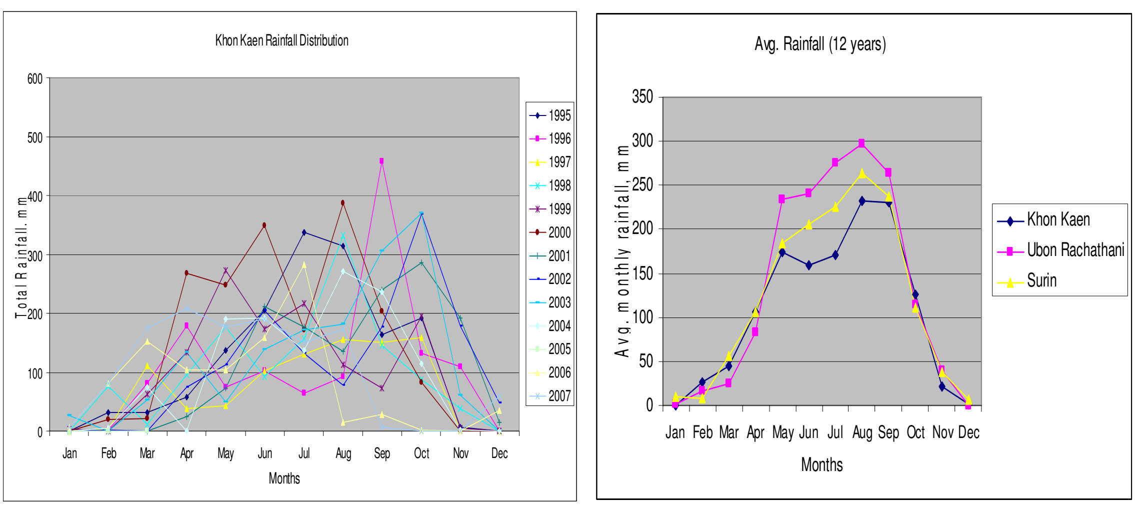
3.3 DSSAT Crop Model

The "Decision Support System for Agrotechnology Transfer" (DSSAT) has been used by researchers worldwide for many years. DSSAT was developed through collaboration between scientists at the University of Florida, the University of Georgia, University of Guelph, University of Hawaii, the International Center for Soil Fertility and Agricultural Development, Iowa State University and other scientists associated with ICASA.

4. RESULTS AND DISCUSSION

4.1 Rainfall Distribution

The study area is located in Northeast of Thailand, where rain-fed type agriculture is mostly practiced. It is necessary to visualize the rainfall pattern in the study area. The weather information of four selected provinces (Khon Kaen, Ubon Rachthani, Roi Et and Surin) for last 12 years were collected and graphically depicted. It can be easily observed that there is a large variation in rainfall among different years for three provinces (Figure 3).



(a) **(b)**

Figure 3: Rainfall distribution; a) Khon Kane province rainfall distribution (1995-2007), b) Average rainfall (12 years) of the study area

4.2 Experiment: Testing of Fertilizer at Roiet, 2007

There was not much significant difference in the observed and simulated values of yield components after calibration for the various fertilizer treatments done at RoiEt for RD6 variety (Figure 4).

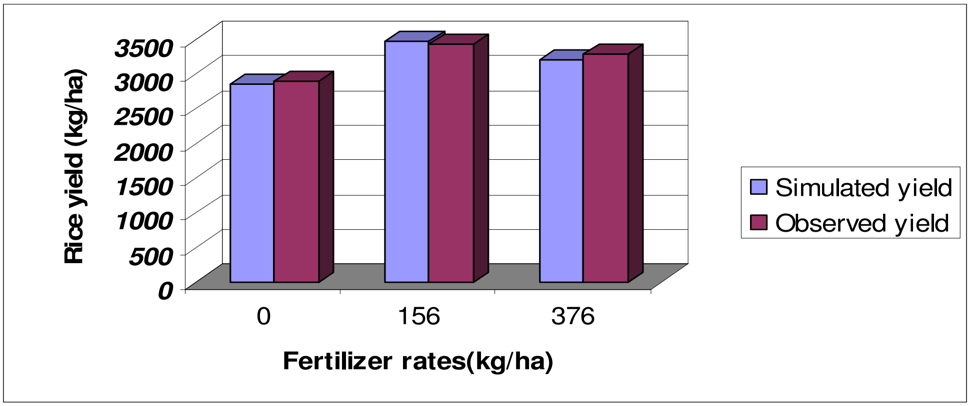
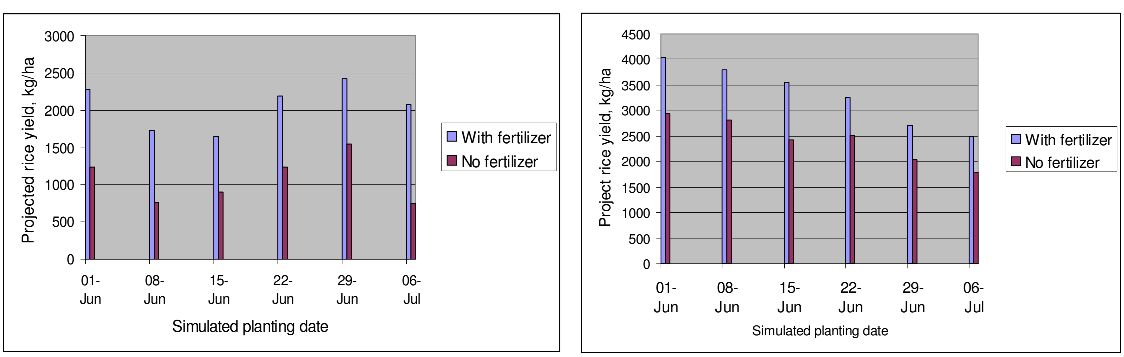


Figure 4: Comparison of simulated and observed rice yield (2007)

4.3 Rice Yield Simulation in DSSAT

PRECIS model data was used to estimate rice for the year 2029 and 2059 for the Roi Et province, Northeast Thailand, using the current crop practices. The model was run for two crop management practices, Such as: a) with standard application of Fertilizer; b) with no supplement application of fertilizer (control condition). The model is also further simulated for different planting dates, which could be required with the unset of monsoon in the region (Figure 5). The weekly simulation was varied for around one month period, ranging from 1st June to 6th July for the crop season with the actual cropping date being 15th June. KDML-105 variety was used as the rice verity for simulation model in DSSAT.



(a) **(b)**

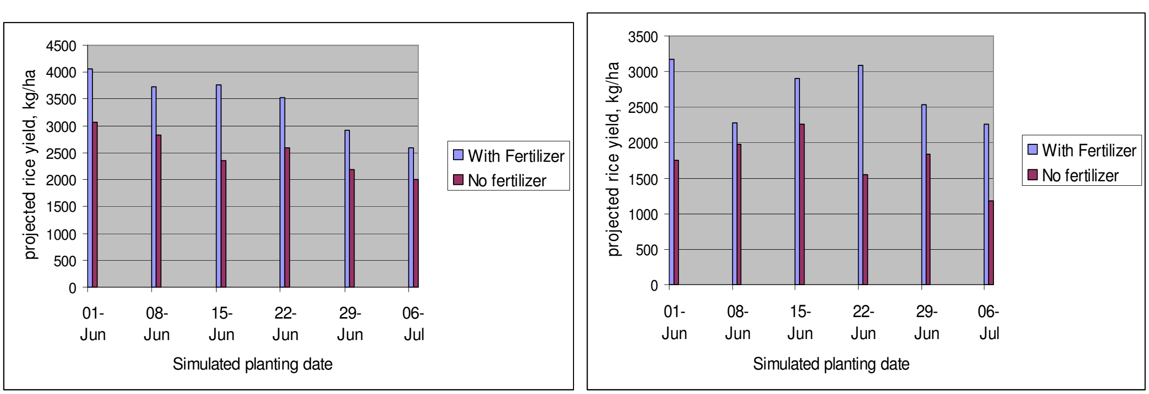
Figure 5: Simulated rice yield; a) for the year 2029, b) for the year 2059 (15 June current rice planting date)

The simulation model, using PRECIS climate model weather scenario, was run with DSSAT crop model for the year 2029. The yield of rice can substantially increased with one week or two weeks delay in initiating the cropping season of rice in the province. Similar trend was found for both under no fertilizer and standard fertilizer application conditions (Figure 5). The simulation model, using PRECIS climate model weather scenario, was also run with DSSAT crop model for the year 2059. The yield of rice can substantially increased, but by initiating the rice cropping season for one week or two weeks earlier in the region.

4.4 Rice Yield Simulation with Temperature Variation

Simulation was further carried out to examine the impact of temperature on the rice production in the region. The simulation was carried out on the basis of 2059 year predicted weather data in PRECIS regional climate model. The model in DSSAT 4.0 was run for 2059 keeping the weather parameters identical except increasing the daily temperature by 1 ^{0}C for whole cropping season. The model was run for six-week simulation period with original planting date as 15th June. Crop management practices with two simulation conditions, such as: a) with standard level fertilizer application, and, b) with no supplemental fertilizer application.

The model was simulated for two temperature variation scenarios, such as: a) by increasing daily maximum temperatures, keeping daily minimum temperature unaltered; b) by increasing both daily maximum temperature and daily minimum temperature by 1 ^{0}C for whole season. The first scenario, though most unlikely to happen showed the increase in rice yield as compared to predicted yield for the base year 2059 season (Figure 6). There is a substantially decrease in rice yield for the second scenario with 1 ^{0}C increase in average temperature, showed the adverse impact of uncontrolled increase in environmental temperature (Figure 6).

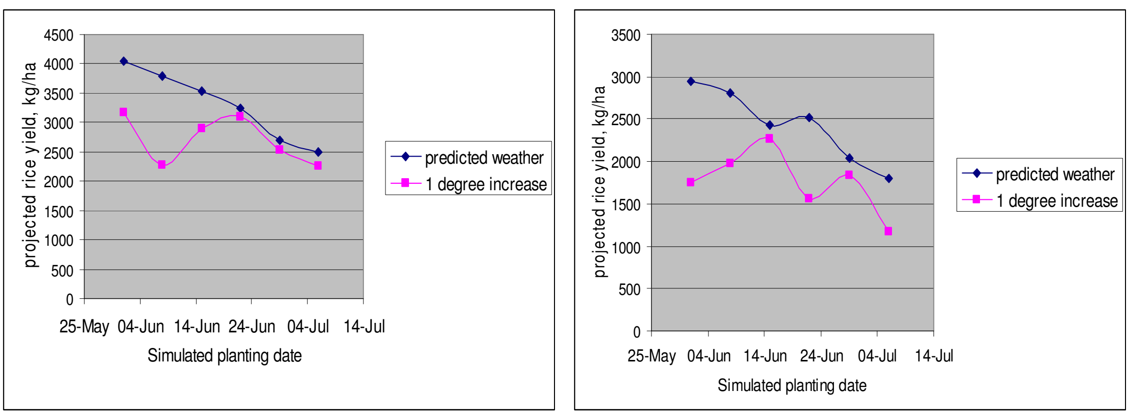


(a) **(b)**

Figure 6: Simulated rice yield for 2059; a) increasing daily maximum temperature by 1^0 C, b) increasing daily maximum and minimum temperature by 1^0 C

The simulated yield for the both temperature scenarios were compared for two management decisions of no fertilizer and standard fertilizer application for the base year 2059. Graphical presentation of comparison further clarifies the harmful impact of rise in average temperature with standard environmental conditions (Figures 7). As, normal understanding, with variation in temperature, the weather scenarios will vary which will further affect the rice yield in the region. Varying the planting data might to some extent will compensate the impacts ensuring better crop yield. The planting date could not be varied very widely as it may affects the fellow crop, lined up in the cropping rotation.

Similar trend in reduction of rice yield was also observed (Yusoff et al., 2009) with increase in average temperature particularly in hot humid tropical weather situation. There is around 10% and 30% decrease in rice yield for 2 ^{0}C and 4^{0}C rise in average daily temperature, respectively.



(a) (b)

Figure 7: Simulated rice yield for 2059; a) for 1^{0} C increase in temperature with fertilizer, b) for 1 ^{0}C increase in temperature with no fertilizer

5. CONCLUSION

The PRECIS model was found superior to CCAM model considering local weather condition. Rain-fed rice will be severely affected by the climate changes. As it was found, with current crop management practices, the expected yield level could be somewhat maintained by just varying the planting data by a week or two with changed weather situation. The farmers should be educated for using up-to-date information on weather condition to decide cropping pattern and crop management practices. As expected, well-fertilizer crop ensured better yield compare to the crop with no fertilizer application. The simulation with rise in temperature showed a gloomy face with lower rice yield. The issue of rice yield with environmental temperature has to be analyzed in details with specifically designed field experiments.

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