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Application of DSSAT crop simulation model to identify the changes of rice growth and yield in Nilwala river basin for mid-centuries under changing climatic conditions

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Abstract

Changes of climate will be one of the deciding factors that affect for future food production in the world because crop growth is highly sensitive to any changes of climatic conditions. As the rice is staple food of Sri Lankans, it is essential to identify the impacts of climate changes on country's rice production. This study was conducted to identify the yield and growth changes of most popular two rice varieties (At362 and Bg357) cultivated in Nilwala river basin at *Yala* season under the global climate change scenario Representative Concentrate Pathway (RCP) 8.5. The Decision Support System for Agro technology Transfer (DSSAT) software is used to forecast the rice yield for *Yala* season in mid-centuries. To simulate the rice yield DSSAT requires data sets of crop growth and management, daily weather data and soil data. Crop management data were obtained from an experiment which was conducted in Palatuwa area at Nilwala downstream in Matara district. Daily weather data were collected from Mapalana weather station and soil data were collected from wet zone soil classification. Model was calibrated using experimental data for *Yala* season 2014 and model was validated using collected data in *Yala* season 2013. Future yield was predicted using forecasted weather data under climate change scenario RCP 8.5 for Mapalana area. The results show that increasing temperature and solar radiation and decreasing rainfall in mid-centuries affects both yield and growth of rice. Grain yield in mid-centuries shows decreasing trend in both varieties by 25% to 35% than the yield at 2014 and growth period will be shorter than the present conditions.

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Keywords: Climate change; DSSAT; rice yield

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1. Introduction

Impacts of climate change on Agriculture will be one of the major deciding factors influencing the future food security of mankind on earth. Since rice is the staple food of Sri Lanka, it is essential to identify the impacts of climate change on rice yield to increase the country's rice production. Climatic factors such as temperature, rainfall, atmospheric CO_2 and solar radiation are important parameters to rice production[1].

The average daily maximum temperature and rainfall pattern will be changed as a result of increasing concentrations of CO_2 and other greenhouse gases in atmosphere. These changes have become the most important considerations for Sri Lankan rice production[2]. Increasing trend of daily maximum temperature may decrease the rice spikelet fertility, which affects for reduction of the yield while the increasing trend of atmospheric CO_2 concentration could increase the rice yield[3].

Matara district is one of the rice cultivation districts in Sri Lanka and have a good potential for rice cultivation in both *Maha* and *Yala* season. Nilwala river is the major water source for rice cultivation in this area. Most of the farmers in this area cultivate improved rice varieties but their yield is always lower than the potential yield due to the different level of management practices and the variation of climatic conditions. Yield gap can be increased in the future due to climate change especially if current agricultural practices are continued[4]. Conducting the field experiments for identify impacts of climate change on rice cultivation will take long time period.

DSSAT is a popular crop model that is used worldwide for modeling growth and yield of 30 different crops including rice under given soil and daily weather conditions. For future yield prediction it is required to calibrate and validate the DSSAT model with adjusting the cultivar genetic coefficients. For rice there were 8 genetic coefficients and they describe the genotype and environmental interactions[5].

Validated DSSAT model can be used to predict the future rice yields with future weather conditions and find the suitable adaptation measures for increase the yield[5].Therefore this study was conducted to identify the changes of rice yield and growth in Nilwala river basin under changing climate in mid-centuries using DSSAT model.

2. Materials and Methodology

2.1. Selection of Rice varieties

Two improved rice varieties namely At362 and Bg357 which are most commonly grown in the study area were selected for yield simulation. Both are medium duration and high yielding varieties.

2.2. Data collection

Technical reports of DSSAT software were used as a guide for data collection. Data sets were obtained from sample analysis, observations and use of existing data.

As Daily weather data Daily maximum and minimum air temperatures, precipitation and solar radiation from planting date to harvesting date were collected from Mapalana weather station. As Soil data Soil class, texture, Bulk density, Organic Carbon%, Sand%, Silt%, Clay%, pH and Cation Exchange Capacity in Surface layer (0-20 cm) and subsurface layer (20-50 cm) were obtained from Palatuwa series wet zone soil classification. The crop management data were collected from ongoing field trials in Palatuwa area in *Yala* season 2014.Planting method, planting date , plant density, row spacing, amount of fertilizer application, irrigation data, panicle initiation date, panicle maturity date, harvesting date, harvesting method, grain yield/m^2, and leaf area index in 5 growth stages were collected.

2.3. Model calibration, validation and future yield simulations

Three input files were created to run the DSSAT model using collected data.

- Weather file: Weatherman program in DSSAT and collected weather data
- Soil file: SBuild program in DSSAT and soil data
- Experimental data file: XBuild program in DSSAT and crop management data

The model was calibrated using collected data from the experimental trials in *Yala* season 2014 through determination of genetic coefficient for both At362 and Bg357 varieties with sensitivity analysis mode in DSSAT 4.5.The model was validated using the experimental data in *Yala* season 2013 by comparing the observed results with simulated results.
Yield and growth parameters of At362 and Bg357 were predicted for year 2040,2050 and 2060. Future weather data generated from Global climate model under the RCP 8.5 climate change scenario for Mapalana area were used to create the weather data file in DSSAT for yield prediction and soil and crop management conditions were kept same as 2014.

3. Results and Discussion

3.1 Calibration and validation results of DSSAT model

Model calibration is changed the cultivar genetic coefficient values in DSSAT model until the simulated values matched quite well with observed values. Eight (8) genetic coefficient values for rice obtained from collected crop management data for *Yala* season 2014 are presented in table 1.

Table 1: Obtained Genetic Coefficient Values

	P1	P2O	P2R	P5	G1	G2	G3	G4
At 362	470	15	305	11.5	65	0.028	1	1
Bg357	390	8	350	11.5	60	0.03	1	1

The validity of the model was checked by using above genetic coefficient values to simulation of growth and yield data for yala season 2013. Obtained results have been shown in table 2.

Table 2: Validation results of DSSAT model

Indicator	Bg357		At362	
	Observed values	Simulated values	Observed values	Simulated values
Panicle initiation day after planting	45	47	47	46
Heading day after planting	30	30	32	30
Maturity day after planting	34	30	29	29
Total period	109	107	108	105
Yield (kg/ha)	6155	6284	5985	6045

Results show the simulated values of model which are matched with the observed values of rice growth and yield in 2013 .Therefore this model used to future yield prediction.

3.2 Changes of climate in mid centuries

According to the fifth assessment report of Inter-governmental panel for climate change RCP 8.5 scenario is considered as highest scenario. Predicted climatic data under the scenario RCP 8.5 for *yala* season in Mapalana clearly shows that there are changes of climatic conditions in mid-centuries than present conditions. Following table shows the average rainfall, average yearly maximum, minimum temperatures and average yearly solar radiation in simulated years.

Table 3: Observed and forecasted weather data for Mapalana area.

	2014	2040	2050	2060
Maximum temperature (^{0}C)	32.1	33.30	33.11	32.96
Minimum temperature (^{0}C)	22.81	23.27	23.42	23.07
Rainfall (mm)	1873.8	1049.9	967.3	1166.7
Solar radiation (MJ/m^2/day)	14.94	18	19.44	18.70

According to the forecasted weather data, both maximum and minimum air temperatures in Mapalana area will be increased and the rainfall will be decreased than present conditions. Also solar radiation will be higher than present conditions. Temperature and rainfall are the main critical factor that can be affect for growth and final yield of rice. Therefor these changes will be affect to rice yield in Mapalana area.

3.3 Changes of rice growth and yield under changing climate

Simulation results of rice growth and yield for variety At362 and Bg357 under future climate conditions in DSSAT model are presented in Figure 1 and 2.

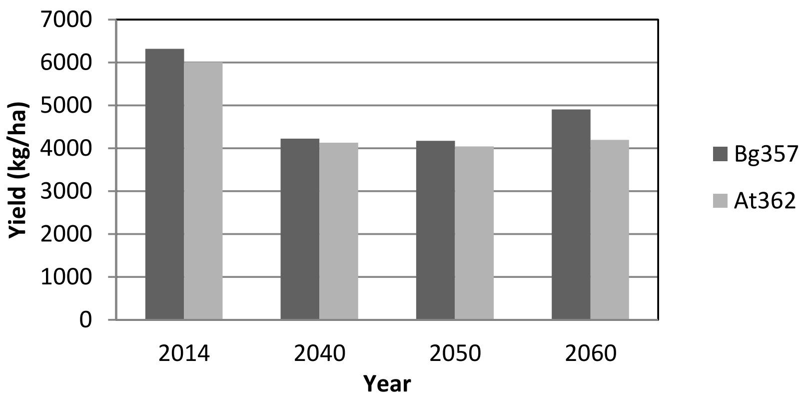

Figure 1: Variation of rice yield in simulated years

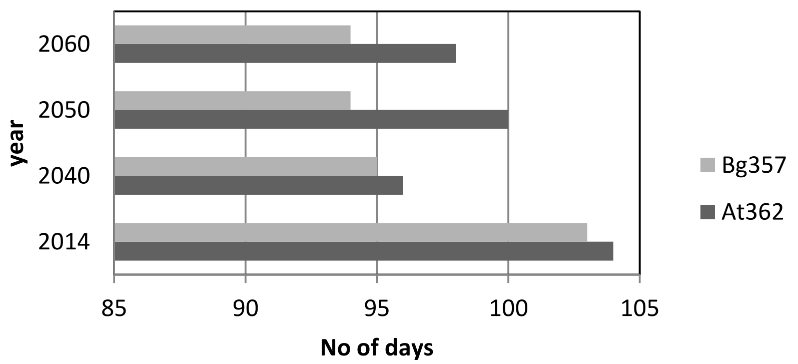

Figure 2: Variation of total growth period in simulated years

According to the simulated results, under climate change scenario RCP 8.5 rice yield of both varieties will be decreased in mid-centuries than the present yield. Average yield reduction vary from 1500 to 2000 kg/ha than present yield with increasing temperatures and decreasing rainfall. Increase of 0.5^0C in temperature can reduce the rice yield by approximately 6%[1]. When compared the predicted yield in mid-centuries in 2060 rice yield will be 12 to 14% higher than 2040 and 2050. For yield simulation process in all seasons crop management and soil conditions were kept as same. Therefore this yield variation occurs due to the changes of climatic conditions. Compared to 2040 and 2050, rainfall is relatively higher and air temperature is lower in 2060 and it may cause to yield increment in 2060. Also simulated results shows the total growth period of both varieties are shorter than present conditions. Rice plant is very sensitive to temperature and higher air temperature cause to early physiological maturity in rice plants and results shorter growth period[1]. This growth period reduction can also affect for the management practices as well as yield reduction.

The simulated results show in mid-centuries under the climate change scenario RCP 8.5, maximum and minimum air temperatures and solar radiation in Nilwala river basin will be increased. But the rainfall will be decreased than present conditions. If same crop management practices will continue in mid-centuries *Yala* seasons, rice yield of both varieties will be decrease by 25 to 35% and growth duration will be shorter due to these climatic changes. Therefore it is essential to find out suitable adaptation measures such as different management practices and use of new cultivars for this area to increase the rice yield in mid-centuries.

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