Impact of climate change on paddy yield: Case studies in Mahailluppallama and Batalagoda, Sri Lanka

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1. Introduction

With the increment of temperature and the changes in rainfall pattern, the growth and the yield of many crops are severely affected worldwide. Especially, the yields of key crops including rice and maize are expected to decline due to the climate change in the tropical region (Karunaratne et al., 2015). Previous studies have shown that the increment of temperature has an adverse impact on paddy yields in Sri Lanka's subhumid areas (Zubair et al., 2015). Paddy is the staple food of Sri Lankans, thus understanding the impacts of climate change on paddy production is important.

Since paddy is cultivated as rainfed cultivation in most parts of Sri Lanka, it is important to understand the impact of changes in rainfall on paddy yield. In this case, traditional agronomic experiments take time and are not economical. Therefore, crop models are one of the best methods to study the impact of climate change on crop yield (Holzworth et al., 2014).

A high-density, well-distributed, and consistent projected climatic data is critical for crop simulations (Baron et al., 2005). Depending on the General Circulation Model (GCM) used for simulation, the yield can be varied. Therefore, the objective of the study was to assess the impact of climate change on the yield of two major paddy cultivars (BG300 and BG358) in Mahailluppallama and Batalagoda, using a crop modelling approach. Pre-tested Agricultural Production Systems Simulator (APSIM) model (Holzworth et al., 2014) was used for yield simulation under 3 GCMs.

2. Materials and Methods

Mahailluppallama (in low country dry zone, 8.1095°N, 80.4631°E) and Batalagoda (in low country intermediate zone, 7.6593°N, 80.5007°E) were selected as the study area. Two improved, medium-duration and high-yielding local rice varieties, BG300 (three months duration) and BG358 (three and half months) were selected as the most prominent cultivars in the area. The Oryza model of (APSIM model) (Holzworth et al., 2014) was used for the simulation.

Observed daily rainfall, minimum and maximum temperatures for 1990–2015 (baseline) period were collected from the Meteorological Department of Sri Lanka while solar radiation data were obtained from NASA POWER database (https://power.larc.nasa.gov). Bias-corrected daily climate data (rainfall, minimum and maximum temperature and solar radiation) for the period of 2040–2065 were downscaled using 3 GCMs; CMCC_CMS, GFDL_ESM2M, MPI_ESM_MR. Future climate data were downscaled from the Consultative Group for International Agricultural Research (CGIAR) Program on Climate Change, Agriculture and Food Security (CCAFS) database under Representative Concentration Pathway (RCP) 8.5 scenario (http://ccafs-climate.org/).

The genetic coefficients for the simulations were obtained from (Zubair et al., 2015). Other crop parameters in the model were set to default. The published data on management practices (plant density, sowing dates, fertilizer applications) were collected from Wimalasiri et al., (2020). Direct seeding was selected as the planting method and the number of plants per seed bed was set as 350 (Zubair et al., 2015). The period between 01 November and 28 February was considered as the growing period. Rice yield for the *Maha* season was simulated for baseline (1990-2015) and future (2040-2065) climates.

3. Results and Discussion

Growing seasonal climate in the baseline period (1990-2015)

In Mahailluppallama, the maximum and minimum temperature for the growing season in the baseline period was 30.1°C and 21.6°C respectively. The total average growing seasonal rainfall of Mahailluppallama was 659 mm for the same location. The maximum and minimum temperatures in Batalagoda were 30.4°C and 21.8°C, respectively, while the total average rainfall was 630 mm.

Growing seasonal climate in mid-century (2040-2065)

The projected climate data in Mahailluppallama showed an increment of average maximum temperature with 1.4°C, 0.9°C and 1.1°C for CMCC_CMS, GFDL_ESM2M and MPI_ESM_MR GCMs compared to 1990-2015 period while, 1.8°C, 1.5°C and 1.5°C increment in Batalagoda.

The average minimum temperature also has increased compared to baseline for both locations; 2.6°C, 2.1°C and 2.6°C for Mahailluppallama and 2.4°C, 1.8°C and 2.3°C for Batalagoda from CMCC_CMS, GFDL_ESM2M and MPI_ESM_MR GCMs respectively. These results are consistent with previous studies, which showed that temperature would increase in the mid centuries (2040-2065) relative to the baseline period (1990-2015).

For Mahailluppallama, CMCC_CMS and MPI_ESM_MR GCMs showed an increment of total average rainfall (50 mm and 47 mm) relative to the 1990-2015 period and for Batalagoda 92 mm and 82 mm increment in respective GCM. While The GFDL_ESM2M showed a reduction of total average rainfall in Mahailluppallama and Batalagoda with 149 mm and 52 mm respectively.

Paddy yield for baseline climate data

The average yield in Mahailluppallama was 3457±342 $kgha^{-1}$ and 4304±340 $kgha^{-1}$ for BG300 and BG358, while for Batalagoda 3352±411 $kgha^{-1}$ and 4189±479 $kgha^{-1}$. In Mahailluppallama, the highest yield was 4418 $kgha^{-1}$ for BG300 and 5084 $kgha^{-1}$ for BG358 respectively (reported in the year 1990). In Batalagoda it was 4316 $kgha^{-1}$ and 5056 $kgha^{-1}$ for BG300 and BG358 which were reported from the same year.

Rice yield under future climate

APSIM simulations showed different responses with the changing climate for all three GCMs (Table 1).

Table 03. Simulated rice yields in mid- centuries for Mahailluppallama and Batalagoda

Location	Variety	Average Yield (kgha^{-1})		
		CMCC_CMS	GFDL_ESM2M	MPI_ESM_MR
Mahailluppallama	BG 300	3171±336	3274±340	3125±343
	BG 358	4069±429	4229±391	4026±453
Batalagoda	BG 300	3180±356	3274±262	3156±349
	BG 358	4070±420	4244±246	4040±436

The statistical analysis for comparison of the GCMs and locations with average yields was not significant ($p>0.05$) for both variables. Compared to the baseline period, the rice yield change is fluctuated for selected three GCMs with different magnitudes for the *Maha* season (Figure 1).

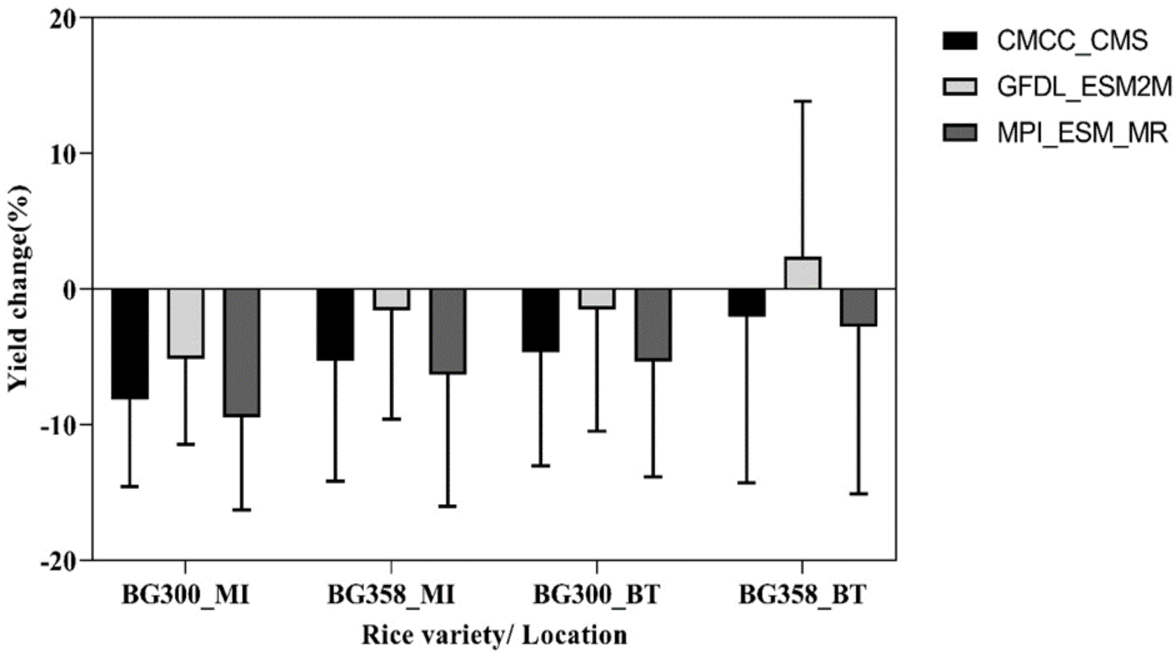

Figure 5. Rice yield change of selected GCMs for BG300 and BG358 in Mahailluppallama (MI) and Batalagoda (BT) compared to the baseline period

The highest yield reduction, compared to the 1990-2015 period was recorded by BG300 (5.7%) cultivar while, BG358 showed the lowest (2.6%) ($p<0.05$). Compared to the baseline period, a significant yield reduction was observed for CMCC_CMS, GFDL_ESM2M and MPI_ESM_MR GCMs as 5.05%, 1.5% and 5.9% respectively ($p<0.05$). The highest yield reduction was observed for the MPI_ESM_MR (5.9%) GCM. The findings are in accordance with previous studies, which has shown rice yields would decrease (Zubair et al., 2015).

4. Conclusions

The impact of projected climate data on rice yield in Mahailluppallama and Batalagoda was analysed in the study. The temperature has increased in considered all three GCMs for *Maha* season for both locations. Under the projected climate, the APSIM model simulations revealed a significant reduction of yield relative to the baseline period. Also, the yield changed with the future climate model and the cultivar used. Out of two cultivars, BG358 showed the lowest yield reduction (2.6%) compared to the 1990-2015 period. Therefore, proper adaptation strategies are essential in order to minimize climate change impacts on paddy cultivation in Sri Lanka.

5. References

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