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Influence of Projected Climate on Rice Yield Over Tamilnadu

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Abstract

A study was carried out at Agro Climate Research Centre, Tamil Nadu Agricultural University using PRECIS and RegCM4 Regional Climate Models (RCMs) by downscaling HadCM3 (Q0) and ECHAM5 global climate model outputs at 25 km resolution. The downscaled data obtained from the RCMs were verified with CRU observed climatology and found to have good agreement. Four weather variables viz., maximum temperature, minimum temperature, solar radiation and rainfall were extracted and employed in DSSAT crop simulation model for rice yield simulation for agricultural grids of Tamilnadu State India from 1971-2100. Two treatments were fixed as control and CO_2 enriched conditions. The maximum temperature and minimum temperature showed increase in temperature at the end of the century with high rate of increase for minimum temperature. Rainfall exhibited high variability. The rice yield simulations showed decline in yield in the study period for both control and CO_2 enriched conditions, with later consistently showing higher yields than the former till the end of 21st century.

Keywords: 21st Century, Climate Projection, Rice Yield, Tamilnadu

1. Introduction

Climate change is a defining challenge of our time as seen from the scientific evidence of its occurrence, its derivation from human activities and its potentially devastating effects[1]. The 0.74°C and 0.78°C increase in the temperature trend for 100 years (1906-2005) and 10 years (2003-2012) is mainly attributed to the human induced greenhouse gas emissions over the past[2,3] and is expected to contribute more in the future. Future climate projections have become an efficient tool for impact assessment studies including agriculture. The regional climate models with their fine scale features and higher resolution outputs enabled a better impact studies than the global circulation models. The crop simulation model is a suitable tool for evaluating the potential impacts of climate change on crop production and on the environment[4]. In this regard further investigations revealed that the increased rice yields due to elevated CO_2 levels were adjusted due to increasing temperature resulting significant reduction in yield. As rice is the staple food of Tamilnadu State, the rice yield response to the possible future climate was studied.

2. Materials and Methods

2.1 Study Area

The Tamilnadu, a state of Indian sub continent chosen owing to the jurisdiction the Tamilnadu Agricultural University enjoys. It is part of Southern peninsular India and geographically located between 7.91°N to 13.65°N latitude and 76.17°E to 80.82°E longitude and predominantly an agrarian region.

2.2 Climate Projections

Two Regional Climate Models (RCMs) were employed viz., Providing Regional Climate for Impact Studies (PRECIS) of UK Met Office Hadley Centre's and Regional

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Climate Model Version 4 (RegCM4.0) of Abdus Salam International Centre for Theoretical Physics (ICTP), Italy to simulate the future climate. The GCM boundaries used to drive the RCMs were HadCM3 (Q0) and ECHAM (EH5OM) models for PRECIS and RegCM4, respectively. The runs were made for 130 years (1971 to 2100) using A1B scenario, which is said to be in good coherence with the climate of Indian sub continent. The weather variables maximum and minimum temperature, global radiation and rainfall required for crop simulations are extracted from the outputs of RCMs. As HadCM3 boundaries had 360 days calendar, the PRECIS output was converted to Gregorian calendar as suggested by Minguez et al[5]. From the daily outputs of PRECIS and RegCM4 decadal estimations were made using Perl programme for climate analysis. The decadal estimations was done for each grids (PRECIS: 220 grids; RegCM4: 218 grids) and then averaged for the state to find the increase or decrease in trend of weather parameters till the end of 21st century.

2.3 Crop Simulation Studies

The agriculturally important grid points were identified using land use Geographical Information System (GIS) for Tamilnadu state. The grid points of the RCM were plotted using ArcGIS 9.1 and grids that covered atleast 50% agricultural area were chosen for crop simulation, which resulted in 139 of PRECIS grids (Figure 1.) and 141 of RegCM4 grids (Figure 2). The Decision Support System for Agrotechnology Transfer (DSSAT) version 4.5 was used in this study, which uses CERES rice sub model for simulating future rice yield projection. The regions ruling rice cultivars ADT 43 was used for rice yield simulations. Initially the model was calibrated and validated using field experiments exclusively done for this study and also from other experiments already conducted in various parts of Tamilnadu state. The GENCALC in the DSSAT was run to identify the suitable genetic coefficients and used in the study for rice (Table 1).

Table 1. Rice - ADT 43 - Genetic Coefficients

P1	P2R	P5	P2O	G1	G2	G3	G4
357	60.5	448.1	11.9	50.8	0.021	0.38	1.03

To understand the effect of CO_2 fertilization for the likely increase in CO_2 levels the crop simulations were made for constant level (380ppm) and for enrichment. The treatments were fixed as per the atmospheric CO_2

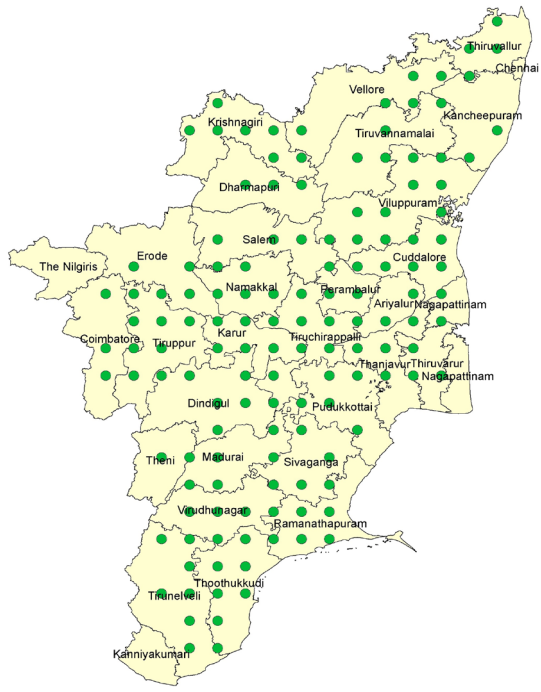

Figure 1. Agriculture grid points of PRECIS.

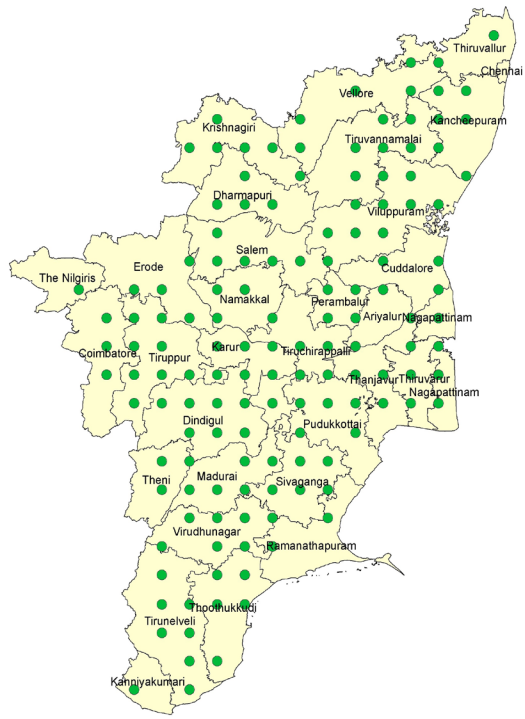

Figure 2. Agriculture grid points of RegCM4.

concentration projection given by ISAM carbon cycle models used in IPCC's Third Assessment Report (http://www.ipcc-data.org/ancillary/tar-iam.txt). A total of 35,584 simulations (139 grids x 128 years x 1 season x 2 CO_2 enrichment) for PRECIS outputs and 36,096 simulations (141 grids x 128 years x 1 season x 2 CO_2 enrichment) for RegCM4 outputs were made. The average productivity (yield kg ha-1) was estimated from DSSAT runs by averaging all grid runs in Tamilnadu for every year. The decadal means were also worked from the annual mean to remove the inter-annual variability.

2.3.1 Percent Relative Difference

Percent relative difference from base years (1971-2000) for crop yields was worked out for near future (2011-2040), mid-century (2041-2070) and late century (2071-2100) using the following equation.

$$\text{R.D. \%} = \frac{\text{Average predicted future years} - \text{Average predicted base years}}{\text{Average predicted base years}}$$

3. Results and Discussion

3.1 Climate Projections over Tamilnadu

The baseline (1971-2000) simulations monthly climatology were compared with Climate Research Unit (CRU) monthly climatology and found to have good agreement statistics. The Solar radiation (Figure 3.) showed no definite increase or decrease from the baseline (1971-2000) and however a slight decrement noticed indicating the dimming because of differences in the aerosol content of atmosphere. Similar observations were also made in different locations[6,7,8]. Maximum temperature is likely to increase in this study (Figure 4.) as reported by Wiltshire et al.[9]. Similar kind of increased projection for India was also observed by Chaturvedi et al[10]. Minimum temperature was also projected (Figure 5.) to increase by all the members studied as reported by IPCC in its AR4 report. The rate of increase in minimum temperature is higher than that of maximum temperature and was in agreement with Ramaraj et al[11] for Tamilnadu.

In case of rainfall (Figure 6.) there was no consistent projection, as both increase and decrease in trend was observed. Members showed both increase and decrease at the end of the century. These wide variations may be due to the prevailing variations in rainfall over Tamilnadu as reported by Rupa Kumar et al[12].

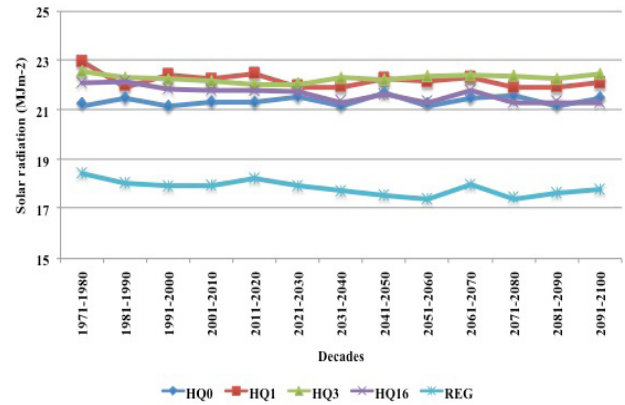

Figure 3. Decadal solar radiation projection over Tamilnadu.

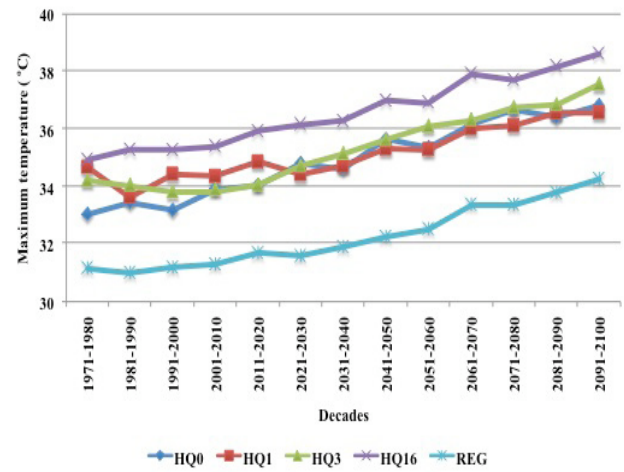

Figure 4. Decadal maximum temperature projection over Tamilnadu.

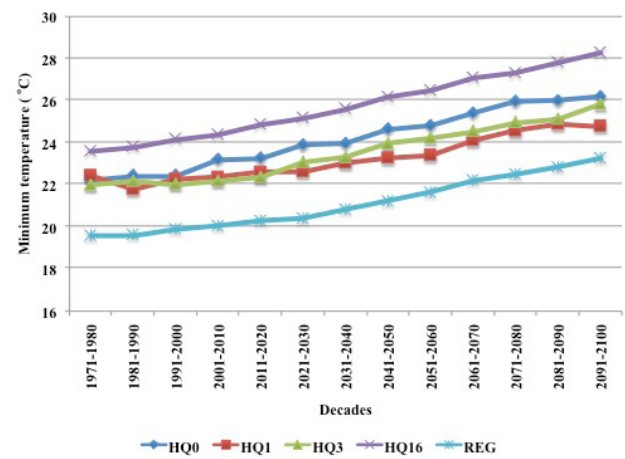

Figure 5. Decadal minimum temperature projection over Tamilnadu.

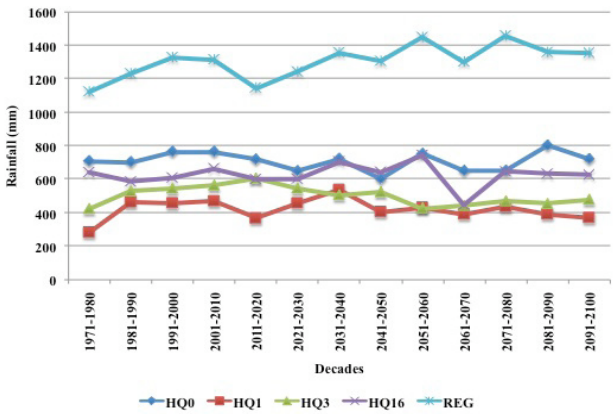

Figure 6. Decadal rainfall projection over Tamilnadu.

3.2 Impact of Climate Change on Rice Yield

Simulated rice yield (Table 2) showed decreasing trend for both control and CO_2 enrichment with a narrow peak during the decade 2051-2060 (572ppm CO_2) and 2041-2050 (532 ppm CO_2) for HQ0 respectively. The sudden peak in yield may be due to the effect of rainfall, which had the same peak in both the models. In control the reduction in yield is attributed to the increased temperature as reported by Aggarwal and Mall[13]. The increase in yield over control might be due to CO_2 fertilization effect, which might have reduced the impact of increased temperature to some extent as reported by Mohandass et al[14]. After the peak yield in CO_2 enrichment, continuous decline in yield was observed as temperature outweighs the CO_2 fertilization effect[15]. The yield predicted for REG output was always higher than that of HQ0, which might be due to the response of rice crop to the projected rainfall and temperature.

Table 2. Decadal mean of rice (ADT 43) yield (kg ha-1) simulated using DSSAT over Tamilnadu

	PRECIS		RegCM4	
Decades	**Control**	**CO_2 Enriched**	**Control**	**CO_2 Enriched**
1971-1980	3153	3176	3010	3030
1981-1990	3007	3028	3028	3047
1991-2000	3127	3151	2989	3013
2001-2010	2949	2984	3011	3044
2011-2020	2954	3051	2940	3026
2021-2030	2601	2803	2906	3109
2031-2040	2595	2920	2692	2993
2041-2050	2331	2755	2658	3106
2051-2060	2474	3066	2469	2989
2061-2070	2005	2605	2217	2787
2071-2080	1764	2405	2110	2735
2081-2090	1721	2425	2182	2911
2091-2100	1716	2472	1934	2648

Table 3. Percent relative difference (R.D %) of rice yield over the century

Time scale	**HQ0**		**REG**	
	Control	**CO_2 Enriched**	**Control**	**CO_2 Enriched**
Near future	-12.24	-6.21	-5.42	0.42
Mid century	-26.67	-9.93	-18.64	-2.29
Late century	-44.00	-21.95	-31.03	-8.76

Note: Near future: 2011-2040, Mid century: 2041-2070, Late century: 2071-2100

4. Conclusion

Maximum and minimum temperatures are projected to increase, while all other parameters indicated no consistent trend at the end of the century. The yield of rice is projected to decrease for both control and CO_2 enriched conditions. However, under enriched CO_2 conditions, the yield was more than that of control.

5. Acknowledgement

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