IMPACT OF CLIMATE CHANGE ON RICE AND GROUNDNUT YIELD USING PRECIS REGIONAL CLIMATE MODEL AND DSSAT CROP SIMULATION MODEL

A.P. Ramaraj[a], R. Jagannathan[b*] and Ga. Dheebakaran[c]

[a*]Senior Research Fellow, [b]Professor and Head, [c]Research Associate
Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore -641003, India

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ABSTRACT:

Impact of climate change on agriculture will be one of the major deciding factors influencing the future food security of mankind on the earth. Climate change studies over the past few decades have mostly focused on regional and local scales which are of paramount importance in assessing the impacts of climate change on agriculture. To assess the impact of climate change in agriculture over Tamil Nadu, outputs of PRECIS Regional Climate Model and DSSAT crop simulation model were used. PRECIS Regional Climate Model was used for downscaling of a domain over the whole Tamil Nadu with a horizontal resolution of 0.22° (~25km). The PRECIS was run from 1960 up to 2098 continuously. However, 28 years of data for 17 grids comprising two districts (Tanjore-6 grids and Tiruvannamalai-11 grids) alone was selectively post processed and used in crop simulation model. The level of CO_2 enrichment had increased the yield of both crops compared to normal level of CO_2 (330ppm). There was no definite trend of impact of predicted temperature on both rice and groundnut yield.

1. INTRODUCTION

1.1 Climate change

Climate change is defined as a statistically significant variation in either the mean state of the climate or in its variability persisting for an extended period (typically decades or longer). It may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of atmosphere or in land use (IPCC, 2001). Climate change is one of the most important global environmental challenges faced by humanity (Mitra, 2007).Climate change in India may pose additional stresses on ecological and socio-economic systems that already face tremendous pressures from rapid urbanization, industrialization and economic development. The IPCC report scripted many observed changes in the Earth's climate including atmospheric composition, global average temperatures, ocean conditions, and other climate changes. The long-lived greenhouse gases like Carbon dioxide, methane, and nitrous oxide are all have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values.

1.2 Climate change and Agriculture

The relationship between climate changes and agriculture is particularly important issue; as the worlds food production resources are already under pressure from rapidly increasing population (Mathews and Stephens, 2002). Agriculture is sensitive to short term changes in weather and to seasonal, annual and longer term variations in climate (STOA, 1999). Self-sufficiency in Indian food grain production and its sustainability is in ambiguity due to climate variability and change that occurred in the recent past. Impact of climate change on agriculture will be one of the major deciding factors influencing the future food security of mankind on the earth. Agriculture is not only sensitive to climate change but at the same time, it is one of the major drivers for climate change.

1.3 Regional scale studies on climate change

Climate change studies over the past few decades have mostly focused on regional and local scales which are of paramount importance in assessing the impacts of climate change on agriculture. The impact of climate change on agriculture could result in problems with food security and may threaten livelihood activities upon which much of population depends. Climate change can affect crop yield (both positively and negatively) as well as type of crops grown in certain areas by affecting water for irrigation, amounts of solar radiation that affect plant growth as well as prevalence of pest (Rao *et al.,* 2008).Understanding the weather changes over a period of time and adjusting the management practices towards achieving better harvest is a challenge to the growth of agricultural sector as a whole. By examining these potential stresses and impacts it is clear that climate science needs prediction of future trends to help policymaking. Improved knowledge is needed on future climate and it's change affecting crop yields and various other processes on regional scale.

2. MATERIALS AND METHODS

2.1 Climate Model

PRECIS is an atmospheric and land surface model of high resolution and limited area, which is locatable over any part of the globe. It has a horizontal resolution of 0.44° (~50km) or 0.22° (~25km) and 19 levels in the vertical (Jones et al., 1995). PRECIS is forced at its lateral boundaries by the simulations of a global climate models *viz.,* HadCM3, HadRM3, ECHAM. The Tamil

* jagan@tnau.ac.in

Nadu Agricultural University by arrangement with Hadley centre, UK Met Office, UK received the PRECIS model and the required GCM boundary data for driving it to make impact studies over Tamil Nadu. The PRECIS was run with boundary data of HadCM3Q0 A1B scenario for a domain covering entire TamilNadu State from 1960 up to 2098 continuously. However, 28 years of data for 17 grids comprising two districts (Tanjore-6 and Tiruvannamalai-11) alone was selectively post processed and used in crop simulation model to study the possible impact of climate change on rice and groundnut.

2.2 Crop simulation model

The data retrieved from PRECIS was exported as weather files in the DSSAT 4.0.2 crop simulation model for further processing. The Decision Support System for Agrotechnology Transfer (DSSAT) is a software package integrating the effects of soil, crop phenotype, weather and management options that allows users to simulate results by conducting experiments. DSSAT is a microcomputer software product that combines crop, soil and weather databases into standard formats for access by crop models and application programs. The DSAAT 4.0.2 which, was released during 2006, was utilized for running crop simulations. The official website of the DSSAT is http://www.icasa.net/dssat/index.html DSSAT crop simulation model was run using daily weather information generated from PRECIS. For the same data the CO2 enrichment option of DSSAT was invoked to understand its impact.

2.3 Study period

The model was actually run for 140 years continuously. However, the data were retrieved for only 28 years to analyse the decadal information for crop modeling. The years 1968, 1978, 1988, 1998, 2008, 2018, 2028, 2038, 2048, 2058, 2068, 2078, 2088 and 2098 and another 14 years (1969, 1979, 1989, 1999, 2009, 2019, 2029, 2039, 2049, 2059, 2069, 2079, 2089, 2099), their consecutive counterparts were also retrieved as the crop seasons are expected to lie on both years.

2.4. Calendar calculations for PRECIS data

The PRECIS uses 30 days calendar per month while the DSSAT crop simulation model uses Gregorian calendar. The procedure described by Minguez *et al.* (2007) was followed to obtain weather files for DSSAT model.

2.5 Assumption made in DSSAT runs

The weather files for 28 years were exported to DSSAT for simulating rice yields of Tanjore district and groundnut yield of Tiruvannamalai district. The following assumption were made in simulating the district crop yields

1. The chemical fertilizers and water was considered as not limiting.
2. There was no major pest and disease attacked the crop.
3. Three sowing dates were assumed as 5th June, 5th September and 5th December for *kharif, rabi* and winter respectively, to average the effect of sowing window.
4. The diverse varieties, irrigation and fertilizer practices etc. were not considered and they were assumed to be same.

2.6. Basic inputs used in DSSAT

The output obtained from PRECIS climate model viz., maximum temperature, minimum temperature, rainfall and solar radiation was given as input for the DSSAT crop simulation model with the required conversions in their units. The weather files created were converted into DSSAT weather file format using Weatherman. Necessary soil, field and other crop management inputs were given through 'X build' of DSSAT. The effect of CO_2 fertilization was included in the study by keeping two environmental modification treatments as with and without CO_2 fertilization. The CO_2 increment over the study period was given as in the Table 1.

Year	**1968-69**	**1978-79**	**1988-89**	**1998-99**	**2008-09**	**2018-19**	**2028-29**
CO_2 increment (ppm)	5	15	30	50	75	105	140
CO_2 (ppm)	335*	345	360	380	405	435	470
Year	**2038-39**	**2048-49**	**2058-59**	**2068-69**	**2078-79**	**2088-89**	**2098-99**
CO_2 increment (ppm)	180	225	275	330	390	455	525
CO_2 (ppm)	510	555	605	660	720	785	855

** Base CO_2 is fixed as 330 during 1968.*

Table 1: CO_2 increments (ppm) over base of 330 ppm

2.7 Simulation runs

A total of 504 simulations (6 grids x 14 years x 3 season - June, September and December x 2 - with and without CO_2 enrichment) for rice crop (IR20) and 924 simulations (11 grids x 14 years x 3 season - June, September and December x 2 - with and without CO_2 enrichment) for groundnut (TMV2) were run. The district average productivity (yield kg ha^{-1}) was calculated from the DSSAT output file by taking average of respective grids of the district.

3. RESULTS AND DISCUSSION

3.1 Influence of predicted weather on rice

The simulated yield for predicted projections revealed that there was no perfect trend of increase or decrease in the yields over the decadal interval studied for June and September sown crop (Figure 1). It varied from year to year and the maximum was observed during the year 2008 (Table 2) and a near stabilized yield state was seen from the year 2028 but it was not continuous but for December sown crop this decline was lesser than that of the other seasons where the difference was higher. Then it reached a peak of

8652 kg ha $^{-1}$ in the year 2008 then decreased up to5324 kg ha $^{-1}$ during the year 2038 and there was no prominent stabilization of yield thereafter.

Year	NORMAL						CO_2 ENRICHED					
	Jun		Sep		Dec		Jun		Sep		Dec	
	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})
1968	10931	5503	11441	6782	9298	4486	10957	5504	11448	6793	9348	4511
1978	9815	3245	10201	5941	7247	4146	9901	3212	10289	6020	7281	4126
1988	10561	4683	11234	6594	9885	5557	10789	4754	11396	6665	10073	5597
1998	9571	4140	10326	5988	10565	5993	10039	4325	10618	6242	10875	6187
2008	14150	8398	12027	6621	14514	8652	14995	8905	12249	6759	15303	9079
2018	11778	6634	12633	7219	10498	6065	12193	6549	13123	7591	10780	6209
2028	11282	5279	11248	6590	10401	5738	12034	5815	12517	7269	11169	6123
2038	11643	5680	10656	6395	9329	5324	12773	6216	11137	6684	10074	5683
2048	11888	5599	13693	7621	12373	7168	14118	6681	15207	8599	14641	8487
2058	12193	6590	8483	5118	12119	6989	13965	7432	10784	6509	13420	7755
2068	10992	5513	11535	6828	9320	4455	12399	6184	12707	7480	11818	6041
2078	9916	3302	10206	5944	7317	4176	12263	3523	13454	7958	8615	4863
2088	10606	4675	11318	6637	9868	5569	13328	5621	12607	7532	12759	7152
2098	9627	4141	10346	6003	10589	5963	13596	6033	12570	7443	12596	7100

Table 2: DSSAT Simulations of Rice Yields (IR 20) for Tanjore District

Year	**NORMAL**						**CO_2 ENRICHED**					
	Jun		**Sep**		**Dec**		**Jun**		**Sep**		**Dec**	
	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})	Dry Matter (kg ha^{-1})	Yield (kg ha^{-1})
1968	13178	2590	12801	4267	12107	4239	13247	2592	12965	4310	12152	4248
1978	12528	1515	12451	3955	12391	3610	12767	1524	12938	4080	12525	3612
1988	13522	1841	11661	3322	11471	4117	14012	1866	12484	3524	11710	4154
1998	13462	2202	10609	2695	12204	4504	14192	2232	11801	2975	12663	4655
2008	14394	4052	10155	3083	14882	5258	15211	4133	11907	3578	15957	5651
2018	14726	3874	12902	3072	14538	4810	15896	3900	15490	3671	15799	5207
2028	14186	2352	11871	3745	12724	4722	15623	2397	14873	4653	13885	4999
2038	13210	2579	12661	3973	12241	4044	14863	2627	16302	5004	13752	4148
2048	13609	3890	13124	3463	13704	4747	15498	3964	17457	4536	15497	5358
2058	14102	3084	12791	4160	13313	4942	16200	3138	17397	5542	15258	5437
2068	13193	2544	12774	4274	12092	4236	15524	2619	17687	5850	13729	4436
2078	12517	1466	12433	3941	12344	3589	15303	1567	17565	5428	14402	3652
2088	13481	1791	11647	3322	11473	4112	16596	1933	16562	4614	13251	4214
2098	9627	4141	10346	6003	10589	5963	13596	6033	12570	7443	12596	7100

Table 3: DSSAT simulations of groundnut yields (TMV2) for Tiruvannamalai District

3.2 Influence of predicted weather on rice for CO_2 enrichment

Initially there was a decrease in the yield from 5504 kg ha $^{-1}$ during 1968 to 3212 kg ha $^{-1}$ during 1978 (Table 2) then it increased and attained a peak of 8905 kg ha $^{-1}$ in 2008 and then gradually decreased up to 2028 (5815 kg ha $^{-1}$). Thereafter the yield of rice gradually increased up to 2058 (7432 kg ha $^{-1}$) and attained its second peak. Then it declined to a yield of 3523 kg ha $^{-1}$ in 2078. There is no prominent trend in June sowing. In September sowing, a near stabilized yield trend was observed from the year 1968 (6793 kg ha $^{-1}$) to 2008 (6759 kg ha $^{-1}$). It reached a maximum of

8599 kg ha $^{-1}$ in 2048 and then decreased. A near stabilized region of yield was again noticed from 2068 to 2098. It recorded an increased yield as the years advances from 1968 to 2098**.** In December sowing, maximum yield (9079 kg ha^{-1}) was recorded during 2008 and then it attained a second peak of 8487 kg ha $^{-1}$ during 2048. As the years an increasing trend of yield was noticed with some exceptional years. There was no prominent increasing or decreasing trend in the yield of rice.

3.3 Influence of predicted weather on Groundnut

On comparing the yield of groundnut obtained over the years due to CO_2 fertilization in all the three seasons it can be stated that, initial decrease in yield from 1968 was uniform and the near stabilized. Yield period varies from between seasons and June sowing has no such prominent trend. (Table 3). In all the season the dry matter production of groundnut due to CO_2 fertilizer follows the same trend as that of yield as given above.

3.4 Comparison between temperature and CO_2 fertilization.

On comparing the yield obtained for both the treatment (temperature effect and temperature and CO_2 effect) for groundnut (Figure 2) the CO_2 and temperature treatment shows a slightly increased yield than the temperature treatment for the same season. The trends of both the yield were almost similar.

CONCLUSION

The DSSAT crop simulation results revealed that there was no definite trend of impact of predicted temperature on both rice and groundnut yield. The level of CO_2 enrichment had increased the yield of both crops compared to normal level of CO_2 (330ppm). There exists a seasonal difference for CO_2 enrichment for groundnut, which was not noticed in rice. In case of rice the enrichment of CO_2 increased the yield but it was not consistent and records a peak in later part of 21st century.

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