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Simulated Projections in Paddy Growing Season over Kashmir Himalayan Region

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***Abstract* – Climate is the primary determinant of agricultural productivity. There has been a growing recognition of the possibility of global climate change on agriculture with an increasing emphasis on regional food security. Climate change impact over agricultural productivity is compounded when farming is practiced at or near the edge of a climatic region where a small change in climate could substantially alter the potential for agriculture, thus creating a mismatch between existing farming systems and prevailing climatic resources for agriculture. Kashmir Himalayan region is expected to be highly prone to the consequences to climate change because of its geo-ecological fragility, strategic location vis-à-vis Himalayan landscape its trans-boundary river basins and its inherent socio-economic instabilities. Food security and sustainability of the region are thus greatly challenged by these impacts. Incurrent study climate projections in paddy growing season were examined over three time slices, viz. short (2010 – 2050), medium (2050 – 2098) and long (2010 – 2098). The results showed a marked change both in precipitation and temperature patterns in paddy growing season, under future climatic scenarios particularly becoming conspicuous after the 2050 over the region. The increase in temperature was found to be more significant in minimum then maximum temperature. The characteristics of daily rainfall over the region showed an overall decrease in amount over the region contrary to increase in amount in growing season. The redistribution of daily rainfall characteristics made the seasonal total to be trendless, bearing serious implications on way we conserve and utilize the water in the region.**

***Keywords* – Climate Change, Growing Season, Agricultural Productivity, PRECIS Model, Himalayan Region.**

I. Introduction

Climate change poses a serious threat to foodsecurity and need to be much better understood [7]. There is now clear evidence for an observed increase in global average temperatures and change in rainfall rates during the 20th century around the world [11, 19, 21, 8, 12].In recent years, with the growing recognition of the possibility of global climate change, an increasing emphasis on world food security in general and its regional impacts in particular have come to forefront of the scientific community [32]. Our current level of understanding of the components of the climate system and their interactions has reached an advanced stage, with the availability of a hierarchy of coupled ocean–atmosphere-sea–ice-land-surface models to provide indicators of global response as well as possible regional patterns of climate change [23]. A variety of experiments have been performed by different modelling groups in the world to simulate expected climate change patterns under different emission scenarios [19]. Future temperature projections using global circulation models (GCM) indicate an increase of 2.5–4°C from the current levels over the Indian subcontinent. However, GCM results are available for a very coarse resolution of 2.5° latitude and 3.75° longitude which will have high uncertainty [33]. Regional climate models (RCM) run athigh resolution taking into consideration the orography, coasts, vegetation and interregional climate variability to predict the future climate with high confidence [20].The Spatio-temporal variations in projected changes in temperature and rainfall at regional level are likely to lead to differential impacts in the different regions[10]. A warming of 0.5°C is likely over all India by the year 2030 (approximately equal to the warming over the 20th century) and a warming of 2-4°C by the end of this century, with the maximum increase over northern India [18].The last decade that ended with 2010 was the warmest in the past over India[16].The rising temperatures with uncertainties in rainfall may or may not have serious direct and indirect consequences on crops especially on cereals contributing to the food security [13, 14, 15]. The projected increase in these events could result in greater instability in food production and threaten livelihood security of farmers [1, 6]. There is need to quantify the growth and yield responses of important crops and also identify suitable options to sustain agricultural productivity under large range of climatic variations by the analysis of seasonal and annual surface air temperatures [36]. Recent trends of a decline or stagnation in the yield of rice-wheat cropping system in Indo-Gangetic plain and north India have raised serious concern about the regions food supply [4, 31, 38].Therefore, there is a widely felt need for understanding the nature of climate change over Kashmir Himalayan region. In this article, regional climate model outputs have been examined to understand the climate change trends in the paddy growing season so as to implement suitable adaptation strategies to sustaining the productivity of staple crop of the region.

II. Materials and Methods

To develop the high-resolution climate change scenarios for impact assessment studies, a high-resolution regional climate model, Providing REgional climates for Impact Studies (PRECIS), developed by the Hadley Centre, UK was run at the Indian Institute of Tropical Meteorology (IITM), Pune at 50 km × 50 km horizontal resolution over the South Asian domain were employed. The PRECIS simulations corresponding to the IPCC SRES A1B emission scenario were used for a continuous period of

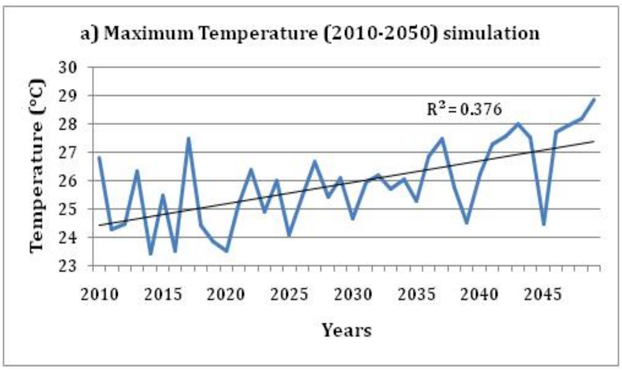
2010 – 2098 to examine the climate change in paddy growing season that extends for four months (June to September) across Kashmir valley. A moderate CO_2 emissions scenario, A1B was selected for future climate projections. From the large number of outputs generated from the models, only maximum, minimum temperature and precipitation were retrieved and analyzed.

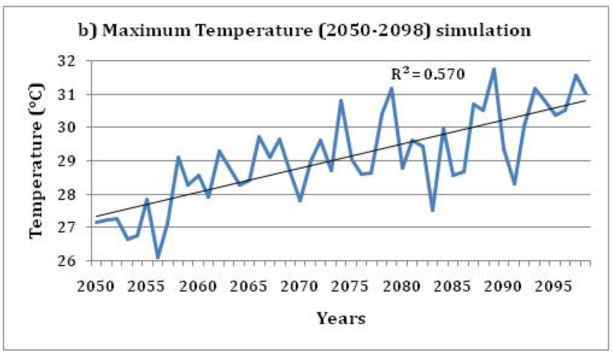
III. Results

The climate projections over the domain were examined over three time slices, viz. short (2010 – 2050), medium (2050 – 2098) and long (2010 – 2098). On a regional scale, the variations in temperatures and amount of precipitation described below were observed from mean simulated in the 2010 by PRECIS model.The change in temporal pattern of lowest minimum, highest maximum temperature and precipitation was assessed to measure the level of warming in valley by 2098.The observed precipitation and temperature variability over Kashmir valley under future climatic scenarios is presented as follows:

Observed temperature variability

The results showed that maximum mean annual temperature in growing season is projected to increase by 2.05°C (±1.41) in 2010 to 2050 (Fig.1a) and 3.86°C (±1.36) in 2050 to 2098 (Fig.1b).Overall maximum mean annual temperature is projected to increase by 4.24°C (±2.10) in 2010 to 2098 (Fig.1c).In the meantime, seasonal minimum mean annual temperature is projected to increase by 2.37°C (±1.0) from year 2010 to 2050 (Fig.2 a) and 2.65°C (±1.05) in year 2050 to 2098 (Fig.2b). The overall minimum mean annual temperature is projected to increase by 5.29°C (±1.67) during growing season in years 2010 to 2098 (Fig.2c).





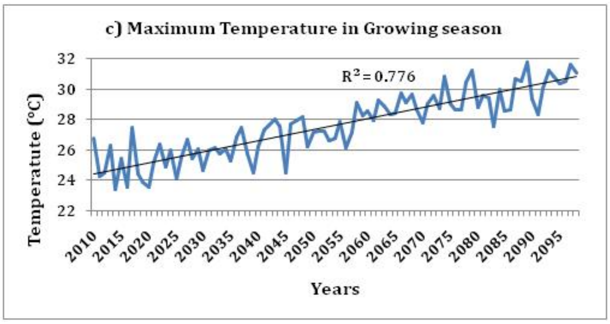


Fig.1. (a-c) Projected mean annual maximum temperature in paddy growing season.

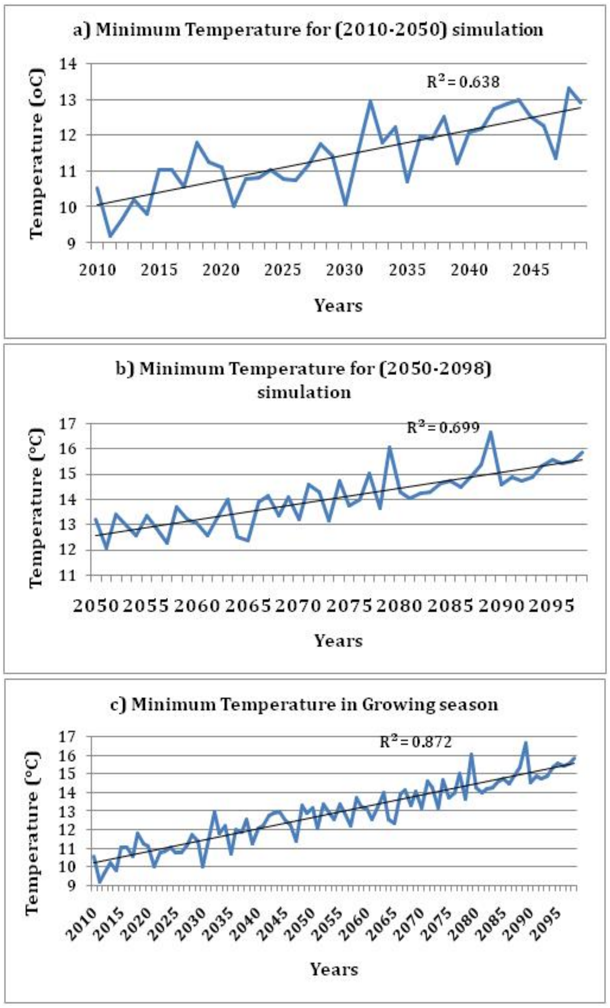


Fig.2. (a-c) Projected mean annual minimum temperature in paddy growing season.

Variability in precipitation

Analysis of the precipitation showed a small decrease with respect to 2010. The annual precipitation is likely to vary between 264.27 mm to 514.59 mm (±151.69) in years 2010 to 2050 (Fig.3a) and 613.96 mm to 344.51 mm (±126) in years 2050 to 2098(Fig.3b). The overall annual precipitation is likely to vary between 264.27 mm to 344.51mm (±300.34) from years 2011 to 2098 (Fig.3c).The projected precipitation in growing season is likely to increase by about 30.36 % in years 2010 – 2098.

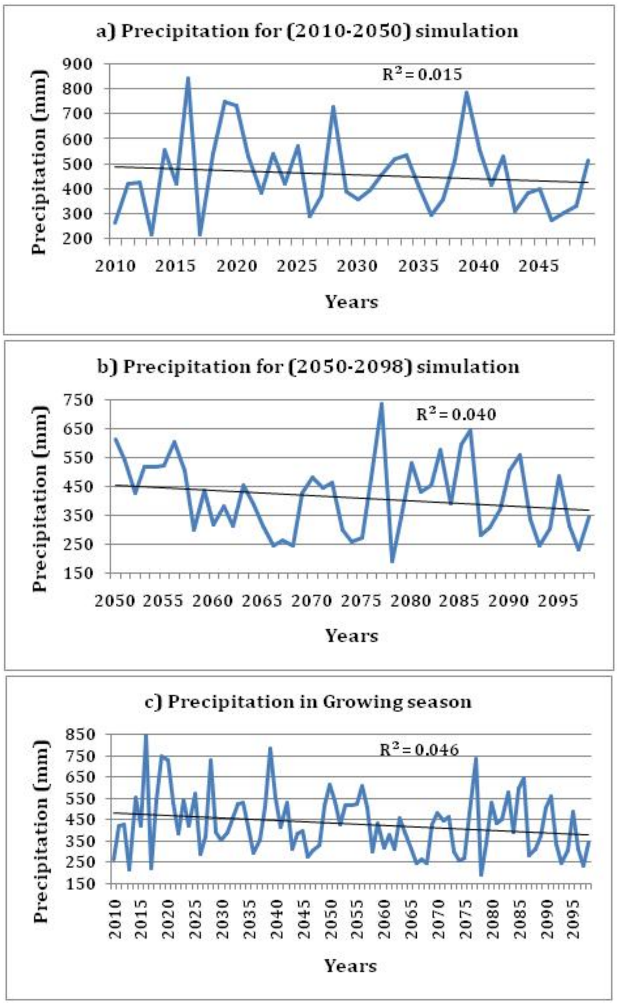


Fig.3. (a-c) Projected annual precipitation in paddy growing season.

IV. Discussion

PRECIS simulations for future climate (2010 – 2098) indicated an all-round warming over the Kashmir valley. The projected data showed intensification of daily extremes in surface air temperature that is daily maximum, minimum temperatures and shift in precipitation patterns over the region. The model projections indicated significant warming over Kashmir valley towards the end of the 21st century.

Observed temperature variability

The projections clearly revealed all around warming with increase in both minimum and maximum temperatures becoming more prominent towards the end of the century. The results showed that maximum mean annual temperature in growing season is projected to increase by 2.05°C (±1.41) in 2010 to 2050 characterized by weak trend (R^2 = 0.37). The projected inter-annual variability of temperatures in Kharif season for rest of India using ECHAM4 and HadCM2 models suggest an increase in annual mean temperature by more than 1^{o}C (1.3^{o}C in ECHAM4 and 1.7^{o}C HadCM2) [41].It has beenestimated that CO_2 level will increase to 397–416 ppm by 2010s from the present CO_2 level of 371 ppm and this would further increase by 605–755 by 2070s projecting an average annual mean warming by 2020 & 2050 between 1 to 1.4^{o}C and 2.23 to 2.87^{o}C respectively [28].

The results also revealed a conspicuous change mean annual maximum temperature in growing season is projected beyond 2050 with increase of 3.86°C (±1.36) in 2050 to 2098 characterized by strong trend (R^2 = 0.57). While as overall maximum mean annual temperature is projected to increase by 4.24°C (±2.10) in 2010 to 2098 with (R^2 = 0.77). Simulating climatic patterns for 2071 – 2100 revealed that annual mean surface air temperature to rise by the end of the century from 3 to 5ºC in A2 scenario, whereas the rise lies between 2.5 and 4ºC in the B2 scenario with warming to be more pronounced over the northern parts of India [42].There will be a warming of 1°C to 4°C towards the 2050s, which may exceed even 4.5°C in most places towards the end of the 21st century [23].

In the meantime, projected mean annual minimum temperature showed an increase by 2.37°C (±1.0) from year 2010 to 2050 and 2.65°C (±1.05) in year 2050 to 2098. The increase in minimum temperature for simulated periods though consistent but seems to be more pronounced with less intra-annual variability which is reflected by less standard deviations for the simulated periods with R^2 of 0.63 and 0.69 respectively.The results clearly the extend of warming temperature in minimum temperatures to be more pronounced then maximum temperature. The overall minimum mean annual temperature is projected to increase by 5.29°C (±1.67) which shows far more increase then maximum temperature 4.24°C (±2.10) during growing season in years 2010 to 2098 characterized with strong trend (R^2= 0.88). The warming trend in mean annual temperature in the recent three decades is contributed by both the maximum (0.20°C/10 years) and minimum (0.21°C/10 years) temperatures with minimum temperature showing slightly greater increase [24, 25].Increase in annual mean maximum and minimum surface air temperatures by 0.7^{o}C and 1.0^{o}C over land in the 2040s with respect to the 1980s also signifying greater increase in minimum temperatures [26]. The increase in minimum temperature resulted in declining trends of potential yields of rice in the Indo-Gangetic plains of India [38]. The accompanied increase in minimum temperatures increases maintenance respiration requirement of the crops and thus further reduces net growth and productivity [5].This changes in the growing season temperature over the years appeared to be the key aspect of weather affecting yearly yield fluctuations [30].

From the results, it is thus clear that there is all around warming with increase in both minimum and maximum temperatures becoming more prominent towards the end of the century. The maximum and minimum temperatures indicate an increase of about (2.05°C (±1.41)50 years) and (2.37°C (±1.0)/50 years) respectively. Increase in minimum and maximum temperatures solely responsible for overall temperature increase [40].Most of the simulation studies have shown a decrease in duration and yield of crops as temperature increased in different parts of India. Such reductions were however, generally offset by the increase in CO_2; the magnitude of which varied with crop, region and climate change scenario [3, 4].

An increase in 1^oC rise in mean temperature has been found to have no significant effect on potential yields under irrigated and rainfed conditions and yields increased in most places. While as increase of 2^oC in temperature reduced potential yields at most places [1, 2]. Increase of 1 to 2^oC temperature without any increase in CO_2 resulted in a 3–17% decrease in grain yield in different regions [3, 4]. Vulnerability of rice crops in northwest India to climate change through sensitivity experiments with CERES-rice models revealed that under elevated CO_2 levels, yields of rice increased significantly by 15% for a doubling of CO_2[27]. However, a 2^oC rise in temperature cancelled out the positive effect of elevated CO_2 on rice. The combined effect of enhanced CO_2 and imposed thermal stress on the rice crop is 4% increase in yield for the irrigation schedule presently practiced in the region. While the adverse impacts of likely water shortage on the rice crops resulting in about 20% net decline in the rice yields.

Even the effect of climate change scenario of different periods can be positive or negative depending upon the magnitude of change in CO_2 and temperature [5]. It has beenestimates that India's climate could become warmer under conditions of increased atmospheric carbon dioxide. The average temperature change is predicted to be in the range of 2.33°C to 4.78°C with a doubling in CO_2 concentrations [29]. The possible impact of these studies showed that the irrigated rice yields in north India will not be significantly affected due to direct effect until 2050. It is only in 2070 when the temperature increases are very large, that the crops show large reduction in yield. The studies have confirmed that impact of climate change on paddy yield in Kashmir valley also varied under different levels of management and change in temperature and CO_2 concentration.The results revealed that with the increased in temperature by ~ 2^oC and increase in yield by 0.6% until year 2020; then, a decrease by 6.64% by year 2040. But beyond that, as temperature increased to ~ 3°C yield decrease was very high about 29.1% from the baseline year of 2010 [34].The productivity of Kharif crops such as irrigated rice in the Western Ghats region is likely to change by +5% to –11% in the PRECIS A1B 2030 scenario depending upon the location with majority of the region is projected to lose the yields by about 4%[35]. The results in light of other studies clearly suggest that the direct impacts of climate changes would be initiallysmall with temperature increase of ~ 2^oC but the impact will become prominenttowards the end of this century with an overall increase of ~ 4°C and ~ 5^oC for maximum and minimum temperatures.

Variability in precipitation

Analysis of the precipitation showed anincrease with respect to 2010. The annual precipitation is likely to vary between 264.27 mm to 514.59 mm (±151.69) in years 2010 to 2050 and 613.96 mm to 344.51 mm (±126) in years 2050 to 2098. The projected results showed the greater uncertainty associated with rainfall projected around 2050 with projected rainfall showing greater standard deviation between simulated years. There has been large uncertainty is with projected kharifrainfall centered on 2050s [28]. Moreover, the standard deviation of future projections of rainfall was found to be significantly highimplying high year-to-year variability with over all projected precipitation is likely to vary between 264.27 mm to 344.51mm (±300.34) from years 2011 to 2098. The projected precipitation in growing season is likely to increase by about 30.36 % in years 2010 – 2098. The kharif season rainfall all over India projected using ECHAM4 model also showed an 13% increase [41].while as simulations using UKMO GCM model, also predicted a greater number of heavy rainfall days during the summer monsoon during kharif period with an increased interannual variability [9].The rainfall fluctuations in India have been largely random over a Century, with no systematic change detectable in summer monsoon season. However, areas of increasing trend in the seasonal rainfall have been found along the West Coast, North Andhra Pradesh and Northwest India and those of decreasing trend over East Madhya Pradesh, Orissa and Northeast India during recent years [39].

The analysis results clearly pointed out that the rainfall patters over region mainly trendless and randomly fluctuates over a long period of time. Several studies during the last four decades had clearly pointed out that the rainfall patters over India are trendless [37]. However, some notable trends do exist on a smaller spatial scale [23, 39, 17].It has been observed in recent years that the characteristics of daily rainfall have been undergoing changes in a way that the frequency and intensity of heavy to very heavy rainfall events are increasing. This redistribution of daily rainfall character is probably making the seasonal total to be trendless; though it can have implications for the way we conserve and utilize the water. When projected precipitation results for the growing season were compared with the overall projected precipitation for growing season over the region for 2011 – 2098, the results showed precipitation is likely to increase by about 30.36 % in the growing season. This is quite contrary to overall projected rainfall for 2010-2098 for the region which show a decrease of 16.7% [34]. This clearly showed that maximum amount of the projected precipitation will be received in summer seasons particularly in the growing season of the crop.Since paddy is cultivation under irrigatedconditions from the waters received from perennial sources like glaciers which in turn depend on the amount of precipitation in the winter months. Shortfalls in amount of precipitation in winter months of Himalayan region can reduce irrigation water supplies, leading to reduce areas under irrigated crops[21].From the results it's evident that in in coming year'sKharif agriculture especially paddy cultivation in valley will be subjected to less amount of water for irrigation due to less down pour in the winter seasons.

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V. Conclusion

The results from future climatic scenarios showed a marked change both in precipitation and temperature patternsin paddy growing season, particularly becoming conspicuous after the 2050 over the region. Towards the end of the 21st century, the mean annual surface air temperature is projected to increase significantly by ~ 4°C for maximum and ~5^{o}C for minimum temperatures. The accompanied increase in temperature was found to be more significant in minimum then maximum temperature of paddy growing season, which will increases respiration requirement of the crops even during the night and thus further reducing net crop growth and productivity. The precipitation in growing season is projected to increase by ~ 36.6 % contrary to decrease by ~ 16.7% over valley towards the year 2098 relative to the year 2010. The results clearly point out that the characteristics of daily rainfall over the region will undergo changes with projected rainfall showing an overall decrease while as increase in growing season. This short fall in amount of precipitation in winter months can reduce irrigation water supplies, during the paddy growing season leading to reduce areas under irrigated cropsand will bear serious implications on way we conserve and utilize the water in the region.At this juncture, based on the results of the study it can be concluded that the agricultural impacts of climate change in Kashmir are certain. The climate scenarios show that climate change will have an overall negative impact or no significant effect on agriculture until 2020. By the end of the century when temperature increase are very large, the agriculture will suffer the most.The present investigation provided a vital clue about the possible climate change impact on crops in the region to enable better preparedness to reduce the negative impacts.

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