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Strategies for climate change impacts on irrigated crops in National Capital Region of India

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Abstract: Irrigation has helped in increasing food production and achieving food security in India. However, climate change is expected to affect the crop production in irrigated area particularly in groundwater irrigated areas. This study was undertaken for suggesting strategies to climate change impact on irrigated crops based on projected change in crop water requirement and groundwater availability for irrigation in the National Capital Territory of Delhi. Prevailing groundwater recharge in the study area during monsoon was 4.01 MCM (Million cubic meter). The same for various scenarios varied from -15.47 MCM to 5.08 MCM. It was revealed that groundwater recharge would increase if it is estimated based on the climate prediction done using local weather data. The impact of climate change on groundwater availability is evident in scenarios based on INCCA and IPCC predictions where it varied from -2.66 MCM to 1.02 MCM. Contrary to common perceptions, crop water requirement of prevailing cropping system would not increase in future if all the important climatic parameters are considered for its prediction. This may be due to the fact that effect of increase in temperature on crop water requirement may be compensated by decrease in other climatic parameters such wind speed and duration of daily sunshine hours. Results indicated that climate change may not have much impact on sustainability of prevailing cropping system as per the crop water requirement is concerned. Based on water requirement and groundwater availability under various climate change scenarios, appropriate strategies to cope up the climate change impact on irrigated crops have been suggested.

Keywords: Coping strategies, Crop water requirement, Cropping system, Groundwater availability

INTRODUCTION

It is reported that the global as well as the regional climate is changing due to increased concentration of greenhouse gases in the atmosphere (IPCC, 2007). The important parameters which control the climate of a region are temperature, rainfall, relative humidity, wind velocity, duration of sunshine hours and amount of solar radiation reaching the earth surface. Trenberth *et al.* (2007) reported that the global mean surface temperature increased by 0.74° C ± 0.18° C during the period of 1906-2005. According to IPCC (2007) global mean air surface temperature would be increased by 1.4 to 5.8° C by the end of 2100 under different emission scenarios.

Climate change is expected to influence the hydrologic cycle which would result in change in evapotranspiration, precipitation and its distribution, change in soil moisture status etc. (IPCC, 2007). A numerous investigators reported that in event of climate change, irrigated agriculture would be severely affected due to increased crop water requirement and decreased water resources availability especially in the arid and semi-arid regions of worlds including India (Mahmood, 1997; Goyal, 2004; De Silva *et al*, 2007; INCCA, 2010: Shahid, 2011). The crop water requirement is further expected to increase due to increase in cropped area to meet the increasing food demand of people. However, there are also contradictory reports on impact of climate change on crop water requirement (Yano et al., 2007). Shahid (2011) reported that the irrigation requirement of *Boro* rice will increase by 0.8 mm day^{-1} in northwest Bangladesh. According to Doria and Madramootoo (2009), irrigation water requirement of vegetable crops would increase by 40–100% and that of potatoes by 80% in southern Quebec province of Canada. A case study on impacts of climate change on paddy irrigation water requirements conducted in Sri Lanka suggest that the potential evapotranspiration of paddy increased by 3.5 % to 5.0 % and consequently the water requirement increased by 23 % and 13 % (De Silva *et al*, 2007). Tung and Haith (1998) evaluated the impact of climate change on irrigated corn in arid zone of Rajasthan and found that 1% increase in temperature from base period might increase evapotranspiration by 15 mm, which would require 34.275 MCM of additional water for irrigation. Doll (2002) conducted a global analysis of the impact of climate change and climate variability on

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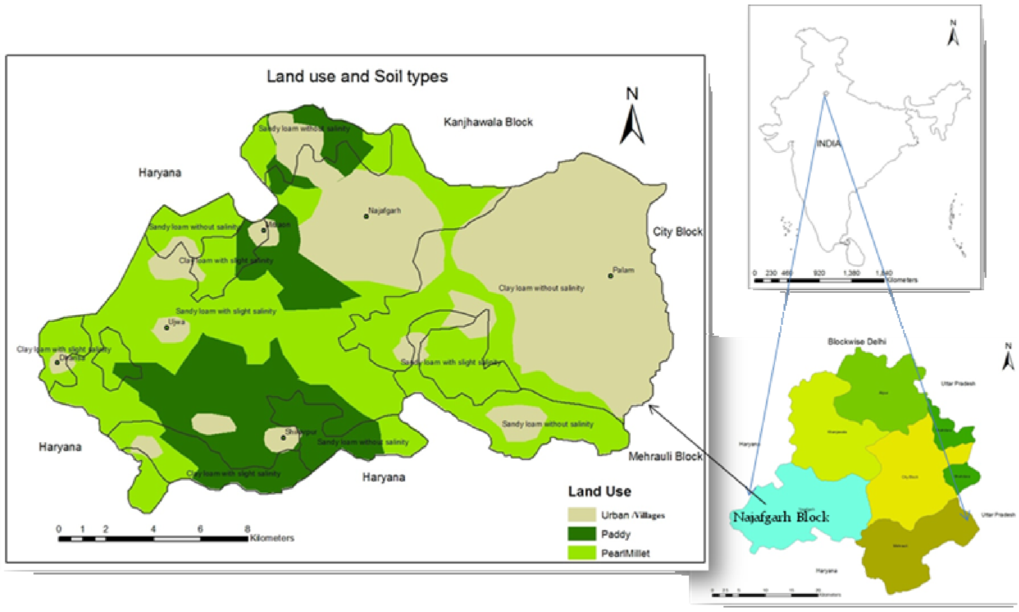

Fig. 1. *Location of the Najafgarh Block in the National Capital Territory Delhi.*

irrigation water requirements and reported that irrigation requirement in two-thirds of the global area having irrigation facilities would increase.

Contrary to above reviews, several investigators (Yano et al 2007; Chattopadhay and Hulme, 1997; Peterson and Keller, 1990) had suggested that there would not be any increase in crop water requirement as a result of climate change. Yano *et al,* (2007) reported that actual evapotranspiration (ETa) from wheat cropland would decrease by 28 and 8% during 2070 and 2079, respectively and ET_a and irrigation water requirements in 2070 and 2079 for maize crop would decrease respectively by 24 and 15 % and 28 and 22 %. Chattopadhay and Hulme (1997) reported that both pan evaporation and evapotranspiration decreased during the period of 1961 to 1992 in various regions of India. The coping strategies for climate change impacts on irrigated crops must consider the changes in water requirement and water availability for irrigation. Numerous strategies and technology have been suggested to cope with the impact of climate change on crop water requirement and water resource availability (Kabat et al 2003). These include efficient utilisation of water resources, efficient irrigation methods, land leveling, zero tillage, direct seeded rice, system of rice intensification, crop diversification, conservation agriculture, appropriate irrigation scheduling, improved weather forecasting, use of drought tolerant varieties, site specific soil and water conservation structures, rainwater harvesting, desalinisation of brackish water, reuse of waste water and improved agronomic practices etc. (Kabat et al 2003). The applicability of these techniques for coping the impacts of climate change needs to be modified in view of climate variability and change at a particular region.

The present study was undertaken to suggest the coping strategies for climate change impacts on irrigated crops based on projected changes in crop water requirement and groundwater availability in National Capital Region (NCR) of India.

MATERIALS AND METHODS

Study area: The study was carried out for the agriculturally dominant Najafgarh Block under South West District of National Capital Territory (NCT), Delhi. It is located between 28° 30¢ 10¢¢ to 28° 39¢ 30¢¢ N latitude and 76° 51¢ 45¢¢ to 77° 6¢ 15¢¢ E longitude in the National Capital Region (NCR) of India which falls under semi-arid region (Fig. 1). Najafgarh Block dominated by agriculture was selected for investigating the impact of climate change on crop water requirement and groundwater recharge. The study area is about 20064 ha. The major crops of the study area are rice, pearl millet, maize and pigeon pea during *kharif* season and wheat and mustard for *rabi* season. The area under the each crop is presented in Table 1.

Methodology: To evaluate the impact of climate change on crop water requirement, a total nine climatic change scenarios based on local weather data (one scenario), Indian Network for Climate Change Assessment (INCCA) (2 scenarios), and Inter-Governmental Panel for Climate Change (IPCC) (6 scenarios) predictions were considered. On other hand, a total twelve climate change scenarios were considered for analysis in the impacts of climate change on groundwater recharge and its availability. Out of twelve, seven scenarios pertaining to varying level of groundwater pumping and recharge. The level of groundwater pumping was decided based on the prevailing rate of pumping in the study area which was estimated to be 0.4946 m y^{-1}.

The scenarios considered for assessing impact of climate change on crop water requirement were: First scenario of predictions for 2030s using local weather data with increase in average air temperature by 0.26 ^{0}C and relative humidity by 4% and decrease in wind speed 5.15 (km day^{-1}) and sunshine hours by 0.26 h. Scenario 2 and 3 for increase in average air temperature by 1.7 °C and 2.0 °C respectively as predicted by INCCA in the 2030s. Scenario 4, 5,6,7,8 and 9 presented as predictions given by IPCC for 2100s increase in average temperature by 1.1 °C, 1.4 °C, 2.9 °C, 3.8 °C, 5.4 °C and 6.4 °C respectively. Scenarios considered for assessment of Groundwater recharge were: Scenario 1 considered as the recharge based on predictions of climatic parameters for 2030s using local weather data. Recharge based on IPCC predictions an average air temperature rise by 1.1 °C and 6.4 °C for 2100s was considered in scenario 2 and 3 respectively. Recharge based on INCCA predictions for 2030s for average temperature rise by 1.7°C and 2.0 °C in scenario 4 and 5 respectively. Natural recharge of the year 2005 have increased by 10 %, 20 %, 30 %, 40 %, and 50 % for the scenario 6, 7, 8, 9 and 10 respectively in the prevailing pumping and decreased by 5 % and 10 % for scenario 11 and 12 respectively. Scenarios 6- 12 are based on anticipated increase or decrease in groundwater pumping due to increase or decrease in demand. Scenarios 11 and 12 were also considered to evaluate the impact of additional water supply from other sources or equivalent increase in recharge through artificial means such as rainwater harvesting for groundwater recharge.

Climate change scenarios were generated by the ARIMA model for 2030s using local weather data, which includes average air temperature, relative humidity, sunshine hours, wind speed and rainfall. The ARIMA predictions for 2030s, IPCC predictions for 2100 and INCCA predictions for 2030s were used to evaluate the impact of climate change on crop water requirement using CROPWAT model of FAO. Crops namely rice, pearl millet, pigeon pea (*arhar*), maize, wheat and mustard grown usually in the region were considered for evaluating the impacts on crop water requirement. Assessment of impacts of climate change on groundwater recharge and its availability for irrigation was done using HYDRUS-1D and MODFLOW software. Groundwater recharge rate and total recharge in the study area were predicted for various climate change, recharge and pumping rate scenarios. The crop water requirements of cropping systems practiced in NCR were also estimated under all assumed scenarios. Based on the predicted water table fluctuation under various scenarios, the total groundwater recharges in the study area were also estimated to evaluate the impact of climate change on groundwater availability for irrigation purpose.

RESULTS AND DISCUSSION

Crop water requirement: Crop water requirement of selected crops were estimated using CROPWAT software and presented in Tables1and 2. The water requirement of rice and pearl millet was estimated to 19.61 and 22.1 MCM, respectively (Table 1). Water requirement of these two crops under other scenarios except the scenario 1 is higher than the reference scenario. This indicates that there is no impact of climate change on water requirement, if it is estimated using local weather data. This can be supported by the findings of Chattopadhay and Hulme (1997) who reported that both pan evaporation and evapotranspiration decreased during the period of 1961 to 1992 in various regions of India. Similar observations were also made by Peterson et al. (1990). In another study, Yano et al. (2007) reported that actual evapotranspiration (ETa) from wheat cropland would decrease by 28 and 8 % during 2070 and 2079 respectively. The same study suggests that ETa and irrigation water for maize crop would decrease by 24 and 15 % and 28 and 22 % in 2070 and 2079 respectively. In case of scenarios 2 to 9, crop water requirement will be more than the reference scenarios. This is supported by the study of Tung and Haith (1998) who evaluated the impact of climate change on irrigated corn in arid zone of Rajasthan. They reported that 1 % increase in temperature from base period might increase evapotranspiration by 15 mm, which would require 34.275 MCM of additional water for irrigation. They suggested that the irrigation, appropriate selection of planting data and cultivars can be potential management options to reduce the impact of climate change. This worth mentioning that under scenarios 2 to 9, crop water requirement was estimated from rise in temperature only. Effect of other climatic parameters was not considered.

However, it is worth to mention that even at the prevailing pumping condition groundwater table is declining, which can be attributed to other conditions and not merely to climate change. However, results obtained from other scenarios indicated that the crop water requirement would be increasing in future. This is mainly due to the fact that the crop water requirement under different scenarios was estimated using increase

Table 1. Volume of water required by the rice and pearl millet in the study area .

Kharif crops	Area (ha)	Total volume of water (MCM)									
		Scenarios									
		Ref	1	2	3	4	5	6	7	8	9
Rice	4161	19.61	19.17	20.4	20.58	20.15	20.30	21.03	21.50	22.30	22.84
Pearl millet	8379	22.10	21.14	23.3	23.18	22.70	22.87	23.69	24.22	25.14	25.74

Table 2. Volume of water required of the different crops grown in NCR under various climate change scenarios.

Crops	Volume of water required (m^3/ha)									
	Scenarios									
	Ref	1	2	3	4	5	6	7	8	9
Wheat	1924	1849	2033	2050	1995	2015	2111	2167	2278	2348
Mustard	1830	1688	1856	1873	1831	1840	1928	1980	2082	2146
Maize	3835	3722	3999	4027	3942	3972	4117	4209	4372	4477
Rice	4712.81	4607.07	4902.67	4945.93	4842.59	4878.63	5054.07	5167.03	5359.29	5489.07
Pearl millet	2637.55	2522.97	2780.76	2766.44	2709.15	2729.44	2827.31	2890.56	3000.36	3071.97
Pigeon pea	3432	3334	3579	3604	3528	3554	3685	3768	3915	4010

in air temperature only. In such cases, pearl millet could be and an alternate crop to be grown as it requires less water.

Water requirement of wheat, mustard, maize and pigeon pea were 1920, 1830, 3835 and 3432 m^3/ha respectively. For these crops also water requirement is higher in all scenarios except scenario 1 (Table 2). In case of scenario 1 the water requirement is not increasing event of climate change. However, if water requirement increases due to climate change as found in case of IPCC and INCCA predictions, pearl millet and maize can be alternate crops during k*h*arif and mustard would be alternate to wheat in *rabi*.

The crop water requirement of important cropping systems includes rice-wheat, rice-mustard, pearl millet -wheat, pearl millet- mustard, maize- wheat, maize- mustard, pigeon pea-mustard and pigeon pea-wheat practiced in this region under various climate change scenarios are presented in Table 3 Water requirement was found to be the highest (783.6 mm) for the rice–wheat cropping system and lowest (421.1 mm) for the pearl millet- mustard under all scenarios (Table 3). Results also indicated that crop water requirement under scenario 1 was lower than the reference scenario. This implies that crop water requirement of prevailing cropping system would not increase in future, if all the important climatic parameters are considered for its prediction. It can be supported by study conducted by Parekh and Prajapati (2013) on impact of climate change on crop water requirement in Sukhi reservoir project area in Gujrat state and they found that crop water requirement of Rabi crops (Wheat, Sorghum, Maize, Small Vegetables, Tomato, Gram and Cowpeas) shows negligible decrease in crop water requirement. However, estimations based on INCCA and IPCC predictions, crop water requirement would be increase for all the cropping systems (scenarios 2-9). It is clear that effect of climate change/climate variability on crop water requirement depends on the number of climatic parameters used in its estimation. It can be interpreted that sustainability of important cropping systems of region namely rice-wheat will depend on water available for irrigation and increase in crop water requirement due to intensification of agriculture including alteration in planting/sowing dates. This

Table 3. Water requirement for different cropping systems of in the NCR under various climate change scenarios.

Cropping systems	Crop water requirement (mm)									
	Scenarios									
	Ref	1	2	3	4	5	6	7	8	9
Rice-wheat	663.7	645.7	694.5	699.5	683.8	689.4	716.4	733.3	763.8	783.6
Rice-mustard	654.3	629.6	676.8	681.8	667.4	671.9	698.1	714.6	744.2	763.4
Pearl millet- wheat	456.1	437.2	478.1	481.7	470.4	474.4	493.8	505.7	527.8	542.0
Pearl millet- mustard	446.7	421.1	460.4	464.0	454.0	456.9	475.5	487.0	508.2	521.8
Maize-wheat	575.9	557.1	603.2	607.7	593.7	598.7	622.8	637.6	665.0	682.5
Maize-mustard	566.5	541.0	585.5	590.0	577.3	581.2	604.5	618.9	645.4	662.3
Pigeon pea-wheat	535.6	518.3	561.2	565.4	552.3	556.9	579.6	593.5	619.3	635.8
Pigeon pea-mustard	526.2	502.2	543.5	547.7	535.9	539.4	561.3	574.8	599.7	615.6

Table 4. Groundwater recharge during monsoon season under various climate change scenarios.

Scenarios	Water table fluctuations between pre and post monsoon (m)	Recharge area (ha)	Groundwater re-charge (ha. m)	Groundwater recharge (MCM)
Reference	0.12	20264	401.07	4.01
scenario 1	0.16	20264	507.93	5.08
Scenario 2	0.03	20264	101.48	1.02
Scenario 3	-0.08	20264	-265.54	-2.66
Scenario 4	0.02	20264	57.06	0.57
Scenario 5	0.02	20264	52.52	0.53
Scenario 6	-0.08	20264	-267.03	-2.67
Scenario 7	-0.18	20264	-596.56	-5.97
Scenario 8	-0.29	20264	-926.07	-9.26
Scenario 9	-0.38	20264	-1237.21	-12.37
Scenario 10	-0.48	20264	-1547.01	-15.47
Scenario 11	0.07	20264	518.75	2.27
Scenario 12	0.12	20264	1037.52	3.92

evident from the fact that at prevailing situations of agriculture intensification, increased water demand in other sectors and reduced groundwater recharge and groundwater levels are declining in several groundwater irrigated areas. It can be supported by Famiglietti (2014) study conducted with NASA and he found that groundwater depletion in northwest India increasing rapidly due increase in population and effect of climate change. Based on the INCCA and IPCC estimates, prevailing cropping pattern in the region have to shift either to pearl millet-mustard or pearl millet –wheat. Other feasible cropping systems may also be selected from the Table 3. Even under present condition also, options presented in Table 3 will be helpful in arresting the decline of water table in the area.

Groundwater recharge: Predicted groundwater recharge during monsoon season under various scenarios is shown in Table 4. Minus sign in the Table 4 indicates that groundwater recharge is less than the pumping. Prevailing groundwater recharge in the study area during monsoon is estimated to be 4.01 MCM. The estimated groundwater recharge at different scenarios varies from -15.47 (scenario 10) to 5.08 MCM (scenario 1) (Table 4). Results indicated that groundwater recharge would be increased, if the estimation is based on the local weather data provided that intensity and pattern of rainfall do not change. Perhaps this is unlikely to happen as the high intensity of short duration rainfall is becoming more pronounced in the region. The increase in groundwater recharge is mainly due to the decreased crop water requirements under scenario 1. The impact of climate change on groundwater recharge is evident in other climate change scenarios which are based on INCCA and IPCC predictions where it varied from -2.66 MCM to 1.02 MCM. Results indicated that volume of predicted groundwater recharge during monsoon season would be vary from -15.47 MCM to -2.67 MCM, if pumping rate will increase in future (scenarios 6 to 10), If the groundwater pumping in the future decreases due to the reason mentioned above as in case of scenario 11, 12, then the groundwater recharge would increase to 5.19 MCM and 10.37 MCM respectively. It is supported by the results presented by Panwar and Chakrapani (2013) and they said the effect of climate change is considered to be worse for semiarid and arid regions, where the recharge will going to reduced and increased under some climate change scenarios. Similar results were observed by Russell et. al. (2013) in the study conducted at high plains aquifer, USA to access potential climate change effects on groundwater recharge.

The suggested strategies for copping the impact of climate change at different scenarios for irrigated crops could be: (1) less water requiring crops such as pearl millet, pigeon pea, maize could be cultivated in place of rice, when crop water requirement crops in the region increases as in case of IPCC and INCCA scenarios, (2) mustard could be e considered as a substitute of wheat, (3) rainwater harvesting and artificial groundwater recharge need to be made mandatory in the study area In addition to these, enhancing water use efficiency through efficient irrigation methods like drip and sprinkler irrigation, appropriate irrigation scheduling, proper land velling, application of marginal quality water, *in situ* moisture conservation measures, zero tillage, direct seeded rice, system of rice intensification, use of drought tolerant and short duration varieties, etc could be other potential strategies for copping the impact of climate change on irrigated crops.

Conclusion

It was concluded that based on the IPCC and INCCA predictions, the rice-wheat cropping system in the study area needs to be replaced with pearl millet-mustard, pigeon pea-mustard, pearl millet -wheat, and pigeon pea-wheat. The estimated ground water recharge in the study area during monsoon was of 4.01 MCM which varied from -15.47 (scenario 10) to 5.08 MCM (scenario 1). The groundwater availability based on INCCA and IPCC predictions ranged between -2.66 and 1.02 MCM. Rainwater harvesting and artificial groundwater recharge need to be made mandatory in the study area for increasing the increased groundwater recharge consequently groundwater availability.

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