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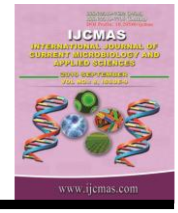

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Simulating Crop Evapotranspiration Response under Different Planting Scenarios for Irrigation Water Management under Climate Change: A Review

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ABSTRACT

Setting up water-saving irrigation strategies is a major challenge farmer's face, in order to adapt to climate change and to improve water-use efficiency in crop productions. However, there is an increasing need to strategize and plan irrigation systems under varied climatic conditions to support efficient irrigation practices while maintaining and improving the sustainability of ground- water systems. To guide the allocation of water resources in the region, it is beneficial to ascertain the effects of changing the crop planting pattern on water saving and farmland water productivity for irrigation water management. Modelling crop evapotranspiration (ET) response to different planting scenarios irrigation water management in a subtropical climate plays significant role in optimizing crop planting patterns, resolving agricultural water scarcity and facilitating the sustainable use of water resources. We evaluated the changes in water savings in irrigation water management projects and resources, the irrigation water productivity and the net income water productivity under different planting scenarios. Crop production can increase if irrigated areas are expanded or irrigation is intensified, but these may increase the rate of environmental degradation. Since climate change impacts on soil water balance will lead to changes of soil evaporation and plant transpiration, consequently, the crop growth period may shorten in the future impacting on water productivity. Crop yields affected by climate change are projected to be different in various areas, in some areas crop yields will increase, and for other areas it will decrease depending on the latitude of the area and irrigation application. Existing modelling results show that an increase in precipitation will increase crop yield, and what is more, crop yield is more sensitive to the precipitation than temperature. If water availability is reduced in the future, soils of high water holding capacity will be better to reduce the impact of drought while maintaining crop yield. With the temperature increasing and precipitation fluctuations, water availability and crop production are likely to decrease in the future. If the irrigated areas are expanded, the total crop production will increase; however, food and environmental quality may degrade. The results indicate that the efficiency of irrigation has increased by 15~20%, while considering drainage, as compared with conventional irrigation efficiency. Additionally, the adjustment of crop planting scenario can reduce regional evapotranspiration by 14.9%, reduce the regional irrigation volume by 30%, and increase the net income of each regional water area by 16%. The irrigation scenario analysis suggested that deficit irrigation is a "silver bullet" water saving strategy that can save 20–60% of water compared to full irrigation scenarios in the conditions of this review study.

Keywords

Water use efficiency; optimization; Climate change impacts; Crop yield

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Introduction

The real challenge of the agricultural sector is to be able of feeding world population that is rapidly growing over time and try to decrease the water usage in the sector. The world's population numbered nearly 7.6 billion as of mid-2017 and this number is projected to increase by slightly more than one billion people over the next years, reaching 8.6 billion in 2030, and to increase further to 9.8 billion in 2050 (UN-Population Division, 2017). Consequently, the food demand will rise by 60% in the same period (Alexandratos and Bruinsma, 2012). Agriculture accounts for roughly 70% of total freshwater withdrawals globally and for over 90% in the majority of least developed countries (FAO, 2011). Without improved efficiency measures, agricultural water consumption is expected to increase by about 20% globally by 2050 (WWAP, 2012) or predicts the world could face a 40% global water deficit by 2030 under a business-as-usual scenario (2030 WRG, 2009).

Due to changing climate and inconsistent precipitation patterns, groundwater is becoming a prominent source of water in arid and semiarid regions of the world (Uddameri *et al.,* 2017). Dwindling groundwater resources pose a threat to global food security (Hanjra and Qureshi, 2010) and adversely impact rural economies worldwide (Wang *et al.,* 2017). Agriculture uses approximately 80% of ground and surface water in the country. Additionally, recent decline in water availability and droughts are becoming critical factors impacting crop yield goals in the India. In recent years, sustainability of groundwater for agricultural production has received substantial attention from the research community along with development of strategies to balance crop production and optimize irrigation water requirements (Guzman *et al.,* 2018). In recent times, it has become important to improve water use efficiency (Dietzel *et al.,* 2016) to sustain the use of groundwater from the aquifer while maintaining crop water productivity (CWP) (Araya *et al.,* 2017). Water resources allocation is an important means to realize effective and reasonable distribution of water resources between different regions and users and to promote the efficient and rational use of water resources (Peng *et al.,* 2017). Several past studies have shown that managing groundwater depletion can be achieved using deficit or limited irrigation methods that decrease irrigation input while maintaining crop production (Lamm *et al.,* 2014).

Global agriculture used about 2,600 km^3 of water each year since the year 2000, i.e. 2% of annual precipitation over land and 17 mm of water spread evenly over the global land surface. This is a +75% increase from 1960 levels and a +400% increase from 1900 levels of irrigation. Out of the world's croplands, 18%, i.e. about 2% of the total land surface are irrigated and produced 40% of the world's food. On average, the irrigated areas receive an addition of 800 mm of water each year (Sacks *et al.,* 2009). About 70% of all water withdrawn worldwide from rivers and aquifers are used for agriculture (Siebert *et al.,* 2013). To estimate the pressure of irrigation on the available water resources, irrigation water requirement and irrigation water withdrawal have to be assessed including strategies for enhancing the water use efficiency (Iglesias *et al.,* 2012). Irrigation water requirement depends on the crop water requirement and the water naturally available to the crops (effective precipitation, soil moisture, etc.). About 2% of the global land area and 17% of the cultivated area, respectively, are irrigated.

The total irrigation amount is greatly affected by the decision on when to initiate the irrigation during the growing season. Among other approaches, measurements or estimates of soil available water and crop water use rates present a more reliable strategy to schedule irrigation for soybean (Rogers 2015) than growth-based scheduling. Irrigation scheduling in this form can be achieved by using either soil water measurement devices or evapotranspiration (ET) -based irrigation scheduling (Ciampitti *et al.,* 2018). Studies have shown that scheduling irrigation for crops by soil water depletion method (30% or 60% of plant available water) uses relatively less water (Ciampitti *et al.,* 2018). The larger the threshold for soil water depletion, the fewer the number of irrigations that were applied. Therefore, a management approach using estimates of soil water content could help to optimize irrigation water use while not reducing crop yields. Given the erratic climate patterns that exist in the THP, the biggest challenge is to optimally implement deficit irrigation strategies without compromising yield and economic returns. Combining short-term field experiments with crop growth models using long-term historic climate data can be a useful tool in identifying suitable irrigation strategies (Kisekka *et al.,* 2016).

Since there are multiple factors that could affect soybean growth and yields for a region, it is imperative that modeling approaches be implemented to strategize irrigation for sustainable use of limited groundwater resources at a regional level. Therefore, this study was designed with an overall goal to identify irrigation management strategies that optimize yield and maximize irrigation water use efficiency (IWUE) while maximizing CWP in the subtropical climatic conditions. However, related studies have focused on (1) the effect of planting structure changes on water requirement and (2) planting structure optimization with limited water resources (Wang *et al.,* 2010). The main objective of this review study were (i) calculating the irrigation efficiency, considering water draining, based on a further simplification of the irrigation efficiency and the definition of the boundary of the spatial scale; (ii) setting up different planting scenario and evaluating the changes in water saving amount, the irrigation water productivity, and the net income water productivity in different scenarios of irrigation water management under subtropical climatic conditions..

Araya *et al.,* (2010) tested AquaCrop for improving crop water use. Ahmadi *et al.,* (2015) reported that the simulated crop growth and soil water content under full and deficit irrigation managements. Greaves and Wang, (2016) evaluated irrigation management strategies for improving agricultural water use in Southern Taiwan. Pawar *et al.,* (2017) used Aqua Crop to improve water productivity of different irrigation strategies in India.

Raes *et al.,* (2011) reported that based on soil water balance and crop growth processes, AquaCrop stimulates crop yields on a daily time step. Its calculation scheme is represented in Fig1a. First, soil water content is calculated by keeping track of a soil water balance through input data. The soil water content is then combined with climatic data and crop parameters to determine canopy development and eventually crop transpiration. Biomass is derived from the transpiration by using the normalized water productivity. Finally, the multiplication result of biomass and harvest index gives the value of crop yield.

Zhang *et al.,* (2013); Linker *et al.,* (2016) reported that in diverse climates, soils, crops, irrigation and field managements to optimise water use for irrigation, there is significant uncertainty in the anticipated results and, often, the alternatives that anticipate higher net returns also have higher risks. AquaCrop model, together with social research, can aid in assisting water managers to optimise a limited supply of irrigation water.

Lamn *et al.,* (2015) reported that the full irrigation scenario, based on a fixed irrigation frequency maintained the soil moisture in the root zone at field capacity on a daily basis, since the literature claims this is the optimal status to maximise yield. The irrigation schedule was generated with a fixed time interval and refill to field capacity (Fig. 1b). Deficit irrigation scenarios with varied field capacity threshold reduce the irrigation dose below the dose at field capacity but keeping the same irrigation frequency, as in full irrigation scenario. Daily generated irrigation doses obtained in full irrigation scenario were reduced by 70, 60, 50, and 40%.

Water productivity is a concept to express the value or benefit derived from the use of water and includes essential aspects of water management such as production for arid and semi-arid regions (Singh *et al.,* 2006). Increasing water productivity means either to produce the same yield with less water resources or to obtain higher crop yields with the same water resources (Zwart and Bastiaanssen, 2004). Bouman, (2007) suggested that just "increasing water productivity" may not solve the dual challenge, so it is necessary to understand the latent mechanism of increased water productivity.

The existing studies show that climate is the single most important determinant of agricultural productivity, basically through its effects on temperature and water regimes (Lal, 2005; Oram, 1989). Climate change impacts on crop water productivity are affected by many uncertain factors (Carter *et al.*, 1999) of which one of the most important factors is the uncertainty in global climate model predictions, especially regarding climate variability. The other factors include soil characteristics such as soil water storage (Eitzinger *et al.,* 2001) long-term condition in soil fertility (Sirotenko *et al.,* 1997) climate variables and enhanced atmospheric CO_2 levels (Amthor, 2001) and the uncertainty of the crop growth model, which is connected with biophysical interactions. Van de Geijn and Goudriaan (1996) also found that positive climate effects on crop growth can be adjusted by effective rooting depth and nutrients; meanwhile, it can improve water productivity by 20–40%.

Khan *et al.*, (2008) presented an approach, combining GIS with groundwater modelling MODFLOW (Modular Three-dimensional Finite-difference Ground-water Flow Model) to enhance water productivity in the Liuyuankou Irrigation Area, China and concluded that the reduction in non-beneficial evapotranspiration can make the extra water be used in other areas, thus improving water productivity. Li and Barker (2004) found that the AWD (alternate wetting and drying) irrigation technique can increase water productivity for paddy irrigation in China. Water productivity concerned with water saving irrigation is dependent on the groundwater level and evapo-transpiration (Govindarajan *et al.*, 2008). Meanwhile, it is inversely related with vapour pressure (Zwart and Bastiaanssen, 2004). Crop water productivity can be increased significantly if irrigation is reduced and the crop water deficit is widely induced. Climate change will influence temperature and rainfall. In the decreased precipitation regions, the irrigation amount will increase for optimal crop growth and production, but this may decrease crop water productivity.

Thomas (2006) studied the effects of climate change on irrigation requirements for crop production in China using a high-resolution (0.25°, monthly time series for temperature, precipitation and potential evapotranspiration) gridded climate data set that specifically allows for the effects of topography on climate was integrated with digital soil data in a GIS.

Future scenarios indicated a varied pattern of generally increasing irrigation demand and an enlargement of the subtropical cropping zone rather than a general northward drift of all zones as predicted by GCM models.

Koch *et al.,* (2011) studied that changing climate conditions in the Jordan River region are likely to have adverse effects on irrigated crop yields and, as a result, increase the demand for irrigation area based on A1B scenario. They applied a regional version of the dynamic land-use change model LandSHIFT to quantify the effect of climate change on the demand for irrigation area needed to maintain a constant production of irrigated crops. Their simulation results showed that climate change may cause an expansion of irrigation area by about 25%, whereas different climate projections only lead to minor variability in the simulated irrigation area demands. By comparison, an increase in crop demand could result in an expansion of irrigation area by about 71%.

Shahid (2011) studied to estimate the change of irrigation water demand in dry-season *Boro* rice field in northwest Bangladesh in the context of global climate change. The study showed that there will be no appreciable changes in total irrigation water requirement due to climate change. However, there will be an increase in daily use of water for irrigation. As groundwater is the main source of irrigation in northwest Bangladesh, higher daily pumping rate in dry season may aggravate the situation of groundwater scarcity in the region.

Long and Huang (2014) studied the impact on irrigation water by climate change in Taoyuan in northern Taiwan. Projected rainfall and temperature during 2046–2065 were adopted from five downscaled general circulation models. Based on a five year return period, the future irrigation requirement was 7.1% more than the present in the first cropping season, but it was insignificantly less (2.1%) than the present in the second cropping season.

The crop yield can be increased with irrigation application and precipitation increase during the crop growth; meanwhile, crop yield is more sensitive to the precipitation than temperature. Ortiz *et al.,* (2008) discussed how wheat can adapt to climate change in Indo-Gangetic Plains for 2050s and suggested that global warming is beneficial for wheat crop production in some regions, but may reduce productivity in critical temperature areas, so it is urgent to develop some heat-tolerant wheat germplasm to mitigate climate change.

Raes *et al.,* (2009) observed that a root zone is viewed as a reservoir; AquaCrop calculates its soil water content per day by means of the soil water balance. Soil water balance is the sum of incoming water fluxes and outgoing water fluxes at the boundaries of the root zone (Fig.2a). The incoming fluxes include rainfall, irrigation and capillary rise. The outgoing fluxes are evapo-transpiration, runoff and deep percolation. It should be noticed that AquaCrop only considers 1D flow. The amount of water stored in the root zone is expressed as an equivalent depth or depletion rate (Dr). Root zone depletion indicates the required water amount to bring the root zone soil water content back to its field capacity (FC). However, when soil water stress occurs, the canopy development and root expansion will be negatively affected, leading to stomata closure, a reduction in crop transpiration and a change in Harvest Index. If this stress is severe, flower pollination can fail, and canopy senescence starts earlier. All of these effects are described in AquaCrop by a water stress coefficient Ks whose value range is from 0 to 1. In particular, the canopy expansion equation is multiplied with Ksexp,w at every simulation step and the reduction in root expansion is determined by the stress response function between root zone depletion and Ks (Fig.2b). This function shape can be either linear or convex. For each of these above processes, there are thresholds for soil water stress. The lower threshold for stomatal closure, senescence and pollination failure are both at PWP while the lower threshold for canopy development is above PWP.

Shrestha *et al.,* (2016) in their study analyzed the impacts of climate change on irrigation water requirement (IWR) and yield for rain fed rice and irrigated paddy, respectively, at Ngamoeyeik Irrigation Project in Myanmar. Climate projections from two General Circulation Models, namely ECHAM5 and HadCM3 were derived for 2020s, 2050s, and 2080s. The climate variables were downscaled to basin level by using Statistical Downscaling Model. The Aqua Crop model was used to simulate the yield and IWR under future climate. The analysis showed a decreasing trend in maximum temperature for three scenarios and three time windows considered; however, an increasing trend was observed for minimum temperature for all cases. The analysis on precipitation also suggested that rainfall in wet season is expected to vary largely from -29 to +21.9% relative to the baseline period. A higher variation was observed for the rainfall in dry season ranging from -42% for 2080s, and +96% in case of 2020s. A decreasing trend of IWR was observed for irrigated paddy under the three scenarios indicating that small irrigation schemes were suitable to meet the requirements. An increasing trend in the yield of rain fed paddy was estimated under climate change demonstrating increased food security in the region.

Kaur *et al.,* (2015) studied the effect of climate change on crop yield, crop duration, water and balance of rice–wheat cropping system using CropSyst model. Model simulations predicted reduction in crop yields in future associated with shortening of growth period due to increased temperature. Yield reduction was more with increase in maximum temperature than minimum; and in finer- than coarser textured soil. Increased rainfall in future would decrease irrigation water requirement of crops but would not offset the adverse effect of increased temperature.

Climate change impacts on crop yield are often integrated with its effects on water productivity and soil water balance. Khan *et al.,* (2009) reviewed water management and crop production for food security in China, who pointed out that it, is necessary to integrate climate, energy, food, environment and population together to discuss future food security in China and in the world as well. This is because climate change has many uncertainties in water management and other water-related issues. Food security is increasingly important for human beings all over the world. Food availability and food quality still are the big challenges for scientists due to changing climate. Food security is always studied with CO_2 effects under changing climate scenarios. Further research on food security needs to integrate population, crop production, climate change and water availability, consequently, to evaluate food security completely and systematically.

Zaveri *et al.,* (2016) observed that groundwater overexploitation has led to drastic declines in groundwater levels, threatening to push this vital resource out of reach for millions of small-scale farmers who are the backbone of India's food security. Historically, losing access to groundwater has decreased agricultural production and increased poverty. However, use short-run random variation in climate in a given area to compare that area's outcomes under different weather conditions after controlling for observed and unobserved characteristics using regional fixed effects, *rd*, and a time fixed effect that further neutralizes any common trends (Fig.3a).

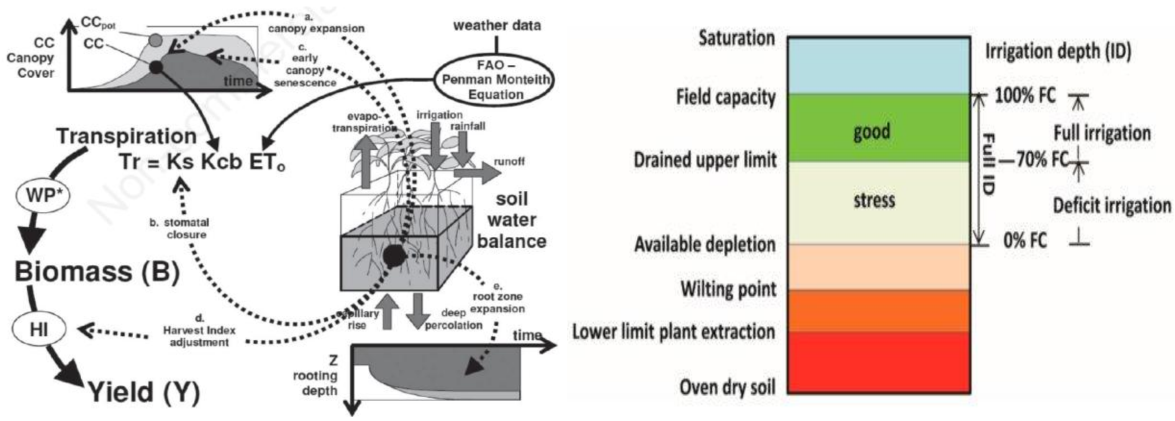
India's northwest region has already experienced significant groundwater level decreases due to UGW use (Rodell *et al.*, 2009). The model projections of future UGW demand to infer how groundwater levels will change up to 2050. If demand increases, then groundwater levels will drop more rapidly (Fig.3b); continued demand will lead to continued rates of groundwater level decline, while reduced but positive demands will slow the rate of groundwater level decline. Some districts will be able to rely solely on sustainable water supplies, allowing groundwater levels to recover (Fig.3b). Under future climate change, most of Punjab and Haryana, northern areas of Rajasthan and Gujarat and parts of Uttar Pradesh and Tamil Nadu will face continued and further groundwater level declines (Fig.3b).

Dar,(2016) reported that the evapotranspiration (ETc) loss forms the major loss of water in water balance components and was computed by the model for both the crops for each year of the observed and future climate. It was found that the average evapotranspiration (ETc) loss (550.3 mm) in baseline would reduce to 541.3 mm (1.64%) in MC and would increase to 592.9mm (7.7%) in EC for rice crop, while as in wheat crop evapotranspiration loss (431.9mm) in baseline would increase to 449.6 mm (4.09%) in MC and 464.7mm (7.6%) in EC (Fig.4a) and evapotranspiration (ETc) loss (550.3 mm) in baseline would increase to 737.7 mm (33.97%) in MC and 802.2 mm (45.76%) in EC respectively for rice crop and for wheat crop evapotranspiration loss of (449 mm) in baseline decreased to 424.3mm (5.5%) in mid-century (MC) and 427 mm (4.9%) in end century (EC) (Fig.4b). It may be due to less increase of overall temperature from baseline in mid-century and significant increase in temperature in the end century for rice crop. But in wheat crop seasonal effects may be contributing to increased trend of evapotranspiration in these three time periods as local weather conditions are important because evapotranspiration (ET) is driven by weather factors that determine the drying power of the air. ET can be accurately predicted in a given area from the measurements of four local weather variables of solar radiation, temperature, humidity and wind. Moreover, its observed for wheat crop that in end century (EC) the evapotranspiration loss was more than mid-century (MC) which may be due to increasing humidity and higher CO_2 concentrations whereby both tend to reduce transpiration and counteract the higher temperature effects on ET (Snyder *et al.*, 2011). Maurer *et al.*, (2008) revealed that the influence of variation in climatic parameters (Temperature, Wind direction, and humidity) on the irrigation water requirement on temporal scale, climate crop water requirement (CCWR) integrated framework (Fig.5a). Moreover, the irrigation requirement for various crops in the command area has been estimated using the irrigation demand estimation module (Fig.5b). The data required for irrigation demand estimation module area) the precipitation that has occurred, b) prevailing climate variables (wind speed, relative humidity, maximum and minimum temperature, and sunshine hours), c) cropping pattern (time of sowing, harvest), and d) type of soil (field capacity, moisture content). It can be observed that the module begins with an estimation of excess rainfall for the rainfall that has occurred in the command area. The process is followed by estimation of the crop water requirement of the available crop types in the study area. In this research the crop water requirement for the type of crop and cropping pattern has been estimated using CROPWAT package.

Table.1 Crop output values in Qingyuan Irrigation District [Source: Liu et al. 2015].

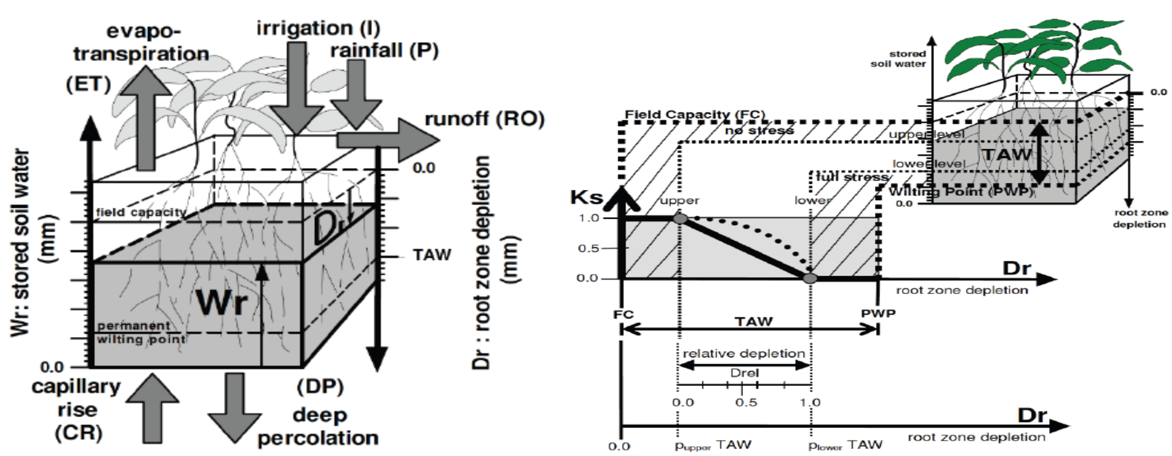
Crop	Yield (kg/ hm²)	Unit price (yuan/kg)	Unit input value (yuan/ hm²)	Unit output value (yuan/ hm²)	Cultivated area (hm²)			Total net output value (10^5 yuan)		
					Current Situation	Scenario 1	Scenario 2	Current Situation	Scenario 1	Scenario 2
Spring wheat	6510	2.1	9525	4146	9357.2	4678.6	9357.2	38.79	19.40	38.79
Summer maize	9900	2.0	13610	6190	7017.9	7017.9	2222.3	43.44	43.44	13.76
Potato	33110	0.8	10800	15688	2807.2	1169.7	3930.0	44.04	18.35	61.65
Soybean	2100	3.2	5400	1320	701.8	2339.3	1169.7	0.93	3.09	1.54
Beet	31500	0.5	10500	5250	1169.7	1169.7	1169.7	6.14	6.14	6.14
Chili	18750	1.1	16500	4125	2339.3	2339.3	3228.3	9.65	9.65	13.32
Watermelon	34872	0.6	12750	8173.2	0	4678.6	2315.9	0	38.24	18.93
Total	-	-	-	-	23393.1	23393.1	23393.1	142.99	138.31	154.13

Fig.1(a) Calculation scheme of AquaCrop with indication of the processes affected by water stress. [Source:Raes *et al.*, 2011]. **Fig.1(b)** Schematic illustration of the soil water reservoir concepts of varied irrigation depth under field capacity irrigation scenarios [Source: Lamn *et al.*, 2015]



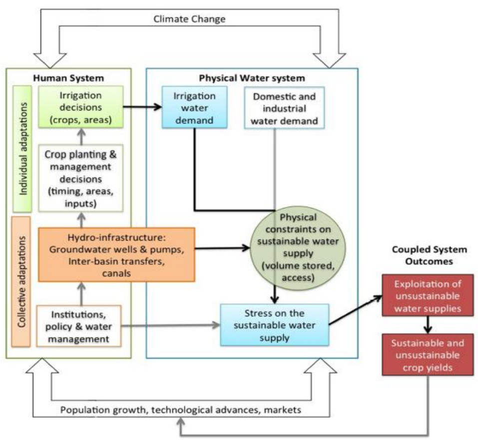
(a) **(b)**

Fig.2(a) Root zone as a reservoir [Source: Raes et al., 2009]. **Fig.2(b)** Water stress coefficient as a function of root zone depletion



(a) (b)

Fig.3(a) Conceptual framework for coupled human-physical water system modeling of India's groundwater future. **Fig.3(b)** Trends in district-level ground water levels (GWL) between 1979–2000 and 2029–2050, inferred from the multi-model mean of changing need for unsustainable groundwater (UGW) to meet irrigation water needs.



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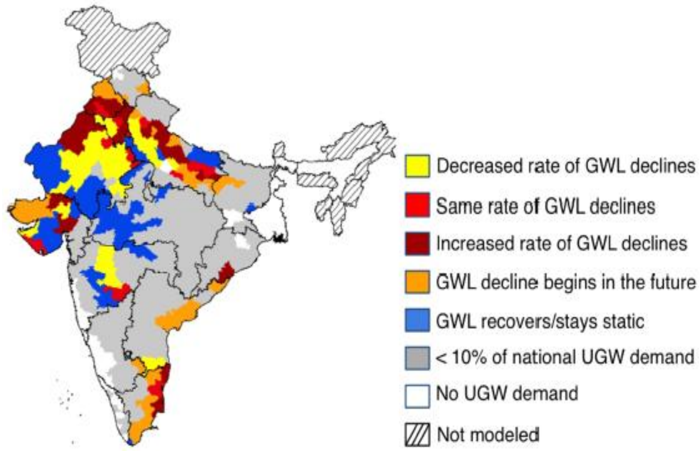
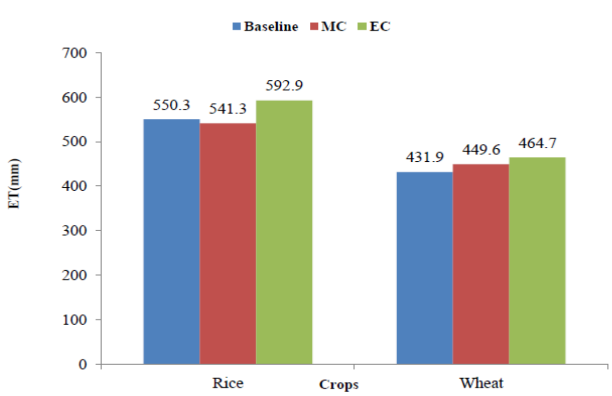


(b)

Fig.4(a) Average evapotranspiration for rice and wheat crop in baseline, MC and EC for Ludhiana under RCP 4.5. **Fig.4(b)** Average evapotranspiration for rice and wheat crop in baseline, MC and EC for Ludhiana under RCP 8.5



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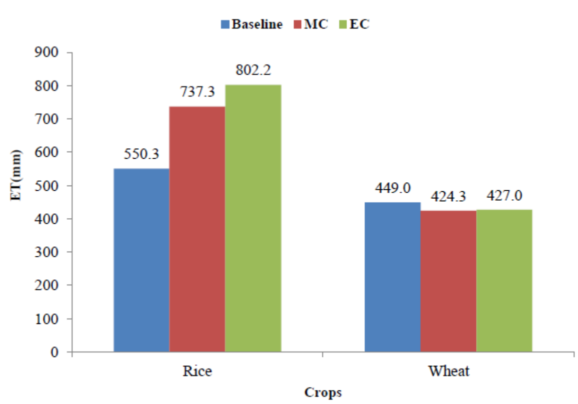


(b)

Fig.5(a) Climate crop water requirement (CCWR) Framework. **Fig.5(b)** Irrigation Demand Estimation Module

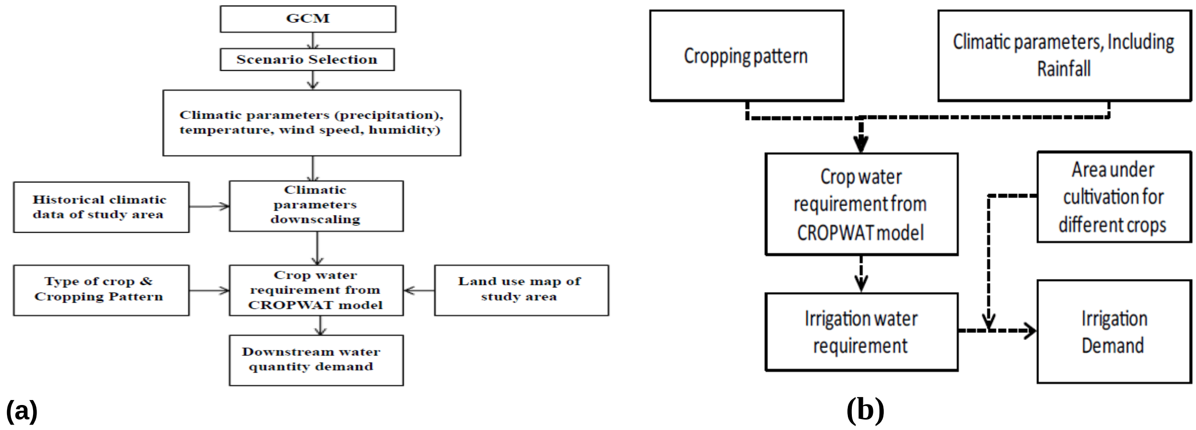


Fig.6(a) Average Irrigation requirements for rice and wheat crop in baseline, MC and EC for Ludhiana under RCP 4.5. **Fig.6(b)** Average Irrigation requirements for rice and wheat crop in baseline, MC and EC for Ludhiana under RCP 8.5

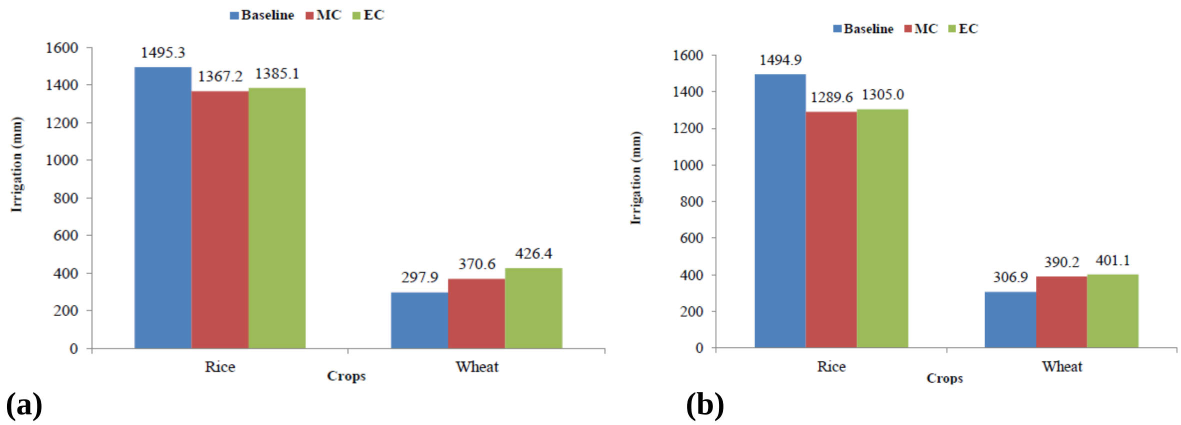
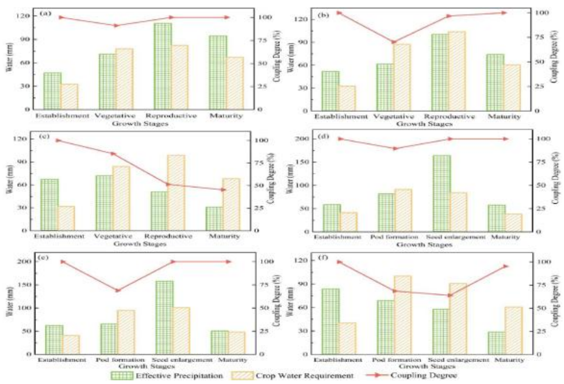
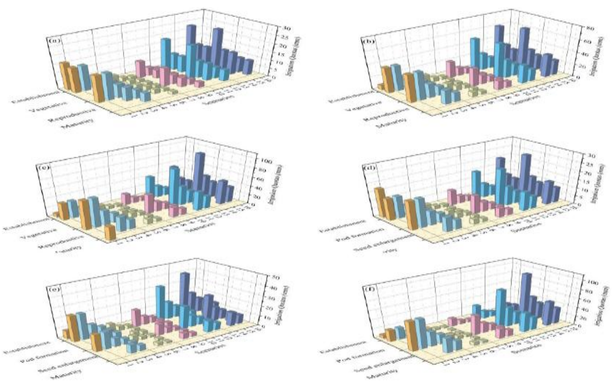


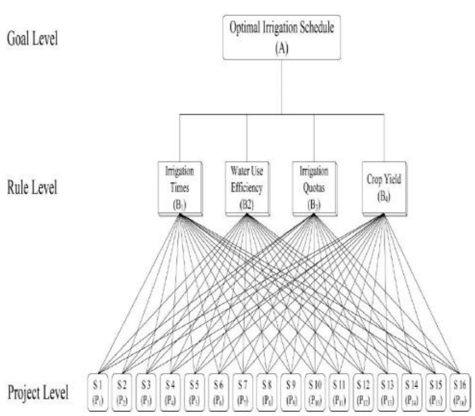
Fig.7(a) Coupling degree between Pe and ETc. (a) corn wet year, (b) corn normal year, (c) corn dry year, (d) soybean wet year, (e) soybean normal year, (f) soybean dry year. **Fig.7(b)** Irrigation scenarios. (a) corn wet year, (b) corn normal year, (c) corn dry year, (d) soybean wet year, (e) soybean normal year, (f) soybean dry year.

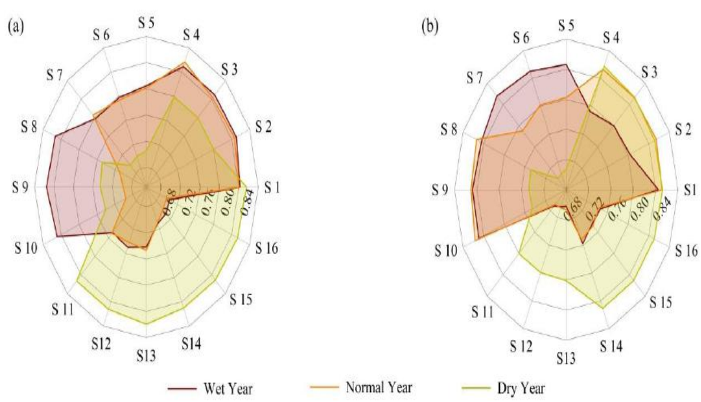




(a) **(b)**

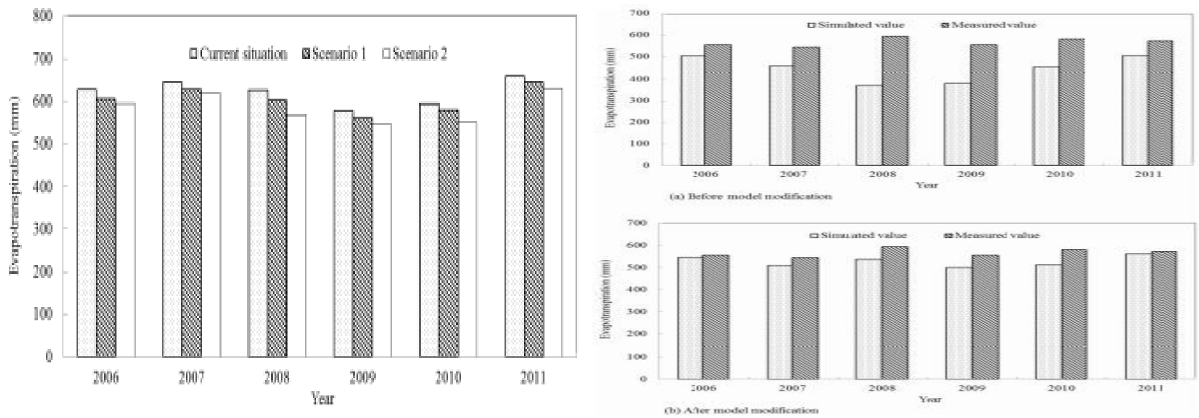
Fig.8(a) Hierarchy diagram. **Fig.8(b)** Absolute correlation degree. (a) corn, (b) soybean





(a) **(b)**

Fig.9(a) Crop evapotranspiration responses to different planting scenarios spring wheat (scenario 1) and summer maize (scenario 2) [Source: Liu et al. 2015]. **Fig.9(b)** Simulated and measured values of summer maize annual evapotranspiration in the verification period.



(a) **(b)**

Dar (2016) also found that for rice crop that the annual water requirement would reduce to 1367.2 mm (8.6%) in MC and 1385.1 mm (7.4%) in EC from the 1495.3 mm in the baseline (Fig 6a). In wheat crop the annual irrigation water requirements would increase to 370.6 mm (24.4%) in MC and 426.4 mm (43.1%) in EC from the irrigation requirement of 297.9 mm in the baseline. Moreover, for rice crop that the annual water requirement would reduce to 1289.6 mm (13.7%) in MC and 1305 mm (12.7%) in EC from the 1494.9 mm in the baseline (Fig 6b). In wheat crop the annual irrigation water requirements would increase to 390.2 mm (27.1%) in MC and 401.1mm (30.6%) in EC from the irrigation requirement of 306.9 mm in the baseline.

The annual irrigation requirement would decrease by 8.6% in MC and 7.4% in EC for rice crop and in wheat it would increase to 24.4% and 43.1%, respectively under RCP 4.5, while under RCP 8.5 the annual irrigation requirement would decrease by 13.73% in MC and 12.70% in EC for rice crop and in wheat it would increase to 27.14% and 30.69%, respectively. Similarly evapotranspiration in MC would reduce by 1.6% and would increase by 7.7% in EC for rice crop and would increase by 4.09% and 7.6% in wheat crop for MC and EC time periods, respectively under RCP 4.5. In RCP 8.5, evapotranspiration in MC would increase by 33.9% and in EC by 45.7% in rice crop and would reduce by 5.49% and 4.90% in wheat crop for MC and EC time periods, respectively which are not similar to the results found by Kaur *et al.,* (2012),due to different model used, having different boundary conditions.

Fu *et al.,* (2019) also showed that the key growth stages of corn and soybean were vegetative, reproductive and pod formation, seed enlargement. Deficit treatments were beneficial to improving crop yield and WUE. The optimal schedules were: the corn was irrigated with four times in key growth stages, and the irrigation quota was 21 mm; irrigation occurred six times in both normal and dry year, with quotas of 84 mm and 134 mm, respectively; the soybean was filled with six times in key growth stages, and the irrigation quotas were 10 mm, 28 mm and 89 mm in wet, normal and dry year, respectively (Fig.7a). The P_e generically increased first then decreased. The coupling degree between P_e and ET_c was first reduced and then increased. However, the scenario with the same column color indicated that the total irrigation quota was the same during entire development stage. The number of columns in the same irrigation scenario represented the irrigation times, and the column height indicated the irrigation quota of the crop at each growth stage (Fig.7b).

Shin *et al.,* (2009) reported that the irrigation schedule a comprehensive evaluation model of three levels was established by the AHP (Fig.8a).The first layer was the target layer, which was the optimal irrigation schedule. The second layer was the criterion layer, including irrigation times B1, WUE B2, irrigation quotas B3 and crop yield B4. The third layer was the scheme layer, including 16 different irrigation scenarios. The target layer was composed of one element, while the criterion layer and the scheme layer were composed of multiple elements. Each element of the same layer had different influences on the upper layer.

Payero *et al.,* (2008) believed that water consumption decreased with decreasing irrigation. A certain range of water stress can significantly improve the WUE of corn. Under the same irrigation quota, more irrigation times will lead to an increase in crop yield and WUE (Fig.8b). However, with the increase in irrigation times, the irrigation schedule may not perform optimally, and the WUE may show a downward trend. One of the important reasons for this change is that with increasing irrigation times, the water consumption of soil evaporation increases (Zhang, 2018). In addition, more irrigation times will bring causes several inconveniences in terms of production and life.

Liu *et al.,* (2015) observed that the modelling of crop evapotranspiration (ET) response to different planting scenarios in an irrigation district plays a significant role in optimizing crop planting patterns, resolving agricultural water scarcity and facilitating the sustainable use of water resources SWAT model incorporating the improved evapotranspiration module (FAO–56 dual crop coefficient method). He indicated that crop evapotranspiration decreased by 2.94% and 6.01% under the scenarios of reducing the planting proportion of spring wheat (scenario 1) and summer maize (scenario 2) by keeping the total cultivated area unchanged in Fig 9. However, the total net output values presented an opposite trend under different scenarios. The values decreased by 3.28% under scenario 1, while it increased by 7.79% under scenario 2, compared with the current situation in Table 1.

The review paper studies show that it is reasonable to expect that regional implications of climate change will affect evapotranspiration as an important aspect in crop cultivation. Ground water availability for irrigation allows, under the given conditions, a short-term buffering towards extremes. Based on the scenario calculations, it can be expected that the current agricultural practice in the county of India will not be directly limited by regional climatic alterations. However, in the more distant future, where climate change is on the one side to become more pronounced and more uncertain to be predicted on the other side, additional measures might be necessary to prevent higher frequencies of crop failures in some years. Changes in irrigation techniques or adaptation of crop rotation types are amongst these measures. Crop evapotranspiration decreased by reducing the planting pro- portion of high water consumption crops and adjusting the proportion of economic crop cultivated areas under the condition of total cultivated area remaining unchanged. However, the total net output values presented an opposite trend by cutting down the planting proportion of upward and down-ward compared with the current situation.

The review study is reasonable to expect that regional implications of global climate change will affect evapotranspiration as an important aspect in crop cultivation. Ground water availability for irrigation allows, under the given conditions, a short-term buffering towards extremes. Based on the scenario calculations, it can be expected that the current agricultural practice in the county of India will not be directly limited by regional climatic alterations. However, in the more distant future, where climate change is on the one side to become more pronounced and more uncertain to be predicted on the other side, additional measures might be necessary to prevent higher frequencies of crop failures in some years. Changes in irrigation techniques or adaptation of crop rotation types are amongst these measures. Since soil climate is expected to change significantly even in North West India, ‘more attention should be paid to studying the impacts of climate change on soil climate’ i.e. soil temperature and hydric soil regimes.

Simulation results can better reflect the evapotranspiration and growth of crops, so it can be used to simulate the water cycle process and analyse the irrigation efficiency of irrigation areas. When considering the irrigation efficiency of drainage, the actual water consumption in the irrigated area was more accurately reflected as compared with the conventional irrigation efficiency, and the irrigation efficiency was improved by 15–20%. The adjustment of crop planting structure can change crop water requirement and economic output. Planting crops with low water consumption and high economic benefits can effectively reduce regional evapotranspiration by 14.9%, regional irrigation by 30% and net income by 16%. In general it can be used to evaluate the impact of planting scenario change on crop evapotranspiration in the irrigation water management under climate change which plays a significant role in optimizing crop planting, resolving the water resource crises and reducing ecological deterioration.

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