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RESEARCH ARTICLE

IMPACT OF CLIMATIC PARAMETERS ON CROP WATER REQUIREMENTS IN DIFFERENT AGRO ECOLOGICAL ZONES OF PAKISTAN

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ABSTRACT

The problem of climate change has become very strongly during last two decades on global scale in view of the projected consequences on the environment of unguarded states. Gradually rising temperature and its effects on the crops here and rainfall are obvious in many areas around the world. Climate change related to natural and anthropogenic processes in Pakistan is the major source of study in this report. The impacts of these climate changes appear to be additional component of the large number of existing water related problems in every station of Pakistan. The objective of this report is to analyze the global warming effect on CWR. For this purpose, we made seven scenarios So, S1, S2, S3, S4, S5 and S6. From So-S3 crop water requirement increases in all regions but from S4-S6 crop water requirement remains same. For this purpose we selected different cities from agro ecological stations to check the effect of climate change on CWR. Faisalabad, Gupis, Jacobabad, Kalat, Karachi, Multan, Nawabshah, Peshawar and Zhob are the regions selected for this research. Different scenarios have been made such that, in So scenario temperature remains same but from S1, S2 and S3 scenarios temperature is increases 1, 2 and 3 degree centigrade respectively. While, in S4, S5 and S6 scenarios precipitation increases or decreases according to the climatic changes of that area (So, S1, S2, S3,) and then we increase or decrease the precipitation rate by 5%, 10% and 15% (S4, S5, S6) in accordance with the zone. From result it is concluded that the crop water requirement in arid and in semiarid is increasing annually on the other hand the total value of effective rainfall in Pakistan is decreasing.

KEYWORDS

Climate change, Crop Water Requirement, Irrigation Water Requirement, Effective Rainfall, Agro Ecological Zones of Pakistan.

1. Introduction

Impact of climate change has now been recognized as a thought-provoking threat to the humanity. It has strongly effect the whole world during last two decades as the most warmer than the preceding (Qin et al., 2013). The greenhouse gases (GHGs) concentrations which includes carbon dioxide, nitrous oxide and methane have increased 40% since pre-industrial times which cause to change climate (Hegerl et al., 2003, Trenberth, et al., 2004). Changes in the total amount of precipitation and in its frequency and intensity directly affect the magnitude and timing of runoff and the intensity of floods and droughts (IPCC, 2007). As a consequence of climatic changes, a significant impact on hydrological parameters like runoff, evapo-transpiration, soil moisture, ground water etc. is expected (Bultot et al., 1988).

Agriculture is much sensitive towards changing climate and showed negative impacts as experienced during droughts, floods and intense storms (Parry et al., 2007). The most important points which influence the CWR or ET is the total dependency upon climate parameters. Any moderate change in these parameters can also affect ET or crop water demand (Houerou and Le-Houerou, 1993). Temperature is more significant aspect in CWR different crops specially wheat at top latitudes (PARC, 1982).

Pakistan is an agricultural country and 70% of its population depends on agriculture. Agricultural products are directly or indirectly depending on climatic parameters such as moisture of soil, temperature of the soil, temperature of air, humidity, muddiness, rainfall, smog etc. Major component of the climate changes was spatial shifts in the rainfall patterns, associated with fluctuations in the general circulation of the atmosphere. Changes in rainfall pattern directly affect water, agriculture and disaster management sectors. The temperature of Pakistan is increasing per year and mostly crops require more irrigation because evapotranspiration rate is high and water is lost from the soil and plants. As the crop water requirement increases, the irrigation requirement also increases because crop needs more water to sustain life. It is very difficult to meet the requirements of crop by irrigation because of limited resources (Rodo, 2003).

Two third area of Pakistan lies in arid region and evapotranspiration rate is already high and water table is shallow, there is an increase in air temperature which may cause loss of water swiftly and as a result the aridity of soil would increase. If the evapotranspiration rate continues to increase then our water reservoirs would dry more quickly and we will face water scarcity (Chaudhry and Rasul, 2004). When crop water requirement will increase due to increase in temperature, more water should be obtainable to meet the crop water requirement (PARC, 1982).

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2. METHODOLOGY

To measure the crop water requirement using Penman-Monteith method climatic data (precipitation, minimum and maximum temperature, wind speed, sun shine hours and relatively humidity) is required. Temperature of air is considered the most important climatic factor that directly influences the evaporation and evapotranspiration. Climatic data is taken from CLIMWAT 2.0 data base and this is connected with CROPWAT 8.0. for calculating water requirements of plants and also irrigation scheduling. Detail of two software used in this study is describe below:

2.1 CLIMWAT (2.0)

CLIMWAT is a climatic catalog that is used in arrangement with the computer software CROPWAT. Figure 1 shows the widow of CLIMWAT 2.0 software representing the 25 station of Pakistan. It allows the calculation of CWR, supply of irrigation and irrigation scheduling for various crops and it provides the 5000 climatic stations all over the worldwide. CLIMWAT provides monthly mean values of 7 following climatic factors which are necessary to calculate CWR.

- Mean every day maximum temperature (°C)
- ➤ Mean every day minimum temperature in (°C)
- Mean relative humidity (%)
- Mean speed of wind (km/day)
- Mean sunshine (hours per day)
- Mean solar radiations (MJ/m²/day)
- Monthly rainfall (mm/month)
- Reference ET_o calculated with Penman-Monteith method (mm/day)

Climatic data of selected stations (9) had been exported from the CLIMWAT 2.0 software and crop water requirement and irrigation requirement were calculated under seven scenarios to check the effect of

climate change on crop water demand and irrigation at those stations of Pakistan.

2.2 Study Area

Nine stations (Faisalabad, Hyderabad, Jacobabad, Kalat, Karachi, Multan, Nawabshah, Peshawar, Zhob, and Sargodha) had been selected for the study showed in Figure 2 which cover the whole climate (dry, semi-arid, arid and humid) of Pakistan.

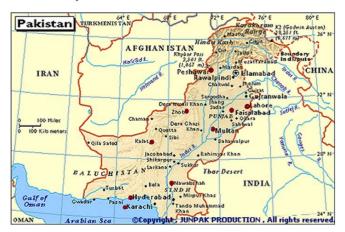


Figure 1: Selected stations of Pakistan for study area

2.3 Climate and Geography of Selected Area

Pakistan lies in temperate region of the globe and has all seasons (spring, summer, autumn, winter) in its geography. The geographic location and temperature condition of the selected stations are given in Table 1 also showing the correlation of station with agro-ecological zones of Pakistan.

Table 1: Nine Stations of Agro Ecological Zones of Pakistan						
Stations	Agro-Ecological Zones	Elevation (m)	Latitude	Longitude	Min. Temp (°C)	Max. Temp (°C)
Faisalabad	Northern Irrigated Plains	184	31.4292° N	73.0789° E	-4	48
Multan	Northern Irrigated Plains	215	30.1978° N	71.4697° E	-1	54
Peshawar	Northern Irrigated Plains	359	34.0167° N	71.5833° E	-3.9	48
Hyderabad	Indus Delta	505	25.3792° N	68.3683° E	3.0	48.5
Jacobabad	Southern Irrigated Plains	59	28.2769° N	68.4514° E	-1.1	51.1
Zhob	Western Dry Mountains	1426	31.3500° N	69.4500° E	12	26.5
Kalat	Western Dry Mountains	2018	29.03° N	66.58° E	3.7	22.3
Karachi	Western Dry Mountains	8	24.8600° N	67.0100° E	0	47.8
Nawabshah	Sandy Deserts	38	26.2500° N	68.4167° E	-3.6	51

2.4 Crop Selected

Wheat and maize are two crops selected for this research because of their gross growth in Pakistan. At present wheat is grown on an area of 9042 thousand hectares and total wheat production of the country is 23million tons with an average yield of 2714 kg ha⁻¹ (GOP, 2012). On the other hand life cycle of maize crop depends much upon water availability, the water deficit at any phonological stage i.e. vegetative, reproductive and maturity stages have different response and can damage the grain yield (Cakir, 2004). Drought due to intense climate change is harmful for crop growth and development of both crops. More CWR or less availability of water also damages the grain yield when it occurs at reproductive stage of crop's life cycle (Heisey and Edmeades, 1999).

2.5 Climatic Scenarios

To analyze the effect of climate change on crop water demand seven scenarios were made. First scenario (So) represents the normal condition of weather, next three scenarios S1, S2,S3 there is 1, 2, 3 degree centigrade rise in mean monthly temperature and in remaining scenarios S4,S5,S6 shows 5%, 10%,15% decrease or increase in mean annual precipitation respectively according to future rainfall predictions in study area (Salma et al., 2012).

Table 2: Climatic Scenarios					
So	Normal conditions				
S ₁	Scenario 1	T+1			
S2	Scenario 2	T+2			
S3	Scenario 3	T+3			
S4	Scenario 4	P+5% / P-5%			
S5	Scenario 5	P+10% / P-10%			
S6	Scenario 6	P+15% / P-15%			

3. RESULTS AND DISCUSSIONS

Crop water requirements of under designed scenarios were calculated using CROPWAT model and graphical representation of CWR on each station were discussed under change in climatic parameters on wheat and maize crops.

3.1 CWR and IWR of wheat crop in Sindh Province

Hyderabad, Jacobabad, Karachi and Nawabshah are the selected regions of Sindh province. Figure 4 shows the CWR, IWR and also effective rainfall of each region under different climatic scenarios. In some regions CWR for wheat crop is more than other regions.

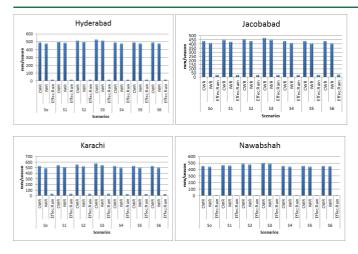


Figure 2: Crop water, irrigation water requirements of wheat crop in 4 cities (Hyderabad, Jacobabad, Karachi and Nawabshah) under seven scenarios

According to IPCC future projection in Hyderabad, Jacobabad, Karachi and Nawabshah the overall rainfall will be decrease that is why rainfall scenarios show decreasing trend in these areas (Salma et al., 2012). In Figure 4 from S1-S3 in Hyderabad crop water requirement of wheat is increasing from 490mm to 520mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement almost remain constant. Similarly in Jacobabad, Nawabshah and Karachifrom S1-S3, crop water requirement showed increasing trend from 435mm to 470mm, 450mm to 500mm and520mm to 580mm respectively but in case of S4-S6 the irrigation water requirements become more due to less precipitation trend in all 4 cities.

3.2 CWR, IWR and Effective rainfall of maize crop in Sindh province

Hyderabad, Jacobabad, Karachi and Nawabshah are the selected regions of Sindh province for maize crop in which CWR, IWR and effective rainfall of each region is find out. In some regions CWR for maize crop is more than other regions.

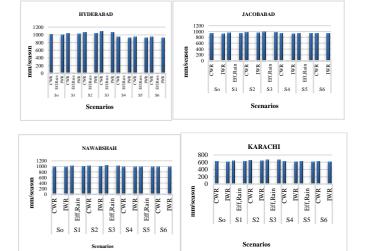


Figure 3: Regions for maize crop in Sindh

In Hyderabad CWR decreases, from S1-S3 , crop water requirement is increasing from 1020mm to 1100mm, but in case of S4-S6(decrease in precipitation rate) the crop water requirement decreased and its value reached at 1020mm.In Jacobabad CWR decreases from S1-S3 , crop water requirement is increasing from 950mm to 1000mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement decreased and its value reached at 950mm. In Nawabshah, CWR decreases from S1-S3 , crop water requirement is increasing from 1000mm to 1040mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement decreased and its value reached at 1000mm.In Karachi CWR decrease from S1-S3 , crop water requirement is increasing from 620mm to 680mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement decreased and its value reached at 620mm (Salma et al., 2012).

$3.3\,$ $\,$ CWR, IWR and Effective rainfall of wheat crop in Baluchistan province

Kalat and Zhob are the regions selected in the Baluchistan province. In Kalat region CWR for wheat crop is more than that of the CWR in Zhob as shown below.

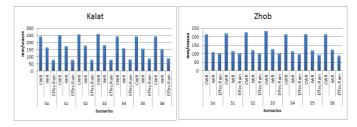


Figure 4: Regions for wheat crop in Baluchistan

In Kalat CWR decreases from S1-S3, crop water requirement is increasing from 240mm to 260mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement decreased and its value reached at 240mm. In Zhob CWR decreases (Salma et al., 2012). We conclude that in Zhob from S1-S3, crop water requirement is increasing from 210mm to 240mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement decreased and its value reached at 240mm.

3.4 CWR, IWR and Effective rainfall of maize crop in Baluchistan province

Kalat and Zhob are the regions selected in the Baluchistan province. In Kalat region CWR for maize crop is more than that of the CWR in Zhob as shown below.

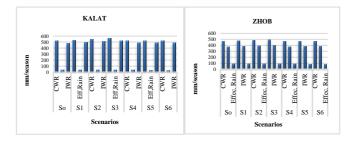


Figure 5: Regions for maize crop in Baluchistan

In Kalat, CWR decreases from S1-S3, crop water requirement is increasing from 520mm to 580mm, but in case of S4-S6(decrease in precipitation rate) the crop water requirement decreased and its value reached at 520mm (Salma et al., 2012). In Zhob, CWR decreases crop water requirement is increasing from 480mm to 500mm, but in case of S4-S6(decrease in precipitation rate) the crop water requirement decreased and its value reached at 480mm.

$3.5\,$ CWR, IWR and Effective rainfall of wheat crop in Punjab province

Faisalabad and Multan are the regions selected in the Punjab province. In Multan region CWR for wheat crop is more than that of the CWR in Faisalabad as shown below.

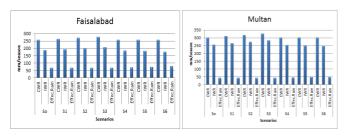


Figure 6: Regions for wheat crop in Punjab

In Faisalabad CWR decreases (Salma et al., 2012). In figure 16, from S1-S3, crop water requirement is increasing from 260mm to 280mm, but in case of S4-S6(decrease in precipitation rate) the crop water requirement decreased and its value reached at 260mm. In Multan CWR decreases (Salma et al., 2012). In figure 17, from S1-S3, crop water requirement is increasing from 300mm to 330mm, but in case of S4-S6 (decrease in

precipitation rate) the crop water requirement decreased and its value reached at 330mm.

3.6 CWR, IWR and Effective rainfall of maize crop in Punjab province

Faisalabad and Multan are the regions selected in the Punjab province. In Multan region CWR for maize crop is more than that of the CWR in Faisalabad as shown below.



Figure 7: Regions for maize crop in Punjab

In Lyallpur CWR decreases from S1-S3, crop water requirement is increasing from 600mm to 640mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement decreased and its value reached at 600mm (Salma et al., 2012). In Multan CWR decreases crop water requirement is increasing from 750mm to 800mm, but in case of S4-S6 (decrease in precipitation rate) the crop water requirement decreased and its value reached at 750mm.

3.7 CWR, IWR and Effective rainfall of wheat crop in Khyber Pakhtunkhwa province

Peshawar is the region selected in the Khyber Pakhtunkhwa province. In Peshawar, CWR for wheat crop increases and effective rainfall also increases.

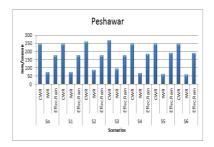


Figure 8: Regions for wheat crop in KPK

In Peshawar CWR increases from S1-S3, crop water requirement is increasing from 240mm to 260mm, but in case of S4-S6 (increase in precipitation rate) the crop water requirement decreased and its value reached at 240mm (Salma et al., 2012).

3.8 CWR, IWR and Effective rainfall of maize crop in Khyber Pakhtunkhwa province

Peshawar is the region selected in the Khyber Pakhtunkhwa province. In Peshawar, CWR for maize crop increases and effective rainfall also increases.

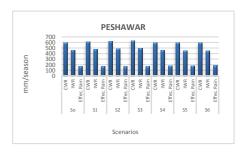


Figure 9: Regions for maize crop in KPK

In Peshawar CWR increases (Salma et al., 2012) from S1-S3, crop water requirement is increasing from 600mm to 640mm, but in case of S4-S6(decrease in precipitation rate) the crop water requirement decreased and its value reached at 600mm.

4. CONCLUSIONS

From the above discussion we conclude that the rainfall and temperature variation occurs in every station all over the Pakistan. The decreasing trend is due to the arid and semi-arid area. In general the rainfall and temperature trend increases in northern areas like Peshawar, Skardu, Gilgit etc and decreases in western areas like Multan, Faisalabad.In future the rate of precipitation is increasing in humid areas but unfortunately rainfall intensity is decreasing annually due to this reason the crop water requirement is increasing rapidly. Furthermore, the trend observed in rainfall data for the whole country is (-3.55mm) in two-time intervals and per decade it became (-1.18mm) which are found in consistent with the IPCC report. From the present study it is concluded that change in the rainfall pattern and prolonged droughts will pose severe risks to agriculture and water management sectors. Therefore, the present study will be useful to detect the changes in the rainfall pattern as a baseline data for future research work in fields of hydrology, agriculture and disaster risk management. In general, the Crop water requirement in Arid and in Semi-arid is increasing annually on the other hand the total value of effective rainfall in Pakistan is decreasing.

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