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Assessment of precipitation deficit using cropwat

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■ **ABSTRACT :** Precipitation deficit of wan river basin was assessed using CROPWAT. It also cleared that more or less the effective rainfall was constant around 600 mm over entire basin. Soil moisture deficit decreased from Wari Bhairavgarh to Khatkali *i.e.* from low to high altitude. There was no precipitation deficit in case of soybean crop whereas it was observed maximum for pigeon pea followed by cotton. Daily soil moisture deficit analysis confirmed that readily soil moisture is available though less than field capacity, to satisfy ETc need of plants up to last decade of September. Thus, two protective irrigations should required during the month of October-November for maintaining optimal growing conditions in the basin.

■ **KEY WORDS :** Cropwat, Precipitation deficit, Pigeaonpea, Cotton, Wan river basin

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Shortage of water for domestic, industry and agriculture use is a cause of concern throughout the world, specially in developing and under developed countries. India has been well endowed with large freshwater reserves, but the increasing population and over exploitation of surface and groundwater over the past few decades has resulted in water scarcity in some regions. However, increasing urbanization and per-capita demand, the water demands of domestic, industrial and other sectors are expected to increase and become highly competitive with the agricultural sector. Agriculture, being the major water user, its share in the total freshwater demand is bound to decrease from the present 83 per cent to 68 per cent due to more pressing and competing demands from other sectors by 2050 AD (GOI, 2013), and the country will face water scarcity if adequate and sustainable water management initiatives are not implemented on substantial scale.

India is a country of diverse agro-ecosystems and cropping preferences. Indian agriculture dominated by rainfed agriculture that accounts 68 per cent of the total net sown area (136.8 million hectare) spread over 177 districts. Rainfed crops account for 48 per cent of the total area under food crops and 68 per cent under non-food crops (Musuku, 2014). There is a need to double annual foodgrain production from about 246 million tonnes (2013) to 420 million tonnes by 2050. Since land is a shrinking resource for agriculture, the pathway for achieving this goal has to be higher productivity per unit of arable land and water (Swaminathan, 2006 and GOI, 2006). Water stress at a particular crop growth stage results adversely in yield (Allen *et al.*, 1998 and Doorenbos and Kassam, 1979). Thus there is a need to use decision support system for determination of precipitation deficit and thereby protective irrigation planning.

CROPWAT is a decision support system developed by Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements and crop irrigation requirements. It allows the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation (Marica, 2002; Diro and Tilahun, 2009; Abdalla *et al.*, 2010; Adeniran *et al.*, 2010; Arku *et al.*, 2012 and Admasu *et al.*, 2014).

Wan river forms the part of northwest boundary of Akola district of Maharashtra State of India, after entering from Amravati district. It rises in the Gawilgarh hills of eastern Satpura range in Amravati district of Maharashtra state and flows southward, draining Amravati, Akola and Buldhana region before emptying into the Purna river in Buldhana district of Maharashta but basin of wan river experienced water scarcity every year and the crop yield also get affected. Considering this fact the study aimed to assess the precipitation deficit of wan river basin using CROPWAT.

■ METHODOLOGY

The basin of wan river is spread over 173.65 km^2 in Melghat Tiger Reserve Project in Satpura ranges, Amravati district of Maharashtra state.

Data collection :

Meteorological data :

Rainfall, evaporation, minimum and maximum temperature data observed at four stations *viz.*, Wari Bhairavgarh, Wan Road Station, Kelpani and Khatkali, in basin area was obtained for the period from 2000 to 2013. The average annual rainfall of basin is 1013 mm. Average daily maximum temperature varies between 28.3 and 44.7 °C. It was found maximum during the month of May, while lowest during the month of January.

Land use land cover pattern :

The detail spatial 'land use land cover (LULC)' map for command was obtained from MRSAC, Nagpur. Area under different land use pattern is presented in Table A. The data indicates that, the major area is under forest (91.50 %) followed by agriculture (6.56 %). Cropping pattern details were obtained from Department of Agriculture, Maharashtra State. Table B presents area under different crops in basin.

The data regarding crop co-efficients and rooting depth of various crops in command was referred from available numerous literature.

CROPWAT model set up :

CROPWAT is a powerful simulation tool which analyzes complex relationships of on farm parameters such as the crop, climate, and soil, for assisting in irrigation management and planning. CROPWAT is one of the models extensively used in the field of water management throughout the world. CROPWAT model is comprised of eight modules *viz.*, Climate/ETo, Rain, Crop, Soil, CWR, Schedule, Crop Pattern and Scheme (FAO Water, 2015).

Climate/ETo module :

This module calculates evapotranspiration using Penman-Monteith method (Allen *et al.*, 1998). The module estimate evapotranspiration based only on temperature data. CROPWAT 8.0 estimate the values for the other climatic data (humidity, wind speed, sunshine hours) based on the temperature and altitude/latitude data,

Table A : Area under different land use pattern in command

Sr. No.	Land use pattern	Area, km^2	Percentage
1.	Agriculture	11.39	6.56
2.	Forest	158.88	91.50
3.	Built up area	0.36	0.21
4.	Wastelands	0.49	0.28
5.	Water bodies	2.53	1.45
Total		173.65	100.00

Table B: Area under different crops in command

Sr. No.	Crops	Total sown area, km^2	Per cent of sown area
1.	Cotton	5.01	43.99
2.	Soybean	3.98	34.94
3.	Pigeonpea	2.40	21.07

as required by Penman-Monteith method.

Rain module :

Rain module is primary for data input of precipitation values on a monthly, decade or daily basis. This module also calculates 'Effective Rainfall' using USDA Soil Conservation Service Formula developed by USCS, using following formulae.

Monthly step :

Peff = Pmonth * (125 - 0.2 * Pmonth) / 125 for Pmonth $\leq$= 250 mm

Peff =125 + 0.1 * Pmonth for Pmonth > 250 mm

Decade step :

Peff(dec) = Pdec * (125 - 0.6 * Pdec)) / 125 for Pdec $\leq$= (250/3) mm

Peff(dec) = (125 / 3) + 0.1 * Pdec for Pdec > (250 / 3) mm

Crop module :

Crop module is essentially for crop data input over different stages of crop development. This crop module essentially requires parameters as planting date, crop co-efficient (Kc), crop stages, rooting depth, critical depletion fraction (p), maximum crop height and yield response factor (Ky).

Soil module :

Soil (non-rice crop) module essentially requires the parameters *viz.*, total available water (TAW), maximum infiltration rate, maximum rooting depth and initial soil moisture depletion. This module also includes calculations, providing the Initial available soil moisture.

CWR (Crop water requirement) module :

Crop water requirement module estimates precipitation deficit or irrigation water requirement of the crop on a decade basis and over the total growing season, as the difference between the crop evapotranspiration under standard conditions (ETc) and the effective rainfall. Precipitation deficit or irrigation requirement indicatively represents the fraction of crop water requirements that needs to be satisfied through irrigation contributions in order to guarantee to the crop optimal growing conditions.

Schedule module :

Schedule module estimates soil water balance on a daily step. This allows to develop indicative irrigation schedules to improve water management; evaluate the current irrigation practices and their associated crop water productivity; evaluate crop production under rainfed conditions and assess feasibility of supplementary irrigation; and develop alternative water delivery schedules under restricted water supply conditions.

Crop pattern module :

The cropping pattern module is primary data input, requiring information on the crops being part of the scheme. With reference to each crop, the required data is crop file, planting date and area.

Scheme module :

The scheme module calculates irrigation requirement for each crop of the scheme, net scheme irrigation requirement, irrigated area as a percentage of the total area and irrigation requirement for the actual area.

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Rainfall pattern of the basin :

Based on rainfall data, CROPWAT estimated effective rainfall, presented in Table 1, while Fig. 1 depicts month wise rainfall and effective rainfall over entire basin area.

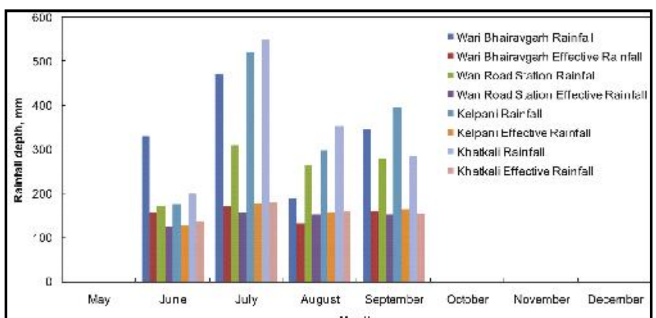


Fig. 1: Month wise rainfall and effective rainfall variation in the wan river basin

Table 1 cleared that maximum rainfall occurs at Khatkali followed by Kelpani, Wari Bhairavgarh and Wan

Road Station. It also cleared that more or less the effective rainfall was constant around 600 mm over entire basin. Fig. 1 cleared that maximum rainfall occurs in the month of July at all observation stations, whereas, minimum rainfall occurred in the month of June.

Crop evapotranspiration :

Variation in crop evapotranspiration over the year in the basin as calculated by CROPWAT model is depicted in Fig. 2.

Fig. 2 clears that crop evapotranspiration (ETc) is less than effective rainfall for all four stations over monsoon months *i.e.* June to second decade of September. Therefore there is no need of irrigation during this period. However, from last decade of September, ETc started increasing due to full vegetative growth of crops. There is almost no rainfall after September, crops survived only on available soil moisture. At the same time due high temperatures of October, ETc further increased. ETc followed similar pattern over entire basin area, as evidenced in the Fig. 2. Therefore, protective irrigation become essential during the month of October and November, otherwise crop yield will be adversely affected.

Table 1 : Rainfall and effective rainfall of basin of wan river

Month	Wari bhairavgarh mm		Wan road station, mm		Kelpani, mm		Khatkali, mm	
	Rainfall	Effective rainfall	Rainfall	Effective rainfall	Rainfall	Effective rainfall	Rainfall	Effective rainfall
May	0	0	0	0	0	0	0	0
June	329	157.9	173	125.1	175	126	199	135.6
July	471	172.1	309	155.9	520	177	549	179.9
August	189	131.8	264	151.4	297	154.7	354	160.4
September	345	159.5	279	152.9	395	164.5	286	153.6
October	0	0	0	0	0	0	0	0
November	0	0	0	0	0	0	0	0
December	0	0	0	0	0	0	0	0
Total	1334	621.3	1025	585.3	1387	622.2	1388	629.5

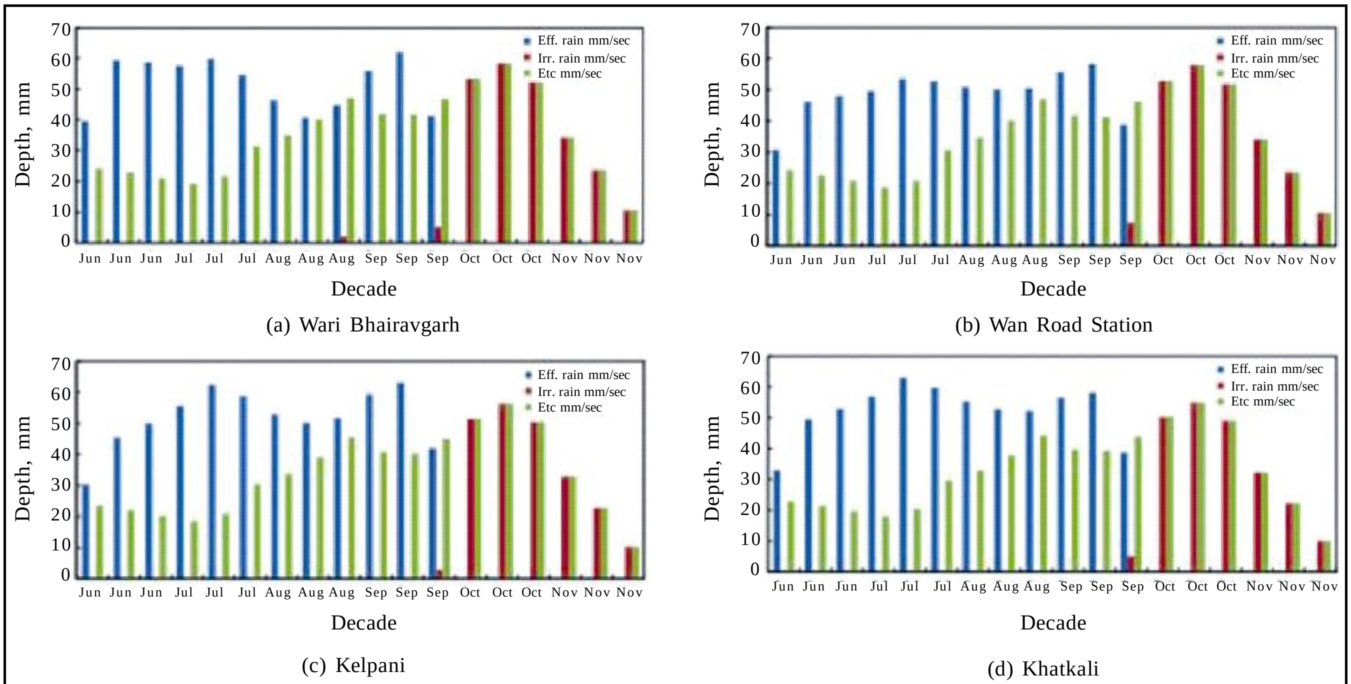
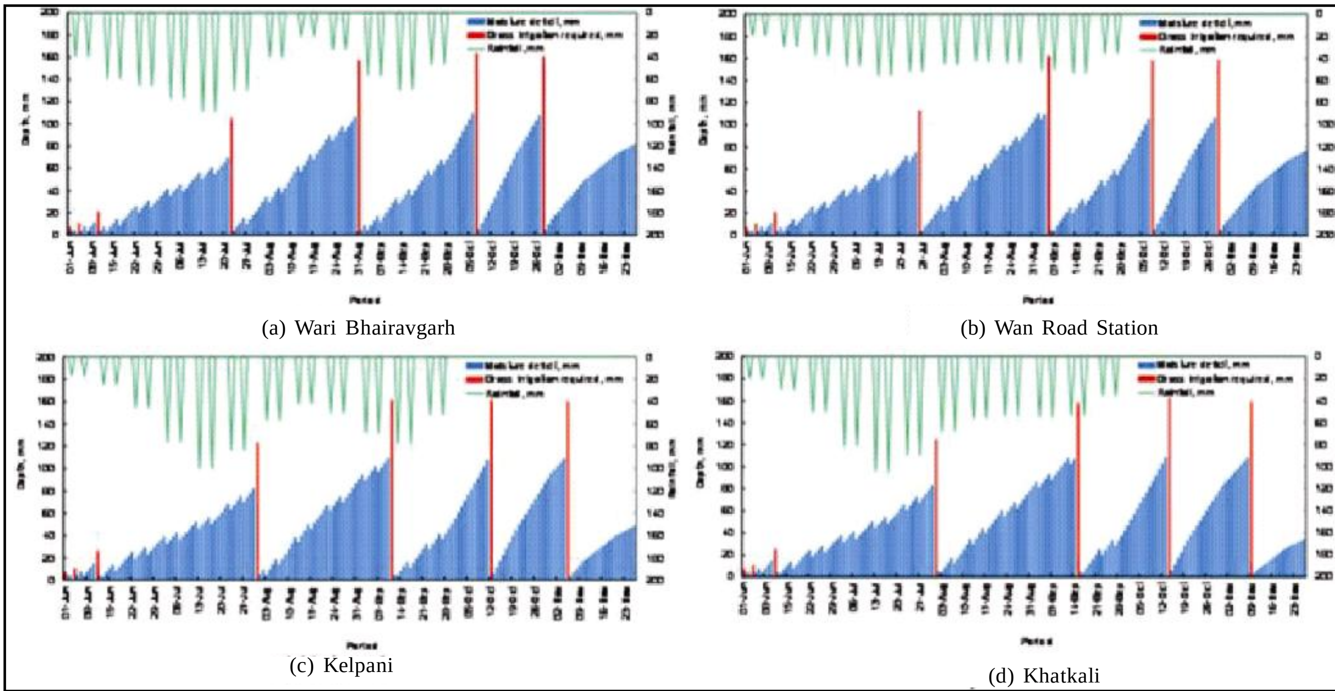


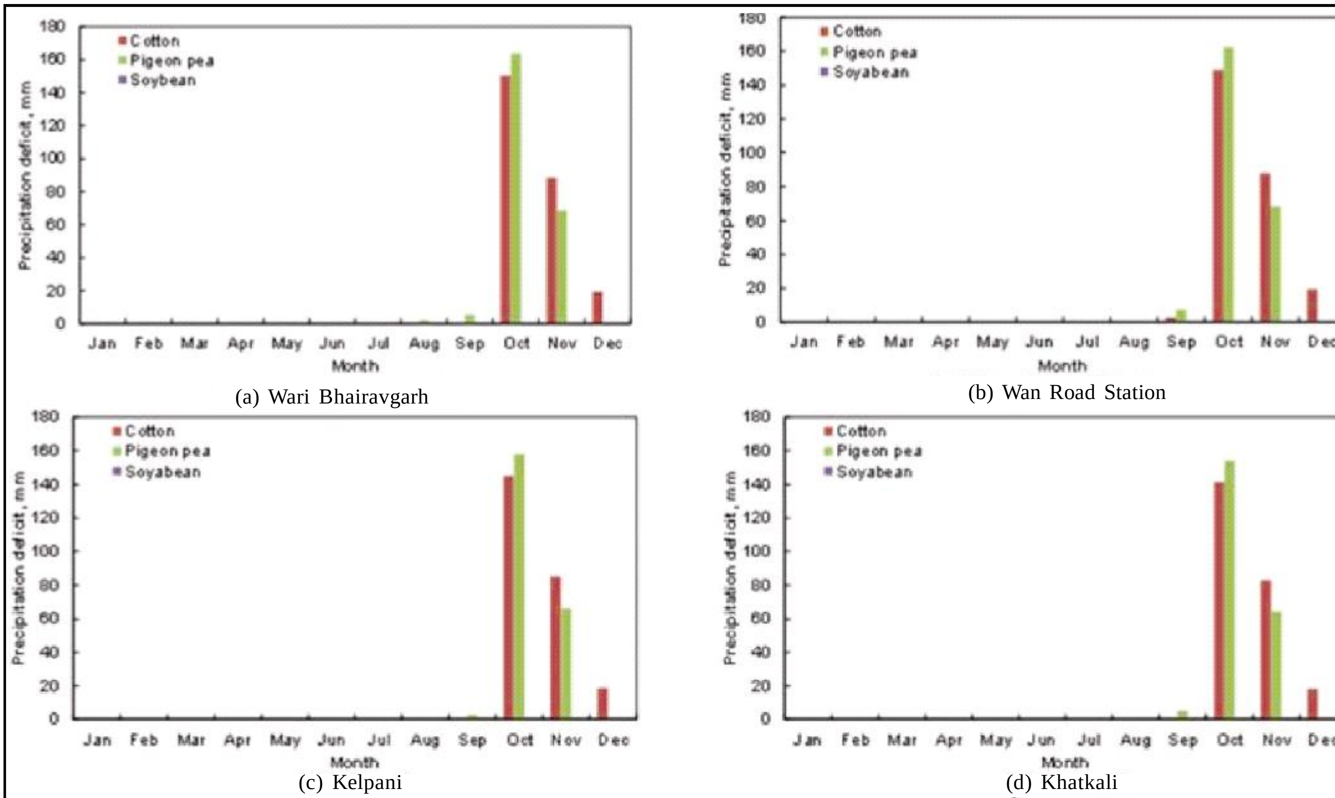
Fig. 2: Variation of ETc over wan river basin



(a) Wari Bhairavgarh (b) Wan Road Station

(c) Kelpani (d) Khatkali

Fig. 3 : Station wise variation of soil moisture deficit



(a) Wari Bhairavgarh (b) Wan Road Station

(c) Kelpani (d) Khatkali

Fig. 4 : Crop wise soil moisture deficit in the basin

Soil water balance for the basin :

Daily soil water balance as given by model in reference to rainfall is depicted in Fig. 3.

Fig. 3 cleared that soil moisture deficit decreased from Wari Bhairavgarh to Khatkali *i.e.* from low to high altitude. It also cleared that in all seven protective irrigations are required in the basin over the crop period. On the contrary, Fig. 2 clears that in all six irrigations are required during September to November, when decadal effective rainfall and ETc were taken into consideration. However, Fig. 3, clears that during monsoon months *i.e.* June to September soil moisture is in readily available zone though less than field capacity. Thus, two protective irrigations become essential during the month of October-November for maintaining optimal growing conditions.

Precipitation for the basin :

Precipitation deficit in respect to crops of basin is depicted in Fig. 4.

It is cleared from Fig. 4 that there was no precipitation deficit in case of soybean crop whereas it was observed maximum for pigeon pea followed by cotton. The precipitation deficit was more or less same over the entire basin as evidenced from Fig. 4.

Conclusion :

Based on daily soil moisture balance study and precipitation deficit estimates, it is suggested to provide at least two irrigations, during the month of October-November, to guarantee crop optimal growing conditions.

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