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Strategies for Water Balance and Deficit in Drought–prone Areas of Jalgaon District (M.S.) India

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Abstract: **The complexity of the water system in the region can be understood by calculating the regional water balance in a distributed scale considering the factors that affect it. Sustainable water management in a drought–prone area requires knowledge of the water availability and water requirements in the present and future for various purposes. Knowledge of the water balance is the basis for the development of agricultural production, crop selection, and determination of cropping pattern (Oldeman and Frere, 1982 in Sujalu, 2000). Water balance is defined as 'the net change in water, taking into account all the inflows to and outflows from a hydrologic system'. The water balance model will be able to assess the water resources, in finding out the moisture deficit and moisture surplus with different temporal and spatial resolutions.**

Analysis of water balance for drought–prone tahsils is done according to Thornthwaite book keeping technique for nine stations for the normal year. There is water surplus from July to October and water deficit from November to May. The study shows that the entire Kharip season is deficit free and during Rabi season the deficit amount is 643.9 mm. The deficit can be mitigated through low cost water harvesting structures, diversion of northern low land water, in situ moisture conservation measures coupled with suitable agronomic practices. Though on an average the study region is under deficit (1072.2 mm), the agro climatic situation of the region is semi–arid (MI = -59.2 %).

Keywords: Drought-prone area, Strategies, Water Balance, Water Deficit, Water Resources, etc.

INTRODUCTION:

Water balance studies have become important in recent years in many countries of the world, because of the increasing demand for fresh water for agricultural production, industrial development and urbanization. The study region includes the drought prone tahsils in Jalgaon district, whose economy depends mainly on agriculture. Thus, for the planning of irrigation schemes, water resource management, and agricultural operations in that drought prone tahsils, it is important to study the components of the water balance, potential evapotranspiration, precipitation, water surplus, and water deficit. This information can be used to help determine if there is water shortage in some parts of the region, or surpluses according to what would be expected under climate change scenarios (greenhouse gas forcing). Knowledge of water balance is necessary to evaluate the possible methods to minimize loss and to maximize gain and utilization of water, which is so often the limiting factor in crop production. The water balance method of determining water deficiency is a powerful tool for irrigation; it not only can indicate when moisture is needed but it also provides information on how much to apply in order to satisfy needs without profligate waste.

In India, where drought and water surplus are two great problems, where water conservation is urgent and the need for irrigation ubiquitous, the water balance method offers a firm basis for appraising the problems in the planning stage and it provides a sound means for determining proper practices on day to day basis. To any form of water, rainfall is the primary source and it is stochastic in nature. The annual rainfall of the study region varies greatly and is not uniformly distributed. Moreover, the areas with high annual rainfall (> 650 mm) and seasonal dry spells experience floods and erosion hazards in agricultural lands, which is of prime concern to soil and water conservation scientists and its programmer planners.

Objectives:

- To study the water balance for the drought prone tahsils.
- To highlight the strategies for combating water deficit in the region.
- To search the geographical background behind the balance and deficit water of the study region.

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Study Area:

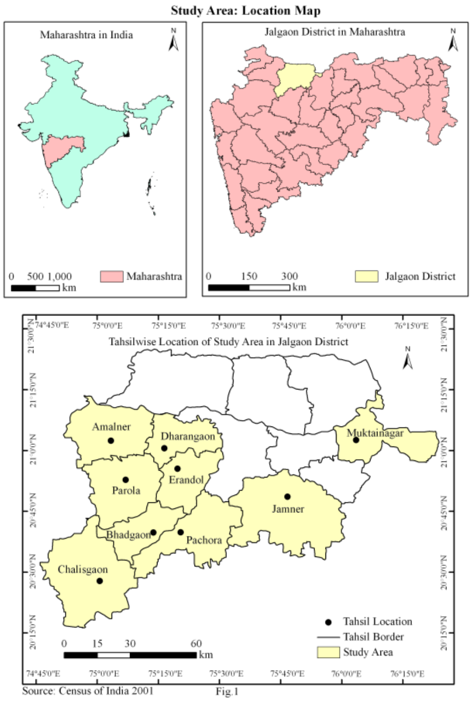

Fig. 1 Location map

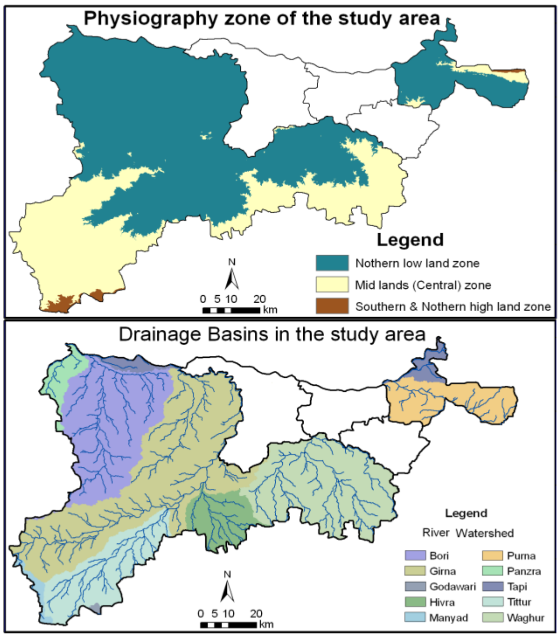

Fig. 2 Physiographic and drainage basin

The region selected for the study is the drought-prone tahsils. They are located in the Jalgaon district of Maharashtra State. There are 09 drought-prone tahsils identified by V. Subramaniam, (Review Committee, 1987). These tahsils are Amalner, Dharangaon, Parola, Erandol, Chalisgaon, Bhadgaon, Pachora, Jamner and Muktainagar. Looking into its delicate ecology and poor socio- economy, the study region is one of the most vulnerable regions of Maharashtra State. The topography of the region is hilly, plateau, undulating and rolling. The degraded soils with exposed rocks resulted from severe erosion is the common landscape. It covers an area of about 6994.54 km^2. It lies between 20^{o}11′ to 21^{o}13′ North latitudes and 74^{o}46′ to 76^{o}24′ East longitudes (Fig.1). Average rainfall is 682.8 mm in the said area. Also, temperature and relative humidity varies 18^{o}C to 35^{o}C and 45% to 72% over the years respectively.

Materials and Methods:

Daily rainfall, Maximum and minimum temperatures data of 31 years (1980-2010) for nine rain-gauge stations are collected from I M D, Pune and HDUG,

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Nasik (Government of Maharashtra Agency). Information regarding soil samples for nine tahsils is collected from Jalgaon district soil conservation department. All other information like area and population data collected from Census Handbook of Jalgaon district for above period. Out of the data collected, computation has made for weekly, monthly and yearly total and average rainfall, maximum and minimum temperature.

Determination of PE:

For water balance, determined PE, It is calculated by Hargreaves's method.

$$PE = 0.0022*RA*(Tc + 17.8)*TD^{0.5} \quad (1)$$

Where, RA = extra terrestrial radiation, mm/day, Tc = mean temperature ^{0}C,

TD =Difference between maximum and minimum temperature, $^{OC.}$

The Field Capacity (FC) calculated by following formula;

$$\text{Weighted F.C.} = \sum (F.C.* A* D)/ 100 \quad (2)$$

Where, F.C. = Field capacity, cm /m, A = Area in percentage, D = Depth of soil.

Computation of water balance:

Soil moisture storage at the end of each month has computed by

$$St = FC * e^{-APWL/FC} \quad (3)$$

Where, St= moisture remaining in the soil as storage and APWL= accumulated potential water loss, which is equal to accumulated (P-PE)

Conditions:

(a) During any month if P ≥ PE, then AE =PE (4)

Any excess P of PE goes to recharge the soil till the soil is brought to FC; any further remainder is termed as water surplus.

(b) When P< PE, then AE = P+ ΔSt (5)

(c) The water deficit is the difference between PE and AE. Using these computations, the water balance was determined month - by month using the following equation,

$$P = AE + \Delta St + WS \quad (6)$$

Equation (6) is valid under the assumption that the ground water inflow and outflow of the study region are equal.

To know the climatic condition, the method adopted by Krishnan and Singh (1972) was used and it was known on the basis of moisture index (MI), which is calculated as,

$$MI = (P – PE)/PE*100 \quad (7)$$

Where, P = Precipitation, mm, PE = Potential evapotranspiration, mm.

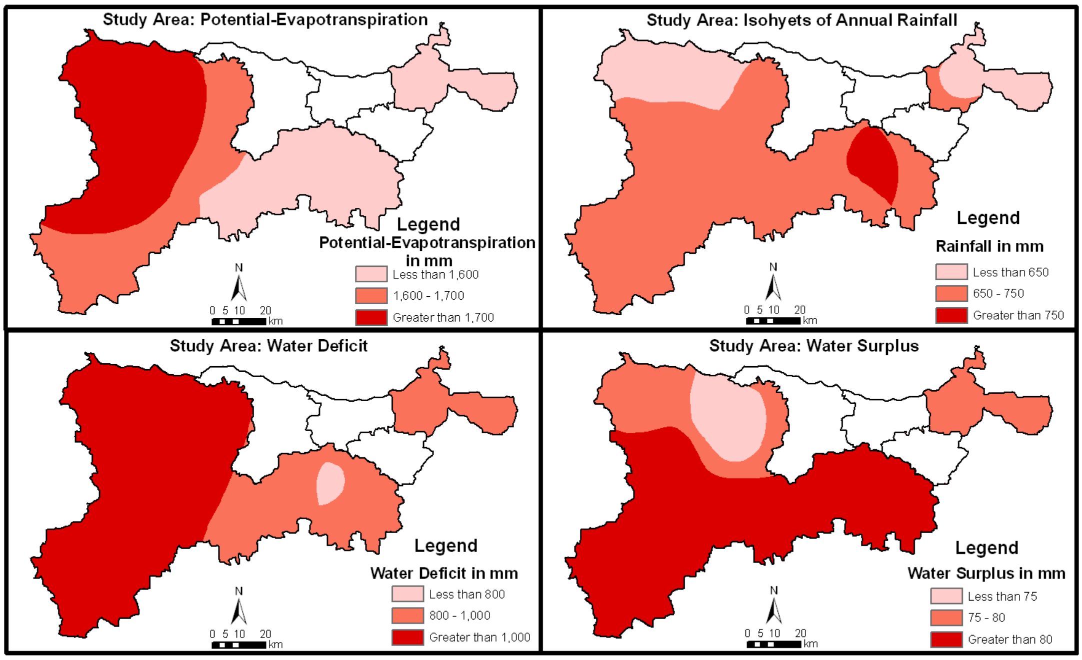

Fig. 3 Water balance components

RESULT AND DISCUSSION:

1. *Water balance components*

As per the procedure described above field capacity for different topo-sequences were determined (Table 1) and using equation 2 weighted F.C. is determined and found as 10.0 cm. Values of various parameters of annual water balance for nine rain - gauge stations are presented in Table- 2. Following the same procedure, water balance of the study region is also worked out for each month & values of different parameters are presented in Table 3.

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Table 1 Average field capacity of 1m-soil profile

Category of land	F.C. (cm/m)	% of area	Depth of soil (m)
Low land	2727.87	39	1.0
Medium land	3357.38	48	1.0
Upland	489.62	7	0.5
Barren & forest	349.73	5	0.3
Rocky	69.95	1	0.0

Source: Computed by researcher, 2015

The annual values of rainfall, water surplus and water deficit of all nine stations were used to plot the isohyets of annual rainfall (Figure. 2), isolines of water surplus (Figure 3) and isolines of water deficit (Figure 4) over the study region. Figure 2 shows that the annual minimum and maximum rainfall values on the entire study region vary from 638.1 to 770 mm. It has been observed from Figure 3 that the northwestern part of the study region has maximum amount of water surplus, which is fed to the river system. The entire study region provides a minimum of 300 mm and maximum 850 mm of water to the river. Figure 4 indicates that the minimum water deficit over the study region is 777.7 mm and maximum water deficit is 1281.0 mm. The water deficit is low in southeast and central part of the study region.

Water balance computed for the study region has been shown graphically in Figure 5. This graph is a comparison of P, PE and AE from which extent and epochs of water surplus, water deficit, soil moisture used and soil moisture recharge can be visualized. When P falls short of PE, water is drawn from soil for evapotranspiration. The negative change in soil moisture has been taken as soil moisture utilization. When P is greater than PE the positive change in soil moisture has been taken as soil moisture used till soil attains field capacity.

Table 2 Annual values of components of water balance (mm)

Station	PE	P	AE	WD	WS
Chalisgaon	1666	737.6	553.5	1219.5	85
Bhadgaon	1703	702.5	572	1169	85
Pachora	1593	667.7	603	1281	89
Jamner	1463	770.3	595.1	1115.9	85
Erandol	1711	667.1	617.5	1085.5	72
Parola	1884	690.8	652.6	1013.4	88
Amalner	1773	630.1	578.9	1014.1	77
Dharangaon	1741	641.0	685.9	777.7	69
Muktainagar	1534	638.1	563.1	970.9	75
Region	1674	682.8	601.8	1072.2	81

Source: Source: IMD, Pune, 1980-2010 (Compiled by researchers, 2016)

Table 3 Water balance (mm) of the study region

Month	PE	P	AE	WD	WS	SMU	IMA	MI
Jan.	83.9	3.1	10.0	73.9		6.9	0.1	-96.9
Feb.	107.3	3.0	9.0	98.3		6.0	0.1	-97.0
Mar	149.4	3.1	11.0	138.4		7.9	0.1	-96.9
Apr	194.1	1.3	5.0	189.1		3.7	0.0	-98.7
May	268.9	9.8	36.0	232.9		26.2	0.1	-90.2
Jun	198.0	122.3	40.0	158.0			0.2	22.3
Jul	122.0	172.2	122.0	0.0	50.2		1.0	72.2
Aug	111.0	133.0	111.0	0.0	22.0		1.0	33.0
Sept	109.4	111.8	107.0	2.4	4.8		1.0	11.8
Oct	145.4	101.0	96.5	50.0	4.5		0.7	1.0
Nov	112.6	12.1	36.0	76.6		23.9	0.3	-87.9
Dec	86.6	6.7	18.0	68.6		11.3	0.2	-93.3
Annual	1674.2	682.8	601.5	1072.7	81.5	85.8	0.4	-59.2

Reference: PE = Potential Evapotranspiration (mm), P = Precipitation (mm), AE = Actual Evapotranspiration (mm), WD = Water deficit (mm), WS = Water surplus (mm), SMU = Soil moisture used (mm), and IMA = Index of moisture adequacy (mm). Source: Computed by the researcher, 2016.

Table 4 Agro - climatic analysis of the region

Station	Amalner	Dharangaon	Parola	Erandol	Bhadgaon	Chalisgaon	Pachora	Jamner	Muktainagar	Region
MI (%)	-64	-63	-63	-61	-59	-56	-58	-47	-58	-59
Climatic-group	Semi-arid	Semi-arid	Semi-arid	Semi-arid	Semi-arid	Semi-arid	Semi-arid	Semi-arid	Semi-arid	Semi-arid

Source: Computed by the researcher, 2016

(74.6.mm). Out of this amount 85.5 mm appears as water surplus and remaining 85.8 mm adds to soil moisture as recharge. It has been observed that in four months (July to October) there is water surplus and eight months (November to Jun) there is water deficit. The water surplus during June and part of July goes to recharge the moisture deficit of the soil mass. On annual basis the study region has a water need of 1674.2 mm whereas the rainfall is 682.8 mm, still 81.8 mm water appears as surplus on account of the relative marches of rainfall from June to September being in excess of water need by an amount of 74.6 mm.

Index of moisture adequacy (Subramanyam, et.al., 1964) indicates the rate at which moisture is available to the crop compared to its demand. IMA values in the range of 0.45 to 0.60 for millets, onion and for groundnut in the range of 0.52 to 0.75 are considered favorable for efficient crop growth (Table 3). The period between July and November is drought-free and favorable for such crops. Moisture Index determination (Table 4) reveals a negative low value, but it is better for (Chalisgaon and Jamner tahsils) Southern part, whereas remaining tahsils show negative high value. Therefore, the catchment area of the two tahsils can best be used for better rain use efficiency and to tide over inter–spell moisture deficiency. For this purpose, the following strategies may be adopted.

2. Strategy for Water harvesting and recycling :

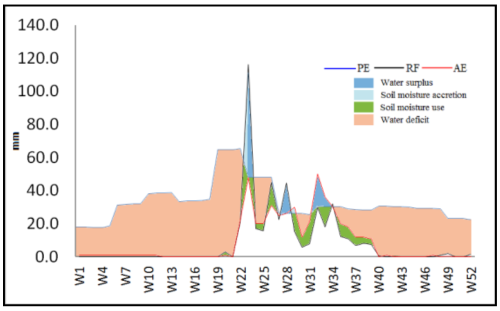
1. It was found that water surplus in the study region is 81.5 mm. Also the southern part of the study region is bestowed with many natural hill streams and farmers are diverting this stream water through earthen channels with very low conveyance (< 30 %). Therefore, harvesting of such water and conveying and distributing through under pipeline system or lined channel can irrigate 800 Km^2 areas out of 2581.39 km^2 catchment area, for supplemental irrigation to remunerative crops like vegetables. In Jamner and Chalisgaon tahsil watershed, installation of underground pipeline system increased potential area under irrigation for vegetables from 220 ha to 350 ha benefiting 645 families; conveyance efficiency also enhanced from 23 to 95 percent (Sudhishri et. al., 2004).
2. In the study region, the water flow remains round the year in the Northern low land part (stabilized broad and terraced gully bed). The Northern low land part water can be harvested / diverted for irrigating adjoining medium lands by constructing water holes of 3 m diameter and depth of 2 to4 meter depth (location specific) at the side of the Northern low land.

3. Strategy for in–situ moisture conservation :

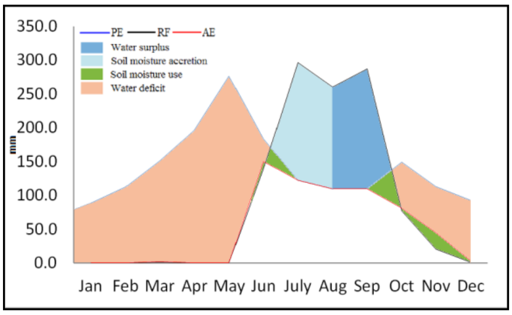
In the study region 9 percent area is under hill and uplands. Also uplands constitute a large portion of cultivable area, which are unbunded and thus generate huge amount of runoff. Constructing graded bunds, vegetative bunds, trench-cum- bund – cum vegetative barriers / hedgrows, terraces etc. may conserve this runoff water. In Chalisgaon and Jamner tahsil upper watersheds due to construction of trench- cum bund (planted with vetiver & sambuta grass and Assam shade & gliricidia as hedge row on bunds); stone bunds with cut outlet structures, bunding and land leveling increased the crop yield by 15 percent during the drought year 2000. In hill slopes due to different in – situ moisture conservation like tick ditch, micro catchment, trench, saucer shape soil working techniques and installation of pitcher in horticultural trees like sandalwood, mango and cashew increased the survival percentage even up to 88 to 95 percent (Patnaik, et.al., 2004).

4. Strategy for Agronomic Practices:

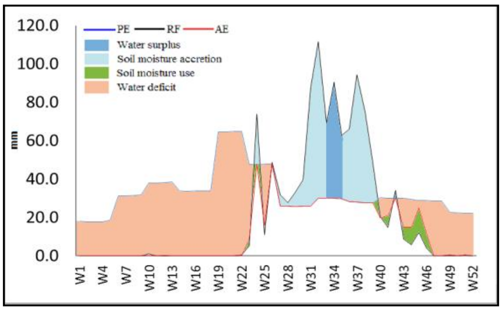
1. Seeds should be placed in the moist zone through line sowing to have uniform germination and better establishment of young seedlings. It was found that line sowing in ragi (the staple food) recorded highest grain yield of 21.94 q/ha and increased plant height, primary branches/plant and better germination compared to broadcast method (Anonymous, 2003)
2. Shallow hoeing /one hand weeding at, 25 days after sowing should be done to maintain moisture availability. It was observed that one hand weeding in horse gram increased seed yield by 12.2 percent over no weeding, may be due to weeding operation maintained enough moisture and nutrients to horse gram crop (Patra and Nayak, 2000).
3. Intercropping of kharip crops like ragi and pulses with pigen pea is the promising system in this region for mitigating ill – effects of water deficit. In an on – farm trial in this region, jowar + pigeon pea(6:2) produced 26 percent higher jowar equivalent yield than sole crop during drought year (2002). In other similar trial, ragi and pigeon pea inter cropping system gave higher net returns as compared to sole crop ragi (Anonymous, 2004).



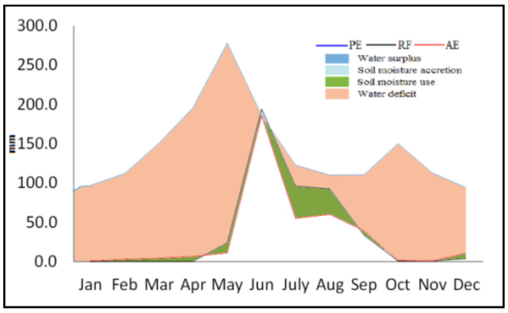
Meteorological week (1998, Wet year)



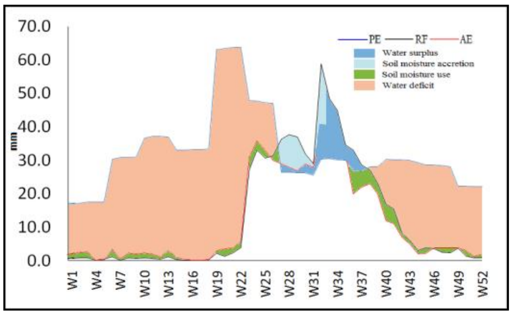
Month (1998, Wet year)



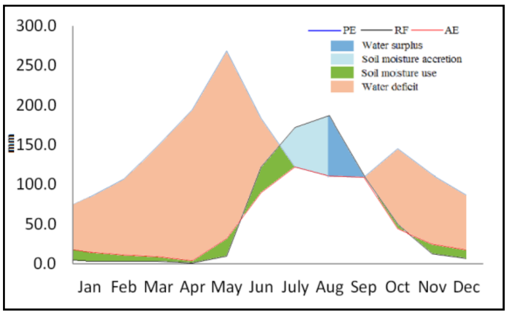
Meteorological week (2000, Drought year)



Month (2000, Drought year)



Meteorological week (2002, Normal year)



Month (2002, Normal year)

Fig. 4 Study Area: Weekly and Monthly Water Balance for Wet, Drought and Normal year.

4. Conservation of residual soil moisture and increase in the yield of Rabi crops using locally available mulches like groundnut / onion / ragi straw, gliricidia leaves lantana and local grass. It was observed that in this area lantana, local grasses and gliricidia mulches @ 8 t/ha was able to retain sufficient moisture to sustain Rabi crops like wheat, gram and Niger (Anonymous, 1997 b). In turmeric, highest moisture content (21.25 %) was observed with paddy straw mulch (6, 8 and 10 t/ha) followed by grass and gliricidia mulch and minimum was under control treatment (Anonymous, 1996).
5. Use of organic / bio-manures also enhances moisture retention. Application of vermin – compost @ 200 gram / plant in tomato and cabbage increased sufficiently the water holding capacity of soil, and increased the yield (Chaudhary, et.al. 2003).
6. Adopting following suitable crop sequence in this region under rain fed conditions to withstand water deficit.

Table 5 Suggested cropping pattern for study area

Upland	Ist crop	2nd crop
Unbunded	Ragi,maize,suan,groundnut,vegetables, beans, black gram, cowpea	Horse gram,niger,
Upland(terraced)	Early high yielding onion,chilli(100 days)	Niger/mustard/mung cowpea
Medium land	Medium high yielding varieties (120 days)	Mustard,gram/safflower/lentil/linseed.
Lowland (Northern part)	Long duration cotton, corn, Banana, Sugercane	onion, vegetables in particularly dried portion

Source: Computed by the researcher, 2016.

CONCLUSION:

Water balance of the study region shows the values of water need, rainfall, actual evapotranspiration, water surplus and water deficit of 1674.2mm, 682.8 mm, 601.8 mm 81.5 mm, and 1072.2 mm, respectively. Under normal climatic condition, entire kharip season is deficit free. Deficit to the

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tune of 81.7 mm of water occurs in Rabi season. Since the water surplus is excess of precipitation over the water needs of the atmosphere and the soil, it must find its way through rivers and streams. Thus, determination of water surplus enables the estimation of yields from the study region. Such information can be used in designing storage structures for use of water during deficit periods. In the same way, water deficit is the shortage of precipitation for satisfying the full demands of evapotranspiration. On an average, the whole can be said to be under water deficit region, though climatic condition is arid. Hence, the Rabi crops are either avoided or taken up in extremely limited area reflecting under utilization of land and water resources. However, there exists scope for taking winter and Rabi crops too in sequence even under rain fed conditions, provided that appropriate water harvesting measures, moisture conservation measures and agronomic practices are adopted in an integrated manner.

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