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Water balance study at Bharuch region of South Gujarat

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Abstract
In this study attempts have been made for Agriculture crops planning at Bharuch region of south Gujarat by using the water balance studies. Weekly water balance computation showed that only ten weeks *i.e.* 24th, 26th, 27th to 31st Standard Meteorological Week (SMW) are water surplus while the rest of the weeks are water deficit week. Availability Index (MAI) which are excellent for crop growth and 40th to 41st weeks are good for crop growth. This finding this region selecting of short duration and drought resistance crops during monsoon season.

Keywords: Weekly water balance, water deficit and water surplus

Introduction
The water balance concept in applied climatology has been widely applied in many earth science fields especially for development of agriculture and water resources of a region. Water balance study in relation to agriculture is one of the important disciplines of applied climatology. The agriculture potential of a region is determined by the climate of the region and the important of which being the amount of rainfall, temperature and duration of sunshine, which altogether regulate the water balance of a region. For the evaluation of complete water balance of a station, it is necessary to compare precipitation with water need making allowance for the storage of water in the soil and its subsequent utilization for evapotranspiration purpose. For the computation of water balance of a station it is essential to calculate Potential Evapotranspiration (PET), Actual Evapotranspiration (AET), Water Surplus (WS) and Water Deficit (WD). These are determined from the book keeping procedure given by Thornthwaite and Mather (1957) [9]. Another important aspect of water balance is the estimation of Water Holding Capacity (WHC) of soils against the gravitational forces. The WHC of the soil, changes with the types of soil and vegetation. Climate is a composite physical state of the atmosphere at a specified locality for a specified interval of time. Thornthwaite is a pioneer who formulated a climatic classification and water balance concept. Temperature and rainfall play a vital role in determining the climatic condition of an area. Water balance is a quantitative expression of hydrological cycle and its various components over a specified area at a period of time. In India water balance at regional, State and basin levels have been worked out widely by Subramanyam (1956) [5], Subramaniyam and Sastry (1969) [6], Ram Mohan (1978, 1980) [2], Subramaniam and Uma Devi (1983) [7], and Subramaniam *et al.*, (1982). In the present study the Thornthwaite's water balance concept has been adopted to identify the prevailing climatic condition of Bharuch district, by analyzing potential evapotranspiration, actual evapotranspiration, water deficit and water surplus parameters. Based on these elements the aridity, humidity and moisture indices were calculated.

Materials and Methods
To study the water balance of the region
The water balance method is a bookkeeping procedure which estimates the balance between the inflow and outflow of water of the system. This method was developed by Thornthwaite in 1948 and was revised by himself and Mather in 1955. This method helps in identifying and estimating the natural water surplus and water deficit months of an area. Among the methods to estimate the soil water balance from simple soil and climate data, the method proposed by Thornthwaite and Mather (1957) [9] is one of the most widely used. This procedure allows estimating the actual evapotranspiration, soil water deficit and excess. Water balance was used to calculate the theoretical irrigation requirements for comparison with actual irrigation water applied.

The demand for water by the crop must be met by the water in the soil, via the root system. The actual rate of water uptake by the crop from the soil in relation to maximum evapotranspiration is determined by whether the available water in the soil is adequate or whether the crop will suffer from stress including water deficit.

Input data

Input data is categorized as a rainfall, potential evaporation, available water capacity. The input data described as below.

Rainfall (P)

- Rainfall data may be on daily/weekly/monthly basis.
- Weekly data are useful for agricultural crop planning.
- Daily data are useful for real time monitoring of soil moisture/irrigation scheduling/ agro advisory.

Potential Evapotranspiration (PET)

Various models are available for computation of PET (Penman is the most reliable).

$$PET = \frac{AH_{n+\gamma E_a}}{A + \gamma}$$

Where, PET = daily potential Evapotranspiration (mm/day)

A = Slop of saturation vapour pressure (mmHg/^{0}C)
Hn = Net radiation (mm/day)
Hn is estimated as
Hn = Rns – Rnl
Rns = Net incoming short wave radiation
R (ns=QA × (1-r) × (0.25+0.50 × n⁄N))
Rnl = Net long wave radiation
R_(nl = f(t)×f(e_a) ×f(n⁄N) the values of which are available from the appendix)
Ea = Evaporation due to aerodynamic method (mm/day)
Ea is estimated as,
Ea = 0.35+(1+u2/160)(e_s- e_(a))
Where, u2 = Mean wind speed at 2 m above ground (km/day)
Es = Saturated vapour pressure at mean air temperature (mmHg)
Ea = Actual vapour pressure (mmHg)

For the computation of PET, data on temperature, wind speed, radiation (or sunshine hours) and vapor pressure (or humidity) are needed.
ϒ = Psychrometric constant (mmHg/^{0}C) (can be taken as 0.49 mmHg/^{0}C)

Available Water Capacity (AWC)

Depends on soil types, density and its depth
AWC= (FC-PWP) × BD × Depth/100

Where,
FC = Field capacity of soil
PC = Permanent wilting point
BD = Bulk density

Steps of Water Balance Computation

- P - PET
- Sum up all negative value of P - PET
- Accumulated potential water loss (APWL)

Accumulated potential water loss (APWL) is calculate the difference between the mean monthly precipitation and the potential evapotranspiration for each month. The potential water loss for a single month is when the potential evapotranspiration exceeds the precipitation. The cumulative loss for the proceeding months are calculated to find out the Accumulated Potential Water Loss (APWL) for each month.

1. During dry seasons to meet the demands of PET when insufficient supply of water,
2. Reduced during wet seasons from soil moisture recharge, and
3. Equals zero when soil moisture equal to the available water holding capacity of the soil. The accumulated values APWL for each month, were calculated by running the sum of the daily P-PET values during the periods when (P-PET) is negative value. Those months having positive (P-PET) have APWL zero.

Soil moisture storage (SMS)

Soil moisture storage is defined as the total amount of water which is held by the plant root zone. The soil texture and the cropping pattern are the main factors that 27 determine the soil storage. The rooting depth of the soil is directly proportional to the amount of water that can be held by the soil root zone. It means that greater the crop rooting depth more amount of water is stored in the soil zone and thus reduces the amount of water migrating beneath the zone to add as groundwater recharge. The maximum amount of water that can be held within the soil zone is referred to as field capacity (Sahai, 2004). At field capacity the soil holds the water against the force of gravity. Conceptually the groundwater recharge does not commence until the moisture content exceeds the field capacity as it acts as the threshold limit. The water holding capacity at root zone is obtained by multiplying the water content at the field capacity by the effective depth of the soil root zone. Soil moisture storage can be calculated using exponential function

SMS = AWC×EXP (APWL/AWC)

- AET is calculated as follow

When R > PET, then AET=PET
Otherwise AET=P + Change is SMS

- Water Deficit (WD)

Soil moisture deficit occurs when there is lack of available moisture to be evaporated and transpired by plants. It means that the actual evapotranspiration is less than the potential evapotranspiration. Hence the soil moisture deficit is calculated as the difference between potential evapotranspiration and actual evapotranspiration (Bakundukize, Camp, & Walraevens, 2011).

WD = PET-AET

- Water Surplus (WS) is excess rainfall over PET after soil gets saturated.
- Moisture Availability Index (MAI)

MAI = AET/PET

Moisture Availability Index (MAI)

MAI= AET/PET

- It is the ratio of AET to PET and is a good indicator of moisture availability to crops
- MAI>0.75 excellent for crop growth
- 0.50< MAI<.75 Good for crops
- 0.25< MAI<.50 Crop under moderate stress
- MAI <0.25 Crop under severe stress

Result and Discussion

Estimating groundwater recharge is often the primary purpose of conducting a water balance. Recharge largely determines the rate at which groundwater can be withdrawn from wells. Recharge is estimated in the water balance model based on the accounting of soil water content. When the water stored in the soil exceeds the field capacity, excess water is assumed to percolate downward beyond the lowest roots.

Thornthwaite and Mather method has been adopted to study the water balance of the study area. The Thornthwaite-Mather procedure for calculating recharge from the soil moisture balance has been extended to use daily input values and to include the delay caused by percolation through the unsaturated zone. It is to be noted that only seven weeks *i.e.* 24th, 26th, 27th to 31st, Standard Meteorological Week (SMW) are water surplus while the rest of the weeks are water deficit week. The surplus water is available after the actual evapotranspiration has occurred. Hence, the surplus water is either available for soil moisture storage or generates runoff or adds as groundwater recharge.

Thornthwaite mather's book keeping method of water balance is a comparison of rainfall and evapotranspiration in a particular area. From the calculation of water balance of Bharuch district it can be inferred that the amount of rainfall exceeds the actual evapotranspiration in the weeks of 24th, 26th to 32nd, 34th and 38th (SMW) (Table-1) and Fig.1. The total average rainfall of 31 years in the study area is 690.6 mm while the surplus water in the system amounts to 83.6 mm. The surplus water 83.6 mm results from the summation of water surplus in the system in the weeks of 24th, 26th, 27th to 31st. The surplus water first satisfies the soil moisture storage and then adds as groundwater recharge or generates run-off. The Available Water Capacity at the study area is 214 mm. The storage is 214 mm in the weeks of 24th, 26th to 31st. This signifies that the surplus water in the weeks of 24th and 26th is required to satisfy the soil moisture storage in the study area. Therefore the surplus water in the weeks of 27th to 31st either adds as groundwater recharge or generates runoff. 32nd to 34th is almost a balanced weeks in terms of soil moisture since the potential evapotranspiration almost equals the actual evapotranspiration. The potential evapotranspiration exceeds the rainfall in the weeks 35th to 52nd and 1st to 23rd which makes them water deficit weeks. These water deficit weeks require irrigation facilities for agricultural practice in the study area. 9th to 21st weeks are the weeks of maximum water deficit while the excess water adds to the system. In 24th to 39nd weeks have more than 0.75 Moisture. Availability Index (MAI) which are excellent for crop growth and 40th to 41st weeks are good for crop growth. While crops are under moderate stress in weeks of 22nd, 23rd, 42nd to 45th, 47th and in weeks of 1st to 21st and 46th to 52nd crops under several stress. Similar result found by Roy and Ophori (2012).

In Bharuch region comes under low rainfall area. The area received rainfall only in monsoon season. Last few years the changes in rainfall pattern, amount of rainfall and uneven rainfall distribution shown in this region which highly affected on water balance of this region.

Table 1: Weekly water balance for the normal data (1985- 2015) for Bharuch with different component computed by Thornthwaite mather's book keeping method

Week	P	Pet	P-PET	APWL	SMS	Delta s	AET	WD	WS	MAI
1	0.4	14.6	-14.2	-457.2	25.3	-1.7	2.1	12.5	-	0.14
2	1.2	16.1	-14.9	-472.1	23.6	-1.7	2.9	13.2	-	0.18
3	0.1	17.4	-17.3	-489.4	21.7	-1.8	1.9	15.4	-	0.11
4	0.7	14.7	-14.0	-503.3	20.4	-1.4	2.1	12.6	-	0.14
5	0.0	16.7	-16.7	-520.0	18.8	-1.5	1.5	15.2	-	0.09
6	0.0	19.0	-19.0	-539.0	17.2	-1.6	1.6	17.4	-	0.08
7	0.8	19.6	-18.9	-557.9	15.8	-1.5	2.2	17.4	-	0.11
8	0.5	20.5	-20.0	-578.0	14.4	-1.4	1.9	18.6	-	0.09
9	0.5	23.3	-22.8	-600.7	12.9	-1.5	1.9	21.3	-	0.08
10	0.6	25.0	-24.3	-625.1	11.5	-1.4	2.0	23.0	-	0.08
11	0.1	26.3	-26.3	-651.4	10.2	-1.3	1.4	25.0	-	0.05
12	0.0	27.8	-27.8	-679.2	9.0	-1.2	1.2	26.6	-	0.04
13	0.0	25.8	-25.7	-704.9	7.9	-1.0	1.0	24.7	-	0.04
14	0.2	23.6	-23.3	-728.2	7.1	-0.8	1.1	22.5	-	0.04
15	0.0	23.6	-23.6	-751.8	6.4	-0.7	0.7	22.9	-	0.03
16	0.1	23.0	-22.9	-774.7	5.7	-0.6	0.7	22.2	-	0.03
17	0.1	23.2	-23.1	-797.9	5.1	-0.6	0.7	22.5	-	0.03
18	0.1	22.1	-22.0	-819.8	4.6	-0.5	0.6	21.5	-	0.03
19	1.4	22.5	-21.1	-840.9	4.2	-0.4	1.9	20.6	-	0.08
20	0.3	23.1	-22.8	-863.7	3.8	-0.4	0.7	22.4	-	0.03
21	0.2	23.2	-23.0	-886.7	3.4	-0.4	0.6	22.6	-	0.03
22	6.7	24.7	-18.0	-904.7	3.1	-0.3	7.0	17.7	-	0.28
23	6.8	26.7	-19.9	-924.6	2.8	-0.3	7.0	19.7	-	0.26
24	31.3	30.2	1.1	0.0	3.9	1.1	30.2	0.0	1.1	1.00
25	30.1	31.7	-1.6	-1.6	212.4	208.5	30.1	1.6	-	0.95
26	76.4	33.8	42.6	0.0	214.0	1.6	33.8	0.0	1.6	1.00
27	59.1	38.0	21.1	0.0	214.0	0.0	38.0	0.0	21.1	1.00
28	52.2	38.8	13.4	0.0	214.0	0.0	38.8	0.0	13.4	1.00
29	63.3	39.8	23.4	0.0	214.0	0.0	39.8	0.0	23.4	1.00
30	63.0	41.0	22.0	0.0	214.0	0.0	41.0	0.0	22	1.00
31	43.8	42.8	1.0	0.0	214.0	0.0	42.8	0.0	1	1.00
32	41.9	42.6	-0.8	-0.8	213.2	-0.8	42.7	-0.1	-	1.00
33	24.0	42.6	-18.6	-19.4	195.4	-17.8	41.8	0.9	-	0.98
34	40.8	41.5	-0.7	-20.1	194.8	-0.6	41.4	0.1	-	1.00

35	26.7	44.4	-17.7	-37.7	179.4	-15.4	42.2	2.2	-	0.95
36	33.9	43.8	-9.9	-47.6	171.3	-8.1	42.0	1.8	-	0.96
37	22.7	45.2	-22.4	-70.1	154.3	-17.0	39.8	5.4	-	0.88
38	22.6	45.0	-22.4	-92.5	138.9	-15.3	37.9	7.1	-	0.84
39	20.3	45.0	-24.7	-117.1	123.8	-15.1	35.4	9.6	-	0.79
40	4.5	42.1	-37.6	-154.8	103.8	-20.0	24.5	17.7	-	0.58
41	6.2	42.4	-36.1	-190.9	87.7	-16.1	22.4	20.0	-	0.53
42	1.2	39.9	-38.7	-229.6	73.2	-14.5	15.7	24.2	-	0.39
43	0.5	36.2	-35.7	-265.3	61.9	-11.3	11.7	24.5	-	0.32
44	0.2	33.5	-33.3	-298.6	53.0	-8.9	9.1	24.3	-	0.27
45	1.4	29.5	-28.2	-326.7	46.5	-6.5	7.9	21.6	-	0.27
46	0.6	22.8	-22.2	-348.9	41.9	-4.6	5.2	17.6	-	0.23
47	2.8	20.9	-18.2	-367.1	38.5	-3.4	6.2	14.8	-	0.29
48	0.0	19.0	-19.0	-386.1	35.2	-3.3	3.3	15.7	-	0.17
49	0.2	17.0	-16.8	-402.9	32.6	-2.7	2.9	14.1	-	0.17
50	0.3	15.7	-15.5	-418.3	30.3	-2.3	2.6	13.2	-	0.16
51	0.0	8.6	-8.6	-426.9	29.1	-1.2	1.2	7.4	-	0.14
52	0.0	16.5	-16.5	-443.3	27.0	-2.2	2.2	14.3	-	0.13

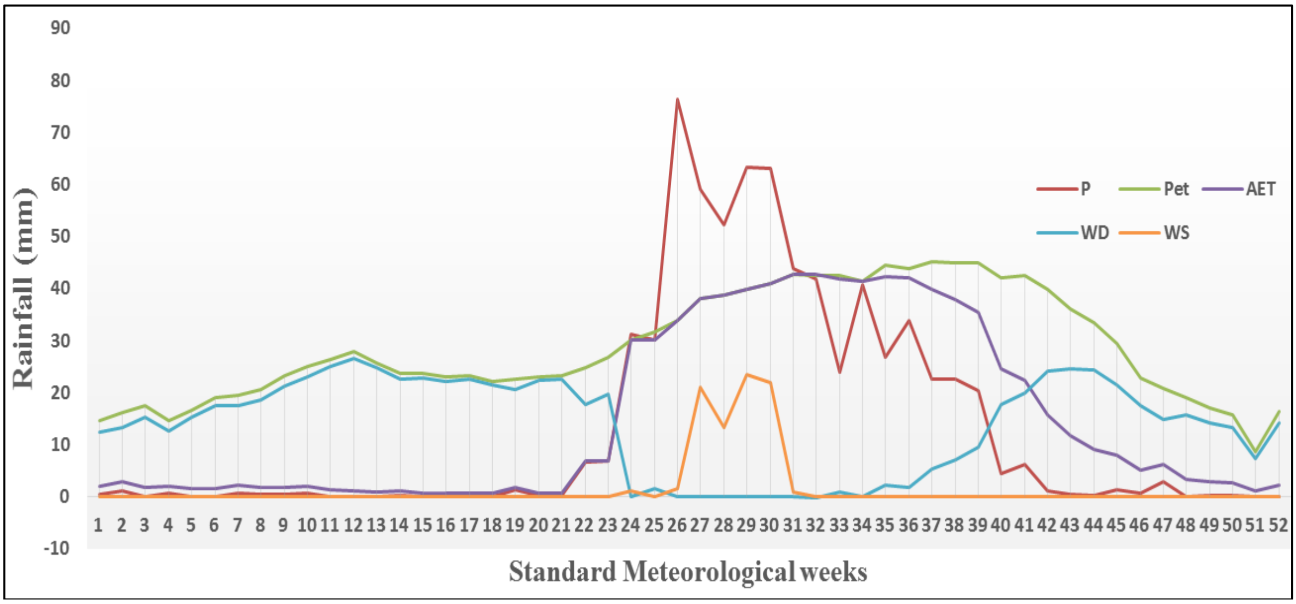

Fig 1: Weekly water balance for the normal data (1985-2015) for Bharuch with different component computed Thornthwait marther's book keeping method

Conclusion

It is to be noted that only seven weeks *i.e.* 24th, 26th, 27th to 31st Standard Meteorological Week (SMW) are water surplus while the rest of the weeks are water deficit week. The surplus water is available after the actual evapotranspiration has occurred. Hence, the surplus water is either available for soil moisture storage or generates runoff or adds as groundwater recharge. The water surplus in the region occurs during 24th, 26th, 27th to 31st weeks, while the rest of the weeks are water deficit weeks in which weeks need artificial irrigation. In 24th to 39nd weeks have more than 0.75 Moisture. Availability Index (MAI) which are excellent for crop growth and 40th to 41st weeks are good for crop growth. The crops are under moderate stress in weeks of 22nd, 23rd, 42nd to 45th, 47th and in weeks of 1st to 21st and 46th to 52nd crops under several stress. This finding this region selecting of short duration and drought resistance crops during monsoon season.

References

1. Bakundukize C, Marc VC, Walraevens K. Estimation of groundwater recharge in Bugesera region (Burundi) using soil moisture budget approach, Geologica Belgica. 2011; 14(1-2):85-102.
2. Ram Mohan HS. A Water Balance Approach to Spatial Coherence of Droughts over Tamil Nadu, Contributions to Marine Sciences (Dedicated to Dr. C.V. Kurian), 1978, 182-194.
3. Roy S, Ophori D. Assessment of water balance of the semi-arid region in southern San Joaquin valley California using thornthwaite and mather's model, Journal of Environmental Hydrology. 2012; 20(15):1-9.
4. Sahai VN. Mineral Nutrients, In Fundamentals of soil (3rd Edition), Kalyani Publishers, New Delhi, India, 2004, 151-155.
5. Subrahmanyam VP. Water Balance of India According to Thornthwaite's Concept of Potential Evapotranspiration, Annals of the Assn. Amer. Geog, 1956, 44(3).
6. Subrahmanyam VP, Sastry CVS. Study of Aridity and Droughts in Visakhapatnam, Annals of Arid Zone. 1969; 8(1):45-60.
7. Subramaniam AR, Uma Devi K. Water Availability and Crop Management in Orissa, Ind. J Soil. Cons. 1983; 11(1):54-59.
8. Subramaniyam AR, Vijaya P. Water Balance Studies in Trivandrum and Vicinity. Transaction, Institute of Indian Geographers, 1982, I.

9. Thornthwaite CW, Mather JR. Instructions and Tables for Computing Potential Evapotranspiration and the Water Balance, Publ. in Cli. Lab of Cli. Elmer, New Jerrsy, 1957.