ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 11, Issue, 08, pp.5938-5942, August, 2019

DOI: https://doi.org/10.24941/ijcr.36119.08.2019

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

A STUDY IN WATER BALANCE AND CLIMATIC CHARACTERISTICS OF DROUGHT – PRONE AREAS IN JALGAON DISTRICT OF MAHARASHTRA STATE

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ARTICLE INFO

Article History:
Received 11th May, 2019
Received in revised form
19th June, 2019
Accepted 15th July, 2019
Published online 31st August, 2019

Key Words:

Potential Evapotranspiration,
Water deficit and water surplus,
Moisture adequacy index.

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ABSTRACT

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'. Rainfall is the main source of water supply on the earth surface and it determines the moisture level at various depths of soil available to crops. The availability of moisture in soil is a controlling factor for growth and development of all types of vegetation especially for exiting crops in an area. Day to day human activities are normally governed by the prevailing climatic conditions of human beings like deforestations, farming practices, industrialization, rapid urbanization etc. The location and physiographic factors also combined influence the climatic characteristics of a region. In the same way climate helps to define climate vegetation of a region and also sets limits for crop growth. In this context, the numerical estimate of climatic water balance and its study has obtained an important place in geography. In the present study an attempt has been made to describe the climatic characteristics of the study region and to evaluate the water balance parameters for the study region according to the revised scheme of Thornthwaite and Mather (1955).The study shows that the entire Kharip season is deficit free and during Rabi season the deficit amount is 643.9 mm. There is water surplus from July to October and water deficit from November to May. Though on an average the study region is under deficit (1072.2 mm), the agro climatic situation of the region is arid (MI = -59.2 %).

***Citation: Dr. Patil Namdeo Arjun,* 2019.** "A study in water Balance and Climatic Characteristics of Drought – Prone Areas in Jalgaon district of Maharashtra State", *International Journal of Current Research*, 11, (08), 5938-5942.

INTRODUCTION

Present farming systems are highly adapted to local climate along with topographical characteristics. In fact, agricultural practices are strongly controlled by thermal and moisture characteristics of an area. Though rainfall is the main source of water and determines the moisture level at various depths of soil available to crops, the actual availability does not depend on rainfall alone, as it should be balanced against the amounts due to evapo-transpiration (Singh, 2005), In the growing period, the availability of moisture in soil is a controlling factor for growth and development of all types of vegetation especially for existing crops in a region. The amount of moisture that is lost to the atmosphere through Evapotranspiration depends preliminary upon the available moisture content in the soil, the temporal variation of which may be determined from knowledge of rainfall distribution. (Sharma, 1983). To explain the cropping pattern, moisture adequacy, a cultural factor should be carefully considered (Mohapatra, 2016). In agro – climatic studies water balance is a key factor to evaluate the amount of continual interchange of water between root zones of soil to the atmosphere. In this process when the water reaches on the land surface through rainfall, part of it diverted as runoff, soon after the soils are saturated and the in filtered rain water returned in the upper layer of the soil atmosphere which is utilized for vegetation or crop growth. (Sharma and Lakshmi- kumar, 2006). The exact information about the soil moisture availability in time and space context give the information about the cropping scheduled and crop combination in a better way. The study of climatic water balance is one of the important aspects of applied climatology. In this perspective the knowledge of water balance elements in space and time is essential for the agricultural practices. In farming practices it provides information about water requirement for crops and vegetation's as well as the water availability for the crops and plants uses. The amount of moisture available can be best derived from the knowledge of Moisture Adequacy Index (I_{ma}), which represents the ratio of actual Evapotranspiration (AET). Moisture Adequacy Index indicates the moisture status in the soil for particular period. An excess or deficit of moisture in the root zone of soil and even in atmosphere highly depends on the magnitude of rainfall. In order to obtain soil moisture, a leading climatologist Thornthwaite (1948) proposed a book – keeping procedure for the computation of the elements of water budget by treating precipitation as income, potential Evapotranspiration as expenditure and the moisture stored in

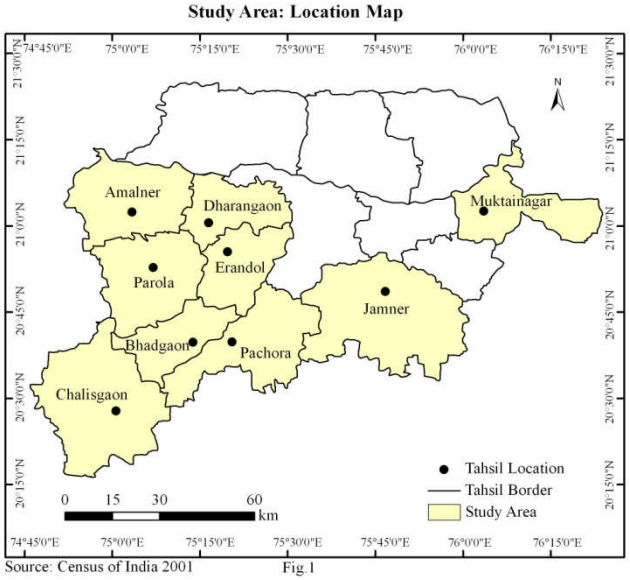
the soil as a reserve for use in times of deficient precipitation (Subrahma-nyam *et al.,* 1963). In recent years the growing demand of water in various sectors of economy for different purposes has drawn much attention of the scientist of many disciplines like applied climatology, agronomy, hydrology, industries, water management, geophysics etc to make better use of this precious resource foe welfare of the human being. Specially, in agro- climatic studies a clear understanding of water balance elements like spatio – temporal occurrence and distribution of precipitation actual Evapotranspiration, potential Evapotranspiration, the water deficiency and water surplus has become an important consideration and also it helps in various agricultural operations.

Objectives

- To derive water balance parameters on the basis of climatic elements to find out seasonal variation in water surplus/ deficit.
- To determine moisture adequacy index.

The study area: The study area is located in the drought-prone tahsils of Jalgaon district of Maharashtra state. These drought prone tahsils are identified by V Subramaniam (1987), Review Committee appointed by the Maharashtra State Government. The tahsils are Amalner, Dharangaon, Erandol, Parola, Chalisgaon, Bhadgaon, Jamner and Muktainagar. There are 09 tahsils which are selected for present study which cover an area 6994.54 sq.km. The area under study is located south of the Tapi River in Jalgaon district. It lies between $20^0$11' to $21^0$13' North latitudes and $74^0$46' to $76^0$24' East longitudes (Fig. 1). The study region is a plateau area with variations of some uneven lands on the banks of rivers. The River Girna and Waghur is the architect of this plateau area.

Data base and Methodology: The required data of climatic elements like rainfall, temperature, were obtained from the IMD, Pune and HDUG Nasik for the period of 31 years. Some other important information was collected through online published research papers and journals. The modified scheme of Thornthwaite and Mather (1955) has been applied for computation of various water balance parameters like PE, AE, WS and WD. Further in order to find out the seasonal variation in soil moisture, Moisture Adequacy Index (Ima) as suggested by J.O Ayoade (1972) later on V.P.



Source: Census of India 2001 Fig.1

Subramaniam (1983) has been computed. The I_{ma} value represents the ratio between Actual Evapotranspiration and Potential Evapotranspiration expressed in percentage.

Climatic Characteristics

The study region is attitudinally situated in a sub-tropical interior part characterized by monsoon climate. Thus the study area experiences the complete reversal of the weather conditions by seasonal reversal of wind direction. The year is mainly divided into four distinct seasons by India Meteorological Department; south-west monsoon season (Jun-Sept), post monsoon season (Oct, Nov and Dec), winter season (Jan- Feb), and summer season (March to May).

Climatic Water Balance

Water balance is a key factor to evaluate the amount of continual interchange of water between root zone of soil and the atmosphere. In this perspective the knowledge of water balances parameters in space and time is essential not only for the hydrological processes but also to the agricultural practices. The water balance gives a good insight of ecologically sensitive parameters. It provides useful information about the existing moisture condition of an area.

Evapotranspiration

To compute the Evapotranspiration /evaporation from free water surface and land areas of the earth, a climatic water balance establishes relationship between water balance and Evapotranspiration in quantitative term. In this regard a leading climatologist C.W.Thorthwaite (1931, 1948, and later on in 1955) firstly introduced the concept of potential evapotranspiration and proposed an empirical formula to obtain its value on the basis of mean monthly temperature. In water balance studies, Evapotranspiration is a major component to measure the degree of dryness and wetness of a region. Like precipitation it is also an important parameter to determine the climate of a region. From a comparison of the seasonal march of precipitation with Evapotranspiration, the magnitude of moisture parameters i.e. water surplus, water deficit, soil moisture storage and water runoff may be determined (Singh, 1977). On the basis of the march of precipitation from month to month and place to place a region experiences both wet and dry seasons in a year. The above aspects are explained as follows (Thornthwaite and Mather, 1955);(1) period of full storage, when precipitation exceeds the water need and a moisture surplus (S) accumulates, the early part of a dry period, when the stored soil moisture and precipitation used in Evapotranspiration, is termed as period of soil moisture utilization, when soil moisture storage steadily diminishes, the actual Evapotranspiration falls much below the potential and a moisture deficiency (D) occurs and a moisture season, when precipitation again starts exceeding the water need, soil moisture is reaching till it attains its full capacity. After the completion of this recharge, a surplus (S) commences again.

Potential evapotranspiration

PE is the amount of water that would evaporate and transpire from a wet vegetated surface if soil moisture were always available in sufficient amount for optimum use. So the annual and seasonal patterns of PE exhibit a close resemblance to the

distribution of temperature. The average annual PE is about 1674 mm. On an average, the maximum water need is observed in the month of May (269mm) and the minimum in January (84). The average seasonal PE values are highest in SW monsoon season (540 mm) because of high temperature, longer day duration and highest vegetal covers. However it is found lowest in winter months (191) due to low temperature.

Actual Evapotranspiration

Actual Evapotranspiration is the most important water balance parameter which may be expressed as the actual amount of water lost to the atmosphere under the existing climatic condition and moisture stored in the soil. So its seasonal distribution is highly controlled by the amount of rainfall and moisture available in the soil region. On an average it is lowest in the month of January (19 mm) and highest in the July (122 mm) in the study area. The amount of actual water loss is highly variable from season to season. In SW monsoon season (JJAS) it is highest (380 mm). In this period, AE increases due to adequate moisture supply through rainfall. Thereafter it started to decrease from the months of Post – monsoon season till the end of winter season. From the beginning of summer months the amount of actual water loss gradually increases with rising temperature.

Water deficit

The water deficit is expressed as the difference between water need (PE) and actual Evapotranspiration (AE). It is simply the shortage of moisture that is not available for utilization. In monsoonal climate where the seasonal rainfall variability is high, the climate becomes drier at the end of moist period. Excepting three months of rainy (JJAS) season, remaining other months experience varying amount of deficiency in the year. On an average the deficiency occurs highest (560.4 mm) in dry summer season due to low or no rainfall. Due to negligible or meagre amount of rainfall and low Evapotranspiration winter season observes least amount of water deficit (172.2 mm).

Water surplus

The surplus water is that part of rainfall which is excess from the Evapotranspiration and soil moisture storage. Therefore the water surplus represents the amount of water that is left after fulfilling the demands of the atmosphere and the soil. The comparison of monthly P, PE and moisture storage gives the information about the moisture surplus of the region. In the study area July, August and September are the rainiest month of the year.

Table 1. The Study Area: Water Balance Parameters in mm (Field Capacity = 100mm).

Parameter	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Temp	18	20	24	28	34	29	26	25	26	26	23	21	25
P	3	3	3	1	10	122	172	187	112	50	12	7	683
Pe	84	107	149	194	269	184	122	111	109	145	113	87	1674
P-e	-81	-104	-146	-193	-259	-61	50	76	2	-96	-100	-80	-991
ST													
ST													
AE	10	9	11	8	36	40	122	111	107	97	36	18	602
WD	74	98	139	186	233	144	0	0	3	49	77	69	1072
WS						83	51	76	5	-47	-23	-11	81

Source: Computed by author, Relevant data Obtained from IMD, Pune.

Table 2 Seasonal distribution of water balance parameters at the study region.

Season	Winter season					Summer season					SW monsoon					Post Monsoon				
Parameters	P	PE	AE	WD	WS	P	PE	AE	WD	WS	P	PE	AE	WD	WS	P	PE	AE	WD	WS
Volume.mm																				
Chalisgaon	8	186	13	173	0	21	614	47	567	0	617	521	354	148	110	91	345	139	206	21
Bhadgaon	6	203	17	3	0	15	615	46	178	0	609	544	366	7	110	73	341	143	638	21
Pachora	7	175	20	155	0	12	546	48	499	0	587	538	377	161	40	62	334	159	175	24
Jamner	8	153	17	136	0	22	495	54	441	0	664	496	375	114	130	76	319	149	170	45
Erandol	3	205	22	183	0	9	627	58	569	0	607	537	384	147	41	66	342	153	189	10
Parola	5	211	24	187	0	13	719	60	659	0	602	549	405	152	4	53	405	163	242	35
Amalner	3	212	21	191	0	8	670	56	614	0	555	534	371	154	22	64	357	130	227	30
Dharangaon	4	206	25	181	0	15	652	75	577	0	555	539	401	150	8	68	344	182	162	34
Muktainagar	11	170	14	156	0	14	574	49	525	0	545	476	371	110	45	69	314	129	185	30
Region	6	191	19	152	0	14	612	55	514	0	593	526	378	127	64	69	345	150	244	21

Reference: P = Precipitation, PE - Potential Evapotranspiration. AE = Actual Evapotranspiration.
WD = Water Deficit.WS = Water Surplus

Table 3 Climatic indices and climatic types of the study regionn based on Thornthwaites rational cliassification							
Mete. station	Im	Climatic code	TE	Climatic code	Ih	climatic code	Climatic types
Chalisgaon	-60.1	E	67.0	B_1	4	d	E, B_1, d
Bhadgaon	-59.2	E	67.7	B_1	4	d	E, B_1, d
Pachora	-58.7	E	67.4	B_1	5	d	E, B_1, d
Jamner	-56.8	E	66.4	B_1	4	d	E, B_1, d
Erandol	-53.8	E	69.8	B_1	5	d	E, B_1, d
Parola	-50.6	E	70.7	B_1	5	d	E, B_1, d
Amalner	-52.5	E	71.0	B_1	6	d	E, B_1, d
Dharangaon	-41.6	E	71.3	B_1	6	d	E, B_1, d
Muktainagar	-53.5	E	70.1	B_1	5	d	E, B_1, d
Region	-54.4	E	69.0	B_1	5	d	E, B_1, d
Source : Computed by researcher, Relevant data Obtained from IMD, Pune.							

Table 4: The Study Area Derived water balance parameters (AE and PE), Moisture Adequacy Index (Ima) and climatic types.					
Station	**PE (mm)**	**AE (mm)**	**Ima %**	**Climatic code**	**Climatic type**
Chalisgaon	1666	553.5	33.22	D	Dry
Bhadgaon	1703	572.0	33.59	D	Dry
Pachora	1593	603.0	37.85	D	Dry
Jamner	1463	595.1	40.68	D	Dry
Erandol	l171	617.5	52.73	Semi-moist	Semi-moist
Parola	1884	652.6	34.64	D	Dry
Amalner	1773	578.9	32.65	D	Dry
Dharangaon	1741	685.9	39.40	D	Dry
Muktainagar	1534	563.1	36.71	D	Dry
Region	1674	601.8	35.95	D	Dry
Source: Computed by researcher, relevant data obtained from IMD, Pune.					

When the soil is fulfilled with rain water after retaining the moisture to its field capacity surplus occurs usually in the month of August and September (30 mm).

Evaluation of Moisture Adequacy Index

Basically, this study focuses upon the assessment of soil moisture and to evaluate moisture status in soil according to their moisture holding capacity. In this context the climatologically water balance provides ecologically sensitive parameter like potential Evapotranspiration, Actual Evapotranspiration, Water Deficit and Water Surplus which are relevance to agriculture (Singh, 2005). In order to assess the soil moisture status, two water balance parameters are considered. The Moisture Adequacy Index (I_{ma}), defined as the ratio between actual Evapotranspiration (AE) and potential Evapotranspiration (PE) expressed in percent. It is a good indicator of the available moisture in the soil in relation to water need. The moisture adequacy index is a true representative of moisture affectivity, thus can be used in correlative studies of vegetation in relation to climate (Gautam *et al.,* 2012). An excess or deficit of moisture above or below field capacity in the root zone of the soil depends upon the relative magnitude of rainfall over the area. The information on spatial and temporal availability of moisture adequacy index could be help full for the optimal utilization of water resources (Mohapatra, 2016).

Lang's rain factor (1920)

In the study of agricultural planning and delimitation of climatic region, climatic aridity is used as an indicator. In this regard Land proposed a simple index i.e. rain factor. It is obtained by dividing the mean annual precipitation and mean annual temperature in degree Celsius. On the basis of Lang's rain factor the study area falls into the Semi-arid dry climate.

Koppen's climatic type

Koppen proposed his first vegetation based empirical climatic classification in 1918. It was revised and modified by him from time to time and the final form of scheme was presented in 1936. In his final classification he used certain critical values of temperature and precipitation. He accepted that vegetation is the best expression of the totality of climate so that his many of the climatic boundaries have been selected

with vegetation limits. The Koppen's system of climatic classification is largely quantitative. To find out the climate of the study area, mean annual precipitation and mean monthly temperature have been used as criteria. According to this scheme the study area experiences mesothermal type of climate.

Thornthwaite's rational classification of climate

In terms of water balance, Thornthwaite established a quantitative relationship between climatic elements and moisture availability essential for survival of vegetation to define climatic types (Singh and Singh, 2011). His new (after 1938 and 1948) scheme of climatic classification was based on the concept of potential Evapotranspiration (PE) the term coined by him and defined as the total amount of water that would be evaporated from the surface and transpired by plant species if there is no dearth of moisture. The degree of dryness and wetness of a place may be determined by computing the water deficit and water surplus in relation to water need. If the supply of water is less with respect to water need it will show water deficient situation but when supply becomes larger than the need, it shows the wet situation. The moisture index refers to moisture deficit or surplus in relation to potential Evapotranspiration i.e. water need. These indices are significant for delimitation of climatic types (Singh, 2012). On the basis of the climatic indices (code), the study area experiences D Semi - arid, Mega thermal third with little or no summer water surplus and summer concentration of third order Mega thermal type of thermal efficiency(E, B1, d) type of climate.

Ayoade' moisture adequacy index

In 1972 Ayoade presented a new concept of climatic classification which is primarily based on Moisture Adequacy Index. He suggested the ratio of actual Evapotranspiration to potential Evapotranspiration in percent as a better measure availability of a region. The Moisture Adequacy Index (I_{ma}) thus, is defined as the ratio between actual Evapotranspiration (AE) and potential Evapotranspiration (PE) expressed in percent. It is a good indicator of the available moisture in the soil in relation to water need. Thus I_{ma} might be useful indicator for irrigation planning in the study of agriculture for irrigation planning in the study of agriculture droughts and land use planning in applied climatology. I_{ma} value computed for the study region is shown in Table 4. Moisture Adequacy Index shows that the region enjoys Dry type of climate due to low I_{ma} values.

Conclusion

The above discussed water balance parameters show that there is a little water surplus (81mm) only in rainy season. The two major components to measure the degree of dryness and wetness i.e. PE Lang's rain factor index shows that study region lies in Arid type of climate, while as per Koppen's classification it comes into arid mesothermal type. Thornthwaite's revised scheme put the area into E, B1, and d type of climate. The Ayoade scheme provides the knowledge about moisture adequacy index which is basically the ratio of AE and PE expressed in percent. On the basis of moisture adequacy index the area experiences moist sub humid type of climate. Moisture Adequacy index is a good indicator of the available moisture in the soil in relation to water need. Such information is very useful for proper irrigation scheduling during the period of agriculture droughts.

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