Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol.5 (S1), pp. 1000-1007/Abounoori
Research Article

ANALYSIS THE ECONOMICS OF WATER-BUDGET IN TEHRAN USING THE THORNTHWAITE'S

***Abbasali Abounoori**
Department of Economics, Islamic Azad University, Central Tehran Branch, Tehran, Iran
**Author for Correspondence*

ABSTRACT
Drought is a random characteristic of natural phenomena, drought about by the irregular deficit or shortage of available water, affects injuriously the plant growth and reduces their yield. Drought is not a physical but a biological phenomenon and should, be defined separately for each plant species and environment. To estimate the intensity and frequency of drought will help to reduce the injurious effect of drought. In this study we used the water-budget methods and Thornthwaite's aridity index and its standard deviation for Tehran city of Iran during 1951-2013 to show the frequency and intensity of drought effects in this place. The result shows during this period this place is faced 32 times different type of drought on the five time disastrous and from the years of 2000 its severity and intensity is increased so far 2011 and 2012 the station is affected disastrous drought.

Keywords: *Drought, Evapotranspiration, Water-balance, Thornwaite's Aridity Index, Soil Storage*

INTRODUCTION
Drought is a period of only a few weeks without precipitation may be a serious matter for agriculture operations, particularly if the weather is hot and humidity low and irrigation project with adequate storage may operate several months without rain, an annual occurrence during the summer in the drought affected areas. The effect of drought and recovery of the region from it may be immediate or delayed, depending on the particular circumstances and the characteristics of the area and activity affected. The word "drought" itself means different things to different people, to the meteorologist, drought is a severe deficiency of rainfall, or rainless situation for an extended period, to a hydrologist, it is a depression of surface and underground water levels, or diminution of stream-flow, and dried-up wells and near-empty storage reservoirs. The agricultural or agronomist considers drought as moisture shortage foe crops or soil moisture deficiency. To the economist, on the other hand, drought means water shortage adversely affecting the established crop economy in the region.

Though the present study is intended to be inter-related or interdisciplinary, to peruse the problem and focus of attention is essentially economics of water.

Palmer (1965) defines drought as "an interval of time, generally of the order of months or years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply".

Van (1953) says, drought is a sustained period of significantly subnormal amount of moisture supply in which the available soil moisture is equal to or less than the water needed for satisfactory of growth of crops.

Subrahmanyam and Subramanian (1964) have defined drought as physical phenomenon producing serious biological effects mainly due to the moisture imbalance in the complex relation between the plant and its habitat.

According to Thornthwaite (1974) drought conditions prevail whenever precipitation is not sufficient to meet the needs of established human and other biological activities. Holding the same view, Mather (1974) also believes that drought occurs whenever the moisture-stored in the soil or occurring –from precipitation, is insufficient to fulfill the optimum water need of plants .

Hoyt (1949) says, if fresh demands of water are created for more than what is normally available in the development of a territory, drought situation are produced. Inferentially, it would seem to follow that, with the same given water deficiency in two areas in a climatologically homogeneous region, one may be said to be drought stricken, when, due to its poor economic development, it cannot fully utilize the available water to meet its needs, in contrast to the other, which is economically well established, and utilizes every drop of water available. So drought, in a general sense, has economic as well as hydrological implications. As drought affects the three main users of water, - plants, animals and men- water shortages has different degree of economic significance .

Morris (1974) pointed out that fluctuation of rainfall affected not only agricultural output, income and all economic activity but also the motivation of agriculturists' and their economic choices.

Thornthwait (1948) has classified drought into four kinds, permanent drought, seasonal drought, contingent drought and invisible drought. Another classification is Meteorological drought (absolute drought and partial drought) Hydrological drought, Agricultural drought. The hydrologic drought is not only of engineering significance but also has a socio-economic concern.

The focus of this study is an analysis of the nature, the magnitude, and the impact of drought on Tehran city of Iran for the period of 63 years (1951-2013.)

MATERIALS AND METHODS

To begin with a mere description of the physical and practical picture of drought, one set of opinion holds the view that drought s have long since been recognized as one of the severest catastrophes of nature against man, but no systematic methods have yet been developed either for their complete understanding or for their prediction.

Notwithstanding the facts, several attempts have been made by climatologists, hydrologists and scientists from other disciplines to delimit drought –prone areas taking into consideration several parameters such as average rainfall, rainfall variability, water availability periods evapotranspiration, soil moisture storage etc., either individually or collectively and there have appeared works in the form of indices such as Thronthwaite (1948), Penman (1963) and Palmer' (1968). In the forthcoming views, Subrahmanyam *et al.*, (1964) Padmanabhamurthy (1968), and Subrahmanyam (1982), all these techniques have been considered in assessing the intensity of drought.

The methods that can be adopted fall into three broad types which are discussed by Abounoori (1988):

a) Statically techniques,

b) Non-statically techniques, and

c) Water-budget methods.

In this paper we used the water –budget methods. This methods using water availability and soil moisture as done by Palmer (1965), Penman's index (1963), Subrahmanyam (1982), Thornthwaite (1948), Abounoori (1988), Wilhite (2005) and others to estimate the drought.

Whereas statistical techniques are quantitative in character, they often back the physical background, while the non-statistical ones are purely empirical. These two techniques are mainly based on an arbitrary relation between temperature and precipitation. The water-budget methods, on the other hand, are not only quantitative but are also based on rational concepts.

According to the water-balance approach drought is a condition in which the amount of water demand for transpiration and evaporation exceeds the amount obtainable from rain and soil. Hence, moisture deficiency and aridity indices derived from water-balance form an important aspect of the study.

Thronthwaite (1947) determined that drought can never be defined in terms of rainfall shortage alone, since it does not take into account either the water-need of the region or the important role of soil moisture for plants. The mere cessation of rainfall is not an indication of the beginning of drought.

Agricultural production is strongly geared to the water-budget which is determined by water supply (precipitation) and water demand (evapotranspiration).Thus, drought for agricultural purposes depends not only on rainfall but also on evapotranspiration and moisture –retaining capacity of the soil. So the water-balance technique or budgeting method, though known for a long time, is used on a systematic basis by Thornthwaite (1948). In this study, the intensity and frequency of drought in Tehran city of Iran are studied by adopting Thornthwaite's aridity index analysis as modified by Subrahmanyam and Subramanian (Thornthwaite, 1948).

Data for the present study for precipitation and temperature are collected from both primary and secondary source of publication of the Iranian Meteorological Organization (Iranian Ministry of Information Iran, 1969) for the year 1951-2013.

RESULTS AND DISCUSSION

The term water budget or water economy recognizes the fact that as strict balance is not always possible because inflows do not equal out flows at a particular place and time.

Precipitation, evapotranspiration (as the combined water loss from soil and vegetation), run-off, soil moisture, and groundwater, each of them is a component of the hydrologic cycle. The climatic water balance method is merely a monthly comparison of the precipitation with the potential need for water or potential evapotranspiration (PE). It provides quantitative information on the magnitude of the periods of water surplus and water deficit during the years. Thornthwaite and Mather (1955, 1957) introduced revised procedure for the assumption of the moisture –holding capacity of the soil as well as for the rate of utilization of soil moisture for evapotranspiration when P (precipitation) fall short of PE, for the moisture-holding capacity of soil depends on its depth, type, and structure. So Thornthwaite and Mather (1955, 1957) increased the moisture –holding capacity of the soil from 100mm to 400 mm and also introduced an exponential depletion pattern of soil moisture during dry periods. They have also assumed the following relationship.

i.e, $S=F.\ e^{(A/F)}$

Where A is the accumulated potential water loss i.e., accumulated values of PE-P [or-(P-PE)] over different periods, and F is the field capacity. Taking logarithm we got,

$\ln S = \ln F + A/F$

Expression of this in differential form produces

$\Delta S/S = \Delta A/F$

Where ΔS is the amount available from soil moisture storage for evapotranspiration (ET) and ΔA is the PE- P value for the period concerned. Thus, ultimately we get a linear model, implying that the change in soil moisture storage that will be available for making up the deficiency for the period concerned is equal to (storage × available moisture capacity) × deficiency. In some stations precipitation (water supply) is always more than the PE so that the soil remains full of water and a water surplus (WS) occurs. In other places, month after month, precipitation (P) is less than potential evapotranspiration (PE) or water need, there is not enough moisture for the vegetation to use and a moisture deficit (WD) occurs.

To illustrate the climatic water budget book-keeping procedure, let us consider the average monthly march of water supply (Precipitation, P) and temperature (T) in °C, to calculated evapotranspiration (E, water need) in potential (PE) and actual (AE), water surplus (WS) and water deficit(WD) for Tehran station in Iran. The average monthly values are given in table I, along with the other steps in the climatic water budget book- keeping procedure.

Table 1: Climatic water-balance computation for Tehran, 19

Item	January	February	March	April	May	June	July
TC°	1.9	3.5	10.6	18.6	22.9	28	31.6
I	0.23	0.58	3.12	7.31	10.01	13.58	16.3
UPE	0.1	2.4	21.7	66.5	100.7	150.3	191.4
PE	0.1	2	22.4	72.5	121.8	181.9	235.4
P	47.9	63.3	43.7	23.9	3.5	0.2	0
P-PE	47.8	66.3	21.3	-48.6	-118.3	-181.7	-235.4

APWL	-	-	-	-48.6	-166.9	-348.6	-584
ST.	200	200	200	156	86	34	10
ΔSt.	188.1	0	0	-44	-70	-52	-24
AE	0.1	2	22.4	67.9	73.5	52.2	24
WD	0	0	0	4.6	48.3	129.7	211.4
WS	47.8	66.3	21.3	0	0	0	0

Item	**August**	**September**	**October**	**November**	**December**	**Annual**
	30.1	25.4	18	12.7	7.9	17.6
	15.1	11.7	6.95	4.1	12	91.04
	173.	123.	62.3	31.7	12.1	
	201.5	127.5	60.4	27.3	10.3	1063.1
	0	0	4.5	22.5	20.2	234.7
	-201.5	-127.5	-55.9	-4.8	9.9	-828.4
	-785.5	-913	-968.9	-973.7	-	-
	4	2	2	2	11.9	-
	-6	-2	0	0	9.9	-
	6	2	22.5	22.5	10.3	287.4
	195.5	125.5	4.8	4.8	0	775.7
	0	0	0	0	0	135.4

In this table:
T = temperature in ℃, i= heat index,
UPE= unadjusted PE, PE= Adjusted PE, P=Precipitation,
APWL =Accumulated Potential Water Loss
St. = Soil storage, (In this station storage capacity in soil is 200mm)
Δ St. = Soil storage change
AE = Actual evapotranspiration,
WD = Water deficit (or moisture deficit)
WS = Water surplus (or moisture

At Tehran, in May PE (122mm) is 118 mm greater than the P (4 mm).While this is the potential loss of water from the soil actually only 70 mm of moisture is removed from the soil. Evapotranspiration cannot go on the potential rate for the soil moisture content does not remain at the optimum evapotranspiration.

Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol.5 (S1), pp. 1000-1007/Abounoori

Research Article

When the P is greater than the PE, the AE equals the potential for at those times there is sufficient moisture in the soil so that evapotranspiration can proceed unhindered. When the P is less than the PE, the AE equals the P plus any moisture stored in the ground which is evaporated or transpired (the storage change).

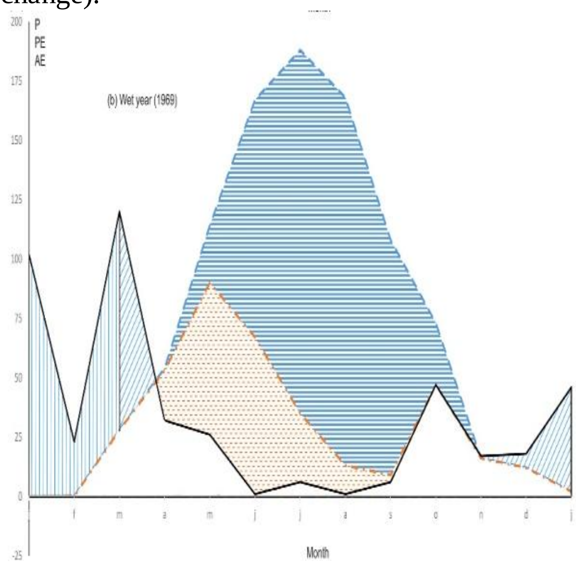

Figure 1: Water balance of Tehran-Wet year (1969)

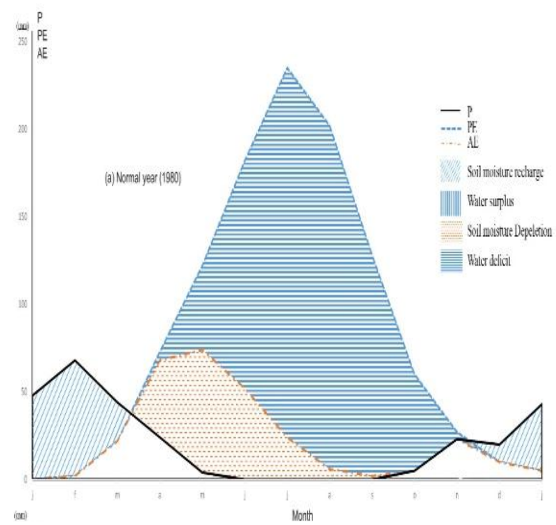

Figure 2: Water balance of Tehran-Normal year (1980)

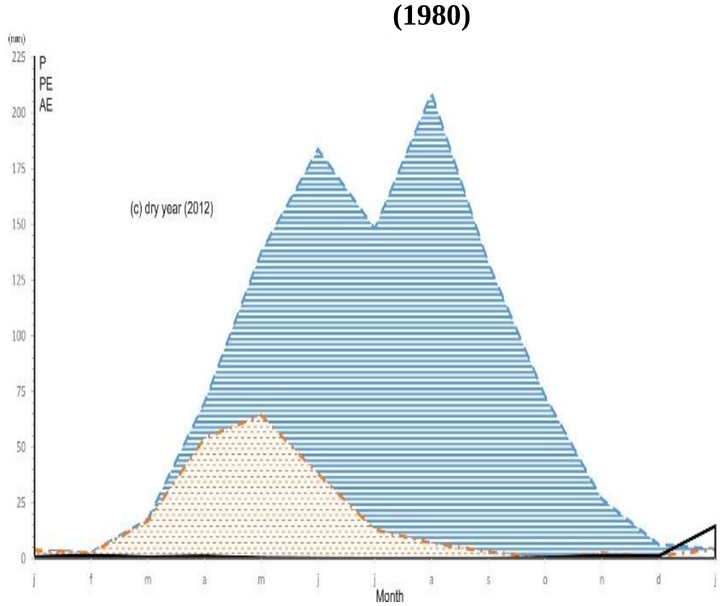

Figure 3: Water balance of Tehran-Dry year (2012)

Moisture or water deficit and surplus follow simply from the book-keeping calculation, the former being the difference between potential and actual evapotranspiration while the latter is the excess precipitation which occurs when the moisture holding capacity of the soil layer under consideration is full of water. At Tehran, in the normal year of 1980, average monthly temperature vary from 1.9 ℃ in January to a high of 31.6 ℃ in july.PE, which is closely related to temperature varies regularly through the year from low values of 0.1 mm in January. To peak values of 235.4 and 201.5 mm. respectively, in July and August PE increase rapidly in spring from less than 22.4 mm in March to 182.9 mm in June and decreases just as rapidly in fall from 127.5 mm in Sept. to 10.3 mm in December. Total climatic water need for the year equal 1063.1 mm.

Precipitation, or water supply, is much less variable through the year. The average annual total of 234.7 mm is evenly distributed, with each month receiving on the average more than 20 mm. Low value are found in spring and summer with 3.5 mm in May and zero in July to September, highest values come in the spring period with 68.3 mm in February and 23.9 mm in April. Thus the wettest period from the stand – point of P is also the period of greatest demand for water in terms of PE. Comparing P with PE on a monthly basis, one finds that they never coincide. There is too much precipitation in winter and too little in summer. In December, the P (20.2 mm) over and above that needed (10.3mm) for evapotranspiration is stored in the soil and results in the upper layers being brought to field capacity. After the soil is at field capacity, any P not needed for evapotranspiration is considered to be surplus and ultimately lost as run-off. Surplus thus increases from 47.8mm in Jan. to 21.3 mm in March and zero from April to December.

Precipitation is greater than the potential climatic water need from January through March on the average. The soil remains at field capacity from January, and some water is added each month to surplus. April is the first month in which the rapidly rising climatic water needs finally exceed the supply of water from P, P fails to supply the water needs by 48.6 mm in April (P-PE = -48.6). Some of this need is supplied by the water stored in the upper layer of the soil (change in storage = -44), but ultimately 4.6 mm (48.6- 44 mm) is not supplied by either precipitation or stored soil water. This is, therefore, the water deficit. In July 235.4 mm of water need is not supplied by precipitation. As the soil dries water is less available from the upper soil layers and only 24 mm is removed from the soil to help supply the need. Deficit in July reaches 211.4 mm.

Storage, which has been at field capacity (200mm) all winter, decrease during the spring as more water, is removed to supply at least some of the water needs. The lowest value of storage is found in September to November (2mm). Storage is quickly brought back to field capacity in December and January as the precipitation in excess of the water-need is retained in the upper soil layers.

While average PE in Tehran is 1063.1 mm year, actual water loss or evapotranspiration equals only 287.4 mm, resulting in a deficit of 775.7 mm. Since average annual precipitation is 234.7 mm and only 287.4 mm are actually lost by evapotranspiration, the annual surplus of water must equal the difference or 135.4 mm.

Based upon the yearly concept, march of aridity indices whose departures from the median and their climatic water-balance situation in normal, driest and wettest years have been presented in Figures-1,2 and 3.

The water budget elements for the normal as well as extreme cases are presented in Figure-1 special attention are paid in analyzing the variation in water budget elements during the study period.

Figure-1 shows that during the normal years, Tehran had a distribution of precipitation that produced a mild water surplus in the months of January to March and recharge of soil moisture in these months. In the wet period of the year 1969, Figure-2, rainfall was about the normal year, causing a mild water surplus in the month of Jan. To March and December, due to 222.9 of surplus of water the resulted from this period water deficit fell by about 775.7 mm of the normal. The water surplus, after compensating the effect of the water deficit, maintained the moisture status at arid category with the moisture index of Im =-31.1 percentage. On the other hand, in the dry period of the year 2012, Figure-3, inactive period resulted only with 14.6 mm of precipitation. As this could not meet the bare water need in any month of the year, water deficit of 16.7 times the normal value resulted thereby shifting the moisture index to -47.9 % compared to the normal year with a moisture index -31.1.

Therefore, acute water deficiencies commence almost immediately after the cessation of rainfall. In the dry year of 2012, the slight amount of rainfall could not meet the water need of the station at any month of the year and the station has got shifted to drier category, hence the moisture status of the station standard to arid category, with -70.1 the moisture index.

The intensity and frequency of drought, their severity and duration are considerations of great practical importance, especially in agricultural and hydrological planning, for, the crucial question is, for a given quantity of water, whether it is a brief drought of instance severity or a long one of mild severity that has a greater economic impact.

Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/01/jls.htm
2015 Vol.5 (S1), pp. 1000-1007/Abounoori

Research Article

A clear understanding and better appreciation of the problem of drought and aridity become possible after (Thornthwaite, 1948) laid the basis for water –balance methods and followed it up with a scheme of rational climatic classification based on the book –keeping procedure of water- balance. For the analytical study of droughts with special reference to their frequency and intensity over Tehran, the following scheme (Subrahmanyam, 1982) has been used here.

Table 2: Categorization of Drought

Departure of Ia from median	Drought intensity
Less than 1/2 σ	Moderate
Between 1/2 σ and σ	Large
Between σ and 2σ	Severe
Above 2σ	Disastrous

Ia is the Aridity Index which has been derived from Thornthwaite's method (1955, 1957). It is the ratio of annual moisture deficiency to annual water need. σ is the standard deviation of Aridity Index during the period of investigation.
Figure -4 shows the severity of drought has been brought out, using standard deviation calculated in relation of median. During the study period (1951-2013) Tehran experienced 32 times difference type of drought, 13 moderate, 3 large, 11 severe and 5 time disastrous drought. The Figure -4 shows that the Aridity Index from the median is Ia =70.1 and the standard deviation of Aridity Index is □ =4.69.The disastrous drought was for 2012 with Ia = 79.9 and lowest Ia was for 1952.

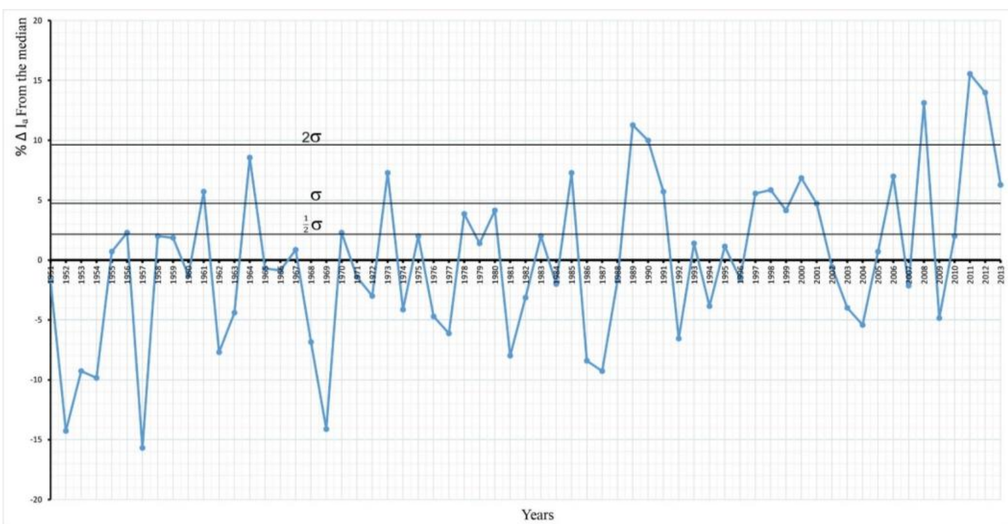

Figure 4: Frequency and intensity of drought - Tehran

Conclusion

This study shows that Tehran station is that in which there is only water deficiencies moisture most of the months of the year and water surpluses of any kind is climatically unknown. The rainfall occurs in winter season and then declines to practically zero value by May remaining so until perhaps to December. The precipitation water evaporates as fast as it comes with the result that there is no accumulation of any moisture in the soil at any time of the year. The capital city of Iran, i.e., Tehran during its study period (1951-2013) experienced a total of 32 different types of droughts.

REFERENCES

Abounoori AA (1988). Agricultural development in drought-prone areas of Iran, Ph.D. Thesis, Submitted to S.V. University in India.

Hoyt WG (1949). *Droughts, in Hydrology*, edited by Meinzer DE (Doven publication) New York 579-591.
Iranian Ministry of Information Iran (1969). the Ministry, Tehran, Iran.
Mather JR (1974). *Climatology, Fundamentals and Application* (MC-Grew-Hill) **6** 167.
Morris DM (1974). What are a Famine, *Economic and Political Weekly* **44**(9) 1855-1864**.**
Padmanabhamurty B (1968). An Agro-Climatic Index of Aridity, In: *Proceedings of the Symposium on Cropping Patterns in India*, I.C.A.R., Delhi, India.
Palmer WC (1965). Meteorological droughts, Weather Bureau, Research paper No.45, U.S. Dept. of commerce, Washington, D.C. Bur 58.
Palmer WC (1968). Keeping track of crop moisture conditions nationwide, the new moisture index, weather wise **21** 156-161.
Penman HL (1963). Vegetation and Hydrology. *Commonwealth Bur Soil Science (Gt Brit) Technical Communication* **53** 124.
Subrahmanyam VP (1982). Water balance and its applications, Andhra University of India.
Subrahmanyam VP and Subramanian AR (1964). Application of water-balance concepts for a climatic study of droughts in South India, *Indian Journal of Meteorology, Hydrology and Geophysics* **15**(3) 393-402.
Thornthwaite CW (1947). Climates and moisture conservation, *Annals of the Association of American Geographers* **37**(2) 87-100
Thornthwaite CW (1948). An approach towards a rational classification of climate, *Geographical Review* **38** 55-94.
Thornthwaite CW and Mather JR (1955, 1957). *The Water Balance* (publications in Climatology) **8**(1) (1955), Drexel Institute of Technology, laboratory of Climatology, Center ton, N.J. 104 **10**(3) 244 (1957).
Van Bavel CHM (1953). A drought criterion and its application in evaluating drought incidence and hazard, *Agronomy Journal* **45**(4) 167-172**.**
Wilhite DA (2005). *Drought Water Crises*, Taylor and Francis Group (CRC press) 431.