

DROUGHT; ITS DEFINITION AND METHODOLOGY

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Introduction:

Studies have been progressing in areas most affected by drought i.e: South West and Midwest of United States, Australia, India, U. S. S. R., Brazil and the Sahel zone. These studies differ in their definition of drought and in following a methodology. These attempts have also been made in Sri Lanka recently.

"Drought" and its alternative spelling "drouth" trace their etymologies to the Anglo - Saxon "drouth" meaning "to dry". The words are characteristically associated with the undesirable aspects of being without water (Thomas H. E. 1962). Dictionaries also indicate a widespread and somewhat varied use of the word "drought".

- (a) Dry weather, especially when so long continued as to cause vegetation to wither; want of water or rain; aridity.
- (b) Dryness of the throat and mouth for want of water; thirst.
- (c) Figuratively, Scarcity of any necessity; dearth.
- (d) Dryness; also a desert (Ibid)

The Encyclopaedias describe some sort of different meaning and definition to each other. The Encyclopaedia Britannica suggest that: "Drought or drouth, lack or insufficiency of rain for an extended period that causes a considerable hydrologic (water) imbalance and consequently water shortages, crop damage, stream-flow reduction and depletion of ground water and soil moisture. It occurs when evaporation and transpiration (the movement of water in the soil through plants into the air.) exceed precipitation for a considerable period."

The encyclopaedia Americana indicates that:-

"Drought, drouth, is a deficiency of water in the ground, streams, lakes and reservoirs resulting from a prolonged deficiency of rain and snowmelt. Drought is essentially an imbalance of the hydrological cycle. Thus drought can simply come from a deficiency in precipitation over a period of time, or it may be caused by excessive evaporation

and transpiration". The Australian Encyclopaedia states somewhat different aspect from the above definitions. It describes that:

"Prolonged periods of dry weather occurring at more or less regular intervals and sometimes covering large parts of the Continent..... Drought is a relative term and definitions vary widely through out the world. The listing of drought is therefore, rather subjective, often depending on the observer and the type of the country or primary Pursuit. Low rainfall, stock losses, water and feed shortages, stock movements, bushfires and dust storms have all been taken into account when classifying drought as severe".

These definitions in Dictionaries and Encyclopaedias have not been taken into account when analyzing drought by the various investigators in the various climatic regions. The criterion for the Southwest and Texas droughts is different from New England drought. Also the definitions for Australian droughts could vary from the definitions which describe the drought events in Sri Lanka or India.

I. O. Problem of Defining Drought

According to Harding (1970) comparatively little attention has been paid to the study of drought and drought hazards. This is more or less true in comparison with other meteorological and climatological phenomena and also it could be said that it is one of the fields which needs more attention. Very recently, however Palmer and Denny (1971) have published a bibliography of drought in which the investigations, carried out in various countries in various languages) have been included. The problems of defining drought have been discussed in different ways by a number of authors.

It is true that the "various investigations have been with different aims and approaches, have derived and used different definitions based on quite different criteria" (Harding 1970). Before considering these works in detail, it can be said that drought has been considered as a hydrological, meteorological, agricultural or economic feature in which:

"Meteorological drought has been defined as a prolonged and abnormal moisture deficiency" (Palmer 1965, Donald J. Fieldhouse and Palmer 1965).

or:

"Drought is a meteorological phenomenon and occurs during a period when precipitation is less than the long term average and when this deficiency is great enough and continues long enough to hurt mankind" (Thomas H. E. 1962)

According to Yevjevich (1967) "the engineer views drought as a set of variables affecting rainfall, run-off and water storage in its many forms. The Geophysicists view of drought may be climatological, general meteorological, hydrological, limnological, glaciological or concerned with aspects of soil physics. The economist views drought from an entirely different point of view, in terms of the areas of human activity affected. In his eyes there are agricultural droughts, water supply droughts, and droughts involving fish, wildlife and range management, to name only a few. The Agriculturist has another point of view, closely tied to the water needs of various crops..... (for each crop); the concept of drought changes during the growing season, mainly by climatic variations, growth state, and the ways in which the crops are cultivated".

According to Fieldhouse and Palmer (1965) drought calculations on a purely agricultural basis, must take account of the kind of crop, its stages of growth and rooting depths as well as the characteristics of the soil and the various meteorological factors that daily affect moisture supply and demand.

From an ecological point of view "drought is an extended period of dryness that is a period moisture deficiency below the normal for the area".

1. 1. Usages in Meteorological Institutions :

Most of these definitions are based on a particular duration of a time without precipitation. The best known definition in this way is probably that formerly used by the British Meteorological Office in which an:

"Absolute drought defined as a period of at least 15 consecutive days to none of which is credited 0.01 inch of rain or more"

A "partial drought defined as a period of at least 29 consecutive days, to none of which the mean daily rainfall does not exceed 0.01 inch of rain"

And a "dry spell defined as a period of at least 15 consecutive days, to none of which is credited 0.04 inches of rain". (Subrahmanyam V. P. 1967)

In a SriLankan context these are the definitions used to find out the absolute and partial droughts and dry spells. (Reports on the Colombo Observatory)

The United States Weather Bureau defined drought as a period of 30 days or more with deficient rainfall and not in excess of a quarter of an inch in any 24 hours. The American Meteorological Society defines drought as a prolonged and abnormal moisture deficiency (Palmer 1965) In Australia 70 percent of

the Australian rainfall never exceeds evaporation in any month of the year.

Only a few of the classical investigators, such as Cole (1933) and Blumenstock (1942) have followed the above type of definitions. As far as the meteorological offices are concerned, this method is followed in many countries. "Because of the difficulty of similarly keeping water accounts for extensive areas, drought is usually defined as a period of consecutive days without rainfall" (Thomas H. E. 1962)

1. 2. Deficiency from the Normal as Drought Definitions.

In previous studies of drought in the United States by the Geological Survey it has been customary to identify the area of drought on the basis of meteorological records (Ibid). For Australian conditions Foley (1957) describes:

"A period of rainfall deficiency extending over months or years can be stated as drought",

Gibbs and Maher (1967) pointed out that:

"rainfall is the best single indicator of drought"

Heathcote (1969) also suggested:

"For Australian conditions, however, rainfall seems to be sufficient"

On the deficiency in precipitation as a drought definition Heyt J. C. (1938) writes:

"although deficiency in precipitation, is the prime cause of drought, it is not possible to set for any region an exact limit of the total annual precipitation above which a drought does not exist and below which a drought may prevail. In general however, in the humid and semiarid states there are no serious drought effects unless the annual precipitation is as low as 85 percent of the mean that is, unless there is an annual deficiency of 15 percent or more. This limit is used in the present report as a measure of a drought year and may serve in many drought studies". (as quoted by Thomas H. E. 1962).

Baldwin - Wiseman (1934) did valuable drought studies in Queensland by using a definition in terms of deficiency of normal rainfall. In this research he pointed out that:

"Symons suggested many years ago that a deficiency of 50 percent or more from the mean rainfall of three or more consecutive

months should be described as an "engineers drought" and the author has adhered to this convention throughout the analysis of the Queensland record....."

Foley (1957) identified droughts in terms of residual mass curve (cumulated residual curve or deficiency mass curve) and in his words "residual mass" or a "cumulated residual" graph is that which shows up at once a succession of deficient or excess months or years of rainfall both in regard to duration and amount of deficiency or excess. In this respect it may be said to be superior for the purpose in hand to any other method of graphing rainfall. In this study residuals have been expressed in units of thousands of the annual rainfall.

In 1935, Bates also stated that drought occurs when the annual precipitation is 75 percent of the normal or when the monthly precipitation is 60 percent of the normal. (Quoted by Subrahmanyam V. P., 1967)

Thomas H. E. (1962) also follows the deficiency in the average precipitation (long term) as a drought definition when he was discussing the drought and the effects in the Southwest United States.

Summarizing droughts definitions he found that the term "drought" has been commonly applied, rather inconsistently, to three major forms of dryness.

- (a) A natural condition caused by less than average precipitation over a certain period of time.
- (b) A natural condition where the average precipitation is low.
- (c) Nature's failure to fulfil the or to meet the developed requirement of man.

From these Thomas (1963) selected form (a) as "drought" as a meteorologic phenomenon and occurs during a period when precipitation is less than the long term average and when this deficiency is great enough and continues long enough to hurt mankind. Drought is thus measured in terms of the duration and magnitude of the departure from the average climate in the area under consideration.

Troxell (1957) also used precipitation deficiency to find out wet and dry period even though his approach was different. Huff and Changnon (1963) discussed the severity of droughts from the length of the period of monthly precipitation deficiency below normal. Severity indices were obtained from frequency diagrams

on log - probability paper between the percentage of normal precipitation and recurrence interval (quoted by Subrahmanyam V. P. 1967). In India Ramdas (1950) considered drought as an occasion when the actual rainfall for a week was half of the normal or less. Departure from normal or seasonal rainfall (June to September) was used to assess the frequency and intensity of droughts by Banerji and Chabra (1963). In Sri Lanka the assessment of drought was carried out by following the same method (Balachandiran 1975). Agricultural drought over Gangetic West Bengale was analysed by following this method too (Swedish Mishna) 1983.

1. 3. Definition by Hydrologic Accounting Technique

When defining drought Palmer (1965) said that the water balance or hydrologic accounting technique to climatic analysis allows one to compute a reasonably realistic picture of the time distribution of moisture excesses and deficiencies.

The foremost among these water balance techniques is that of Thornthwaite (1948) and according to him 'in permanent drought, precipitation is never sufficient to meet the needs expressed by the potential evapotranspiration'' (Encyclopaedia Britannica 1963 quoted by Thomas F, S. 1966.)

On the basis of the well known Thornthwaite, (1948) and Thornthwaite and Mather (1955) water balance concept, some investigators tried to classify droughts in India. The aridity index (the ratio of the annual water deficiency to the total annual water need expressed as a percentage) is considered to be a very useful parameter for drought studies (Subrahmanyam 1967), Subrahmanyam & Subramaniam 1964., Subrahmanyam and Sastri (1969). According to this scheme droughts and their severity are determined by the departure of the aridity index from normal classified by using the standard deviation (σ) as a unit and categorization of droughts has been done by assuming various arbitrary limits of standard deviation. Subrahmanyam and Sastri (1969) used "Median" on the basis that they think that the Median is a better and more realistic average than the simple arithmetic mean which was used by Subrahmanyam and Subramaniam, (1964) to show the normal.

TABLE 1

Scheme of Drought Classification:

(Subramanyam & Sastri 1969).

Departure of Aridity Index

from the median	Drought Intensity
$< \frac{1}{2} \sigma$	Moderate
$\frac{1}{2} \sigma$ to σ	Large
σ to 2σ	Severe
$> 2 \sigma$	Disastrous

In India various research workers such as Choudhury, Ramastry and Rentalag (1977), George and Ramasastry (1972 & 1975) used the water balance Technique (Aridity Index). Further Jutta Dikshit (1983), followed the aridity index method when explaining drought in Maharashtra, Subramaniam A. R. and M. Venkateswara Rao (1983) followed the same method in the Rayala seema region (Deccan). When explaining the Kharif agricultural drought in India the particular method had been employed by Appa Rao G. and G. S. Vijayaraghavan (1983). In the same way study of agricultural drought over India was also made by Appa Rao (1982).

By using the potential evapotranspiration computed from Thornthwaite's formula by means of the Palmer-Havens Diagram (Palmer and Heaxens 1958) Palmer analyzed the meteorological drought by stating the main concept that "the amount of precipitation required for the near-normal operation of the established economy of an area during some stated period as dependent on the average climate of the area and on the prevailing meteorological conditions both during and preceding the month or period in question (Palmer 1965). He therefore, regards soil moisture as an index of accounting based on Thornthwaite's method (Thornthwaite 1948 & Thornthwaite and Mather 1955) and taking into account the amount of moisture required for normal weather during each month, in the area in question, deviations from this normal weather are expressed in terms of a numerical index. In this index positive values indicate wetter than normal conditions. In table 02 the positive classes are not given.

TABLE 2

Negative Classes which Represents the Degree of Drought Severity (Palmer and Fieldhouse 1965)

Positive Classes are Omitted,

— 0.05	to	— 0.99	Incipient Drought
— 1.00	to	— 1.99	Mild „
— 2.00	to	— 2.99	Moderate „
— 3.00	to	— 3.99	Severe „
		— 4.00	Extreme „

Many drought investigators have followed Palmer's technique in their studies. For the whole of India (Excluding Assam, Jammu and Kashmir, Konkan and Coastal Mysore where very high run-off prevails) the spectral analysis of drought (index) by means of Palmer's technique has been performed (Rao et al 1973). Incidence of drought in Andhra Pradesh, Tamil Nadu and Mysore (South Indian States) has also been analyzed by means of the same technique (George et al 1972). On the basis of Palmer's approach Vaiksnovas et al (1973) analysed Tennessee drought and Weedfall disussed droughts in west Virginia, (1969)

1.4 Definition by Moisture Status index

Palmer's drought index has been added to by a new index called the Moisture Status Index which is introduced as a measure of the wetness or dryness of place at a given time by Shear and Stella (1973). They made an assessment of drought intensity by this index in Kentucky and Tennessee. According to them paralleling Palmer's definition, drought is defined as an interval of time during which the actual moisture status of a given place falls short of the mean moisture status of that place, So the magnitude of drought is a function of both the duration and intensity of the monthly moisture deficiency.

TABLE 3

Categories of Drought (Shear and Stella 1973)

Moisture Status Class	Drought Index
Above Normal	— 1-00
Near Normal	— 0.99 to 0.99
Mild Drought	— 1.00 to — 1.99
Moderate Drought	— 2.00 to — 2.99
Severe Drought	— 3.00 to — 3.99
Extreme Drought	— 4.00

1.5 Soil Moisture Based Definition

Soil moisture has been regarded as the most important variable in defining drought. Especially in humid zones, several scientists define drought on the basis of the deficiencies in soil moisture as stated earlier i. e. water balance approaches. It was pointed out by Thornthwaite (1963) that drought is most accurately described as a condition in which the amount of water needed for transpiration and direct evaporation exceeds the amount available in the soil.....
..... the effect of a shortage of rainfall depends on whether soil is moist or dry at the beginning of the period. Further more he says that drought does not begin when rain ceases but rather only when plant roots can no longer obtain soil moisture. In relation to the same aspect, Shantz (1927) had already pointed out that drought in its proper sense is related to soil moisture and that it begins when the available soil moisture is diminished
(Quoted by Thomas H. E. 1962)

As far as soil moisture itself is concerned Rodda (1965) has analyzed droughts in South East England, giving more importance to soil moisture rather than to hydrologic accounting techniques by forming a soil moisture index. In his own words:

“ Nevertheless there is a real difficulty in obtaining a wholly satisfactory definition of the drought phenomenon not only because drought has a variety of meanings, but for the reason that effectiveness of precipitation is a seasonal feature. A further consideration is that the effects of lack of rain can be greatly modified by conditions existing in the soil due to the previous rainfall. Indeed soil moisture content provides perhaps the best single drought criterion”.

Though Rodda's scheme also is based on hydrologic accounting techniques, it is different from them in some degree because it gives priority to the Penman method (1949) of calculating potential evapotranspiration and also give priority to soil moisture to derive the drought index.

Important studies on drought in the Soviet Union revealed the recognition that the unbalanced state between the available soil moisture and the water needs of plants is a specific feature of drought and the greater this imbalance is the more severe is the drought (Subrahmanyam 1967)

1.6 Statistical Runs as Definition

In this definition, the term drought in a hydrological sense is defined as the deficiency in water supply on the earth surface or the deficiency in precipitation, effective precipitation, run off or in accumulated water in various storage capacities (Yevjevich 1967). Strictly, he says basically a hydrologic drought means a deficit of water supply in time and area or both.

In a search for objective definition for drought he describes that runs as statistical properties of sequences, both, in time and area, represent the best basic concepts for an objective definition of droughts. The runs of the sequences of a stochastic variable (or combination of stochastic and deterministic components making a composite sequence) may be defined in various ways.

In Australia, following Brooks and Carruthers (1953), Body (1966) has calculated the number of occasions when runs of monthly rainfall have been less than or equal to the medium value i. e. probability - 0.5, 0.3, 0.1 etc. (quoted by Mather 1967), Persistence ratio and its confidence limit in terms of runs is also discussed by Body (1966). Runs of dry spells were also studied to identify drought by Banerji and Chabra (1963).

1.7 Rainfall Deciles as Drought Indicators

In Australia, Gibbs and Mather (1967) describe drought in terms of the rainfall deciles for the period of 1885 - 1965. They defined drought as the following: "if the minimum water need for a given period of time is met by rainfall of a given amount "X", drought may be said to occur whenever the rainfall during that time interval is less than "X", and severity of drought linked to the amount by which rainfall falls short of requirement",

They suggest that by selecting the decile method, if rainfall amounts are not normally distributed, rainfall occurrence is best described by quoting the limits a certain proportion of the occurrences, and it is possible to indicate that a certain percentage of values fall below a stated limit. This method of describing distribution is to state limits of each ten percent (or decile) of the distribution. Thus the first decile is that rainfall amount which is not exceeded by the lowest 10% of totals, the second decile is the amount not exceeded by 20% totals and so on. The decile ranges are the ranges of values between deciles, thus the first decile range is that below the first decile, the eight decile range between deciles seven and eight and so on.

TABLE 4

Decile Ranges		Decile Range
Very much above "average" — highest	10%	10
Much above average — next highest	10%	9
Above average — next highest	10%	8
Slightly above average — next highest	10%	7
Average — middle	10%	5 & 6
Slightly below average — next lowest	10%	4
Below average — next lowest	10%	3
Much below average — next lowest	10%	2
Very much below average — lowest	10%	1

There were more studies carried out by using the decile method at Mysore state (Surya narayana et al 1971); and at Bihar State (George c. j, and Kalyana-sundaram 1969) in India. The same method also had been followed in analysing drought in Sri Lanka (Domros 1978)

1.8 Want of water Concept

Thomas H. E. (1962) quoted this approach stating clearly that:

"In connection with present day activities of a highly organized civilisation, it is increasingly difficult to define and delineate drought on the basis of a study of meteorological and hydrological conditions alone! (Hoyt W. G. 1942)

Thomas H. E. also suggests that the water needs for established human activities are an essential criterion for drought condition. Troxell (1957) followed Hoyt's view, in determining the severity of drought. It has been necessary to study both the meteorological and hydrological factors as well as the water requirements of the inhabitants. The severity of the drought is then represented by the combination of these three factors.

According to Troxe ;

" to the city dweller as well as to the Agriculturist, a drought exists whenever he is required to reduce his water uses....."

The frequency of a drought will depend largely on the amount of water requirement. If the reservoirs are large in terms of the water requirement then many a period of deficient precipitation may pass without any curtailment of the water requirements and the drought may go unnoticed as a meteorological phenomenon"

He goes on to say that a period of different precipitation is recognized as a drought where reservoirs are small.

2.0 Conclusion on the Definitions

In addition, drought has been studied in relation to atmospheric circulation by Namias (1972) in the United States and Brazil and by Ramage (1968), Ramasamy (1972) in monsoon areas in India. The shift of global circulation systems and the prevalence of droughts were discussed by Lamb (1974) and Winstanley (1973). Charney (1974) discussed a biogeophysical feedback mechanism which tends to produce changes in plant cover and rainfall. "Two integrations of a global general circulation model, differing only in the prescribed surface albedo resulting from a decrease in plant cover causes a decrease in rainfall" (Charney et al 1975). Thus "this tendency could initiate or perpetuate a drought".

Landsberg came to a conclusion that drought could not be designated as an event beyond expectation (1975). Further, a study on the precipitation fluctuations in Monsoon Asia during the last 100 years shows that these fluctuations were paralleled with the Southern Oscillation (Hakkarinen I. M. and Landsburg 1981).

Mooley stated that droughts are random series in China and there have been no increase in drought frequency (1981). He applied the poisson distribution for the analysis. In Soviet Union, Rauner pointed out that the drought sequences are a random process of a stationary type (1977). From the theoretical surveys revealed one conclusion could be suggested which is in agreement with Carr (1966). He pointed that "some considerations found to be common in most definitions of drought are:

- I Rainfall.....The meteorologic parameter most used to determine when drought is in progress.
- II Duration and magnitude of rainfall deficiency - the key to soil moisture deficiency which is in turn the key to the severity of agricultural drought.
- III Purpose of the technical paper report or study strongly influences the definition of drought given by the author; chooses an existing definition or coins a new one which best suits his needs at the time"

Thus it is easy to come to a universally agreed conclusion "drought, by its very nature, is difficult to define, because clearly the definition must vary for

different purpose. There can be therefore no universally agreed definition of drought (Maher 1967). As described in the Australian Encyclopaedia, the severity of drought is rather subjective often depending on the observer and type of the country. So it should be pointed out here that "generally accepted definition is drought is the "point of view" of the investigator (Tannehill (1948).

To the meteorologist drought is a rainless situation (Subramanyam V. P. 1967) for an extended period during which some precipitation should have been normally received depending upon the climatological location of the place and time. If one is not interested in agro - climatology or dynamical climatology this definition should be accepted.

Such a rainless situation is, generally not enough to describe the drought. Thus as pointed out earlier, the definition which Thomas H. E. (1962) described could be used. According to him:

"drought is a meteorologic phenomenon and occurs during a period when precipitation is less than the long-term average, and when this deficiency is great enough to hurt mankind"

At the same time there is no reason to reject the definitions of Thornthwaite or Palmer, in fact they are very suitable to study drought effects in various places. In other words the discussion of drought in terms of agro - climatology should use water balance or soil moisture based definitions of drought, As done by Thomas H. E. who studied the effects of drought in the South western United States.

3.0 Assessment of drought in Sri Lanka

Sri Lanka has experienced droughts several times. Sometimes these occur in the South west and central massif regions and sometimes they occur in the North, central, and East regions of the country. Occassionally these events cover all the regions. The studies which dealt with drought in Sri Lanka are very few.

The Southwest monsoon drought of 1929 over Sri Lanka, was discussed by Jameson (1931). He also assesses the liability to drought at Colombo (1932). Until 1956, there were no further studies of drought. In 1956 Farmer (1956) analyzed the incident of rainless months. In 1970 by employing Thornthwaite's water balance technique, water needs and irrigation facilities in the dry zone of Sri Lanka have been assessed (Sri Nanda 1970). Balachandiran (1975) made an assessment of drought in Sri Lanka by following the method of departure from the normal. The categories of drought were also defined in the same way as follows:

Table 3

Categories of drought

- A. Slight drought 76% to 89% of the normal
- B. Moderate drought 51%-75% of the normal
- C. Severe drought 26%-50% of the normal
- D. Extreme drought 25% of the normal
- E. Far extreme drought No rain at all.

Defining magnitude in terms of the percentage to the normal of particular area is in agreement with the approach of Thomas H.E. (1962) though slight changes have been made in the classification used here. Normally 11% variation from the normal is treated as drought free. In particular the first three divisions i. e. A, B & C have followed the categories of Banerji and Chabra (1963) while the other two divisions (C & D) have been created, because it seemed necessary for a finer identification of drought in a Sri Lankan context.

For this, the monthly rainfall data for 30 stations throughout Sri Lanka for the period of 23 years (1948 - 70) were utilized. In this study the persistence tests showed that two thirds of observed droughts were free from persistence effects and chi-square tests showed observed and expected drought in close agreement (Balachandiran 1975).

Domros (1978) studied aridity and drought in Sri Lanka. For aridity investigations he used an 'aridity' index developed by De Martonne Laur (1936/1952). For drought investigations he used the index developed by Gibbs and Maher in 1967. The rainfall figures from 1931 to 1960 were used in this study, "It can be seen from this that drought can be called a typical although irregular and spatially limited phenomenon in the monsoon climate of Sri Lanka (Domros 1978)".

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