Hydrological Drought and Its Indices

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Abstract— Hydrological drought is associated with the effects of periods of precipitation shortfalls on surface (stream-flow level) or subsurface water supply (ground-water level). The frequency and severity of hydrological drought is often defined on a catchment. Beginning with a discussion of drought definitions, this paper provides a review of fundamental concepts of drought, classification of drought and hydrological drought indices. It also discusses advantages and disadvantages of drought indices.

I. INTRODUCTION

Water is one of nature's most important gifts to mankind and is very much essential for human civilization. Our daily lives are built on water and shaped by it. Throughout the history of mankind, civilizations have flourished only where water has been respected.

Natural disasters include drought, flood, earthquake, landslide, tsunami, environmental degradation, mining disaster, cyclone etc., which cause devastating impacts on various activities/properties of the earth. Water is directly related to the first two i.e. droughts and floods (result of deficit/excess water), known as hydrologic extremes. The total water available on the earth remains constant but its distribution with respect to time at a place is highly variable leading to hydrologic extremes. Also, it may vary in space in such a way that when one part of a country experiences drought, another part may go through a flood almost simultaneously. Such occurrences of droughts and floods pose a great challenge for the people to face them during different periods and to the Government at the same time. Among these two extremes, flood is characterized by quick inception, vigorous growth and evident spread terminating eventually with disastrous impacts. But, drought is a non-event and a creeping phenomenon. Its beginning is subtle and invisible, progress is gradual and deceptively lethargic in spread and the effect can be devastating. It may start at any time and attain different levels of severity. Indeterminacy regarding onset and ambiguity regarding its spread and severity has rendered these phenomenon's all the more harmful. Therefore, studies regarding droughts are very important for the mankind in general and the economy of the nation in particular. As the present study concentrates on Droughts, its details are presented in the subsequent sections.

II. DROUGHTS

A. Classification of Droughts

(National Commission on Agriculture, 1976) broadly classified droughts into the following three types.

1) Meteorological drought

It is defined as a lack of precipitation over a region for a period of time. It is a situation when there is a significant decrease in rainfall from the normal over an area. It is based on the degree of dryness. Precipitation has been commonly used for meteorological drought analysis.

Definitions of meteorological drought must be considered as region specific since the atmospheric conditions that result in deficiencies of precipitation are highly variable from region to region (Water - A Vital Nebraska Resource, University of Nebraska - Lincoln).

2) Hydrological drought

Meteorological drought, if prolonged, results in hydrological drought with marked depletion of surface water and consequent drying up of inland water bodies such as lakes, reservoirs, streams and rivers and fall in level of water table.

The frequency and severity of hydrological drought is often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system. Hydrological droughts are usually out of phase with or lag the occurrence of meteorological and agricultural droughts (Water - A Vital Nebraska Resource, University of Nebraska - Lincoln).

3) Agricultural drought

It occurs when soil moisture and rainfall are inadequate to support crop growth to maturity and cause extreme crop stress leading to the loss of yield. Agricultural drought, usually, refers to a period with declining soil moisture and consequent crop failure without any reference to surface water resources.

A good definition of agricultural drought should be able to account for the variable susceptibility of crops during different stages of crop development, from emergence to maturity (Water - A Vital Nebraska Resource, University of Nebraska - Lincoln).

B. Progression of Drought

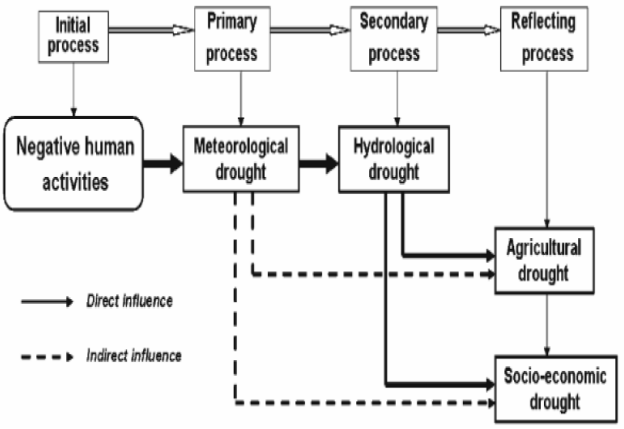

Fig. 1: Progression of Drought

C. Importance of Hydrological Drought

Hydrological drought is defines as a significant decrease in the availability of water in all its forms appearing in the land phase of the hydrological cycle (Nalbantis, 2008).

Hydrological drought is related to a period with inadequate surface and subsurface water resources for established water uses of a given water resources management system. Stream flow data have been widely applied for hydrologic drought analysis (Clausen & Pearson, 1995) (Rangacharya & Mohan, 1991).

Hydrological drought is described as a sustained and regionally extensive occurrence of below average natural water availability.

Hydrological drought may be the result of long term meteorological droughts that results in the drying up of reservoirs, lakes, streams, rivers and a decline in groundwater levels.

D. Aspects of Hydrological Drought

Six types of drought may be distinguished based upon variations in the duration, season of year, or severity:

1) A three-week to three-month runoff deficit during the period of germination and plant growth. This could be catastrophic for farming that is dependent upon irrigation drawn directly from the river without the support of reservoirs.
2) A minimum discharge significantly lower or more prolonged than the normal minimum but not necessarily advanced much in its position relative to the growing season. Because the germination period is not affected this type of drought is of less consequence to agriculture.
3) A significant deficit in the total annual runoff. This affects hydropower production and irrigation from large reservoirs.
4) A below normal annual high water level of the river. This may introduce the need for pumping for irrigation.
5) Drought extending over several consecutive years. Discharge remains below a low threshold or the rivers dry up entirely and remain dry for a very long time.
6) A significant natural depletion of aquifers. This is difficult to quantify because observation of the true level of the aquifer is disturbed by the over-utilization of groundwater during the drought.

III. IMPORTANCE OF DROUGHT INDICES

Drought indices have been developed by several generations of researchers during the 20th century in the domains of meteorology, hydrology, agricultural research and application, remote sensing, and water resources management.

Drought indices are indispensable tools to detect, monitor, and evaluate drought events. The main objective of drought indices is drought monitoring, early warning, and improving drought preparedness and mitigation.

IV. HYDROLOGICAL DROUGHT INDICES

A. Standardized Runoff Index (SRI)

Standardized Runoff Index (SRI) is a hydrological drought indicator, based on the assessment of the runoff of a given basin. The SRI is the "unit standard normal deviate associated with the percentile of hydrologic runoff accumulated over a specific duration.

Runoff data should not be affected by human activities. SRI is a useful complement to Standardized Precipitation Index for depicting hydrological aspects of droughts.

B. Effective Drought Index (EDI)

It is an intensive measure which considers daily water accumulation with weighting function for time passage. EDI is able to represent the gradual development of droughts. EDI can measure both long term and short term drought. It calculates daily drought severity. It indicates current level of available water resources. It is able to diagnose prolonged droughts that continue for several years.

C. Surface Water Supply index (SWSI)

The surface water supply index (SWSI) (Shafer & Dezman, 1982) was primarily developed as a hydrological drought index and it is calculated based on monthly non-excedance probability from available historical records of reservoir storage, stream flow, snow pack, and precipitation.

The definition of surface water supply and the factor weights vary with spatial scale (one watershed to another) as well as temporal scale (season or month) due to differences in hydro climatic variability resulting in SWSIs with differing statistical properties.

SWSI represents water supply conditions unique to each basin. Changing a data collection station or water management requires that new algorithms be calculated, and the index is unique to each basin, which limits inter basin comparisons.

D. Palmer Drought Severity Index (PDSI)

Using precipitation and temperature for estimating moisture supply and demand within a two-layer soil model, (Palmer, 1965) formulated what is now referred to as the Palmer drought index. PDSI is perhaps the most widely used regional drought index for monitoring droughts. The index has been used to illustrate the areal extent and severity of various drought episodes and to investigate the spatial and temporal drought characteristics as well as to explore the periodic behavior of droughts, monitoring hydrologic trends, crop forecasts, and assessing potential fire severity, droughts over large geographic areas, and drought forecasting (PDI). Many U.S. government agencies and states rely on the Palmer to trigger drought relief programs. It is the first comprehensive drought index developed in the United States. Palmer values may lag emerging droughts by several months; less well-suited for mountainous land or areas of frequent climatic extremes.

E. Stream flow Drought Index (SDI)

The Stream flow Drought Index (SDI), has been recently proposed. It is based on cumulative stream flow volumes for overlapping periods of three, six, nine and twelve months

within each hydrological year. Exclusive use of stream flow is made as the key variable for assessing hydrological drought.

SDI is a simple and effective drought index. In SDI exclusive use of stream flow is made as the key variable for assessing hydrological droughts (Nalbantis, 2008).

V. CONCLUSION

Many attempts have been made to compare the various indices in order to find the most suitable indices for the specific objectives of drought monitoring. In PDSI it is assumed that all precipitation is rain and it can be slow to respond to developing and diminishing drought. While SRI is based on the concept of Standardized Precipitation Index (SPI). SRI incorporates hydrologic processes that determine the seasonal loss in stream flow due to the influence of climate. EDI have been found to be able to detect the onset of a drought, its spatial and temporal variation consistently and EDI has been found to be more responsive to the emerging drought and perform better. The purpose of SWSI is primarily to monitor abnormalities in surface water supply sources. Hence, it is a good measure to monitor the impact of hydrologic droughts on urban and industrial water supplies, irrigation and hydroelectric power generation. In SDI stream flow is used as a key variable for assessing hydrological drought.

It can be seen from the above discussion that the performance of drought indices is region specific. This is due to the variability in meteorological variables as well as stream flow characteristics which are generally used for deriving indices.

REFERENCES

[1] Clausen.B., & Pearson. (1995). Regional frequency analysis of annual maximum streamflow drought. *J. Hydrol.* , 173, 111–130.

[2] Nalbantis, I. (2008). evaluation of hydrological drought index. *EWRA* .

[3] (1976). *National Commision on Agriculture.*

[4] Palmer. (1965). Meteorologic Drought. *US Department of Commerce* , Research Paper No. 45, p. 58.

[5] Rangacharya, & Mohan. (1991). A modified method for drought identification. *Hydrological Sci. J* , 11–21.

[6] Shafer.B.A, & Dezman.L.E. (1982). Development of a Surface Water Supply Index(SWSI) to Assess the Severity of Drought Conditions in Snowpack Runoff Areas. *Colorado State University* , 164–175.

[7] *Water - A Vital Nebraska Resource, University of Nebraska - Lincoln*. (n.d.). Retrieved march 7, 2014, from http://water.unl.edu: http://water.unl.edu/drought/typesofdrought

