Journal of Advances and Scholarly Researches in Allied Education
Vol. XV, Issue No. 4, June-2018, ISSN 2230-7540

Meteorological Droughts Forecasting Using Fuzzy Logic

Mr. Ayub Shaikh[1]* Prof. (Dr.) Indrajit Yadav[2]

[1] Research Scholar, Shridhar University, Rajasthan

[2] Professor, Shridhar University, Rajasthan

Abstract – Droughts are devastating extreme weather events which can damage the environment and human lives significantly. Preparations for drought can be developed to manage the effects of drought. The success of this amongst other things depends on the well-defined and quantified Droughts characteristics. A preliminary forecast of drought conditions is the essential requirement for reducing the harmful effects of droughts. The main aim of this study is therefore to develop a methodology for the evaluation and forecasting of drought. The drought assessment was performed on the basis of the methods of the Indian Meteorological Department (IMD) and the SPI. To generate drought severity maps, Droughts severe values were used. Drought spatial distribution was found with the nearest GIS neighborhood analysis. The block boundaries and drought-risk maps of the spatial drought proneness of the blocks are overlaid. For the Droughts evaluation a meteorological methodology for meteorological drought risk assessment was developed. This provides a unique way of long term understanding of every area's overall drought situation. Droughts are long periods of rainfall, resulting in insufficient availability of water and adverse effects on crops, animals and human beings. Drought forecasts are essential to the planning and management of water resources to minimize the adverse effects. Many models for this purpose were developed and indeed, the selection of the best model for your research would be a long process for researchers. A timely, comprehensive and informative overview of the concepts and history of the models would prevent researchers from overlooking the potential choice of models and from saving them considerable time. Models are classified by mechanism: regression analysis, stochastic analyses, probabilistic analysis, artificial intelligence based, hybrids and dynamic modelling. The details of the selected documents are tabulated for ease of reference and include modelling approaches, authors, publishing year, methods, input variables, assessment criteria, time scale and drought type. In addition to historical applications, advantages and limitations, the basic concepts for each approach with key parameters are explained. Finally, for the continuing research into drought, future prospects and possible modeling techniques are developed.

Key Words – Meteorological, Droughts Forecasting, Fuzzy Logic, Environment and Human lives, Indian Meteorological Department, Animals and Human Beings

- X -

INTRODUCTION

Droughts are overland events of long period extreme weather that are described over months or years as below-normal precipitation. Droughts may be classified according to conditions into four classes: meteorological, agricultural, hydrological, socio-economic and Droughts. A meteorological drought is conceptually described as a precipitation deficit for a period of time across a region. Drought is considered regionally specific due to the fact that weather conditions are highly variable from region to region, due to low precipitation, dry winds and high temperatures. When air humidity is reduced to a level that affects soil moisture, an agricultural drought will start immediately. During this period the decline in soil moisture will affect the crops and animals and reduce crop production, which will then affect the food chain balance in the ecosystem. A dry period is defined in a hydrological manner as being very long, in that affected river flows and water storages are below long-term mean levels in aquifers, lakes, or reservoirs. It is slugger than the last two classes, as it not only covers the depletion process but also the refilling stage. As a consequence, a socio-economic drought occurs when the water resources systems fail to meet demand for the economic good. Droughts can also practically be classified on the basis of precipitation anomalies schedules. For example, the SPI-1 and SPI-2 for meteorological droughts, from SPI-1, to SPi-6 for agricultural droughts, and SPI-6, for hydrological draughts where they occur within months, for example, the

SPI-2 standardized precipitation index (SPI-2). The dry seeds reviewed in this paper are classified into the weather, agriculture and hydrological drought categories, unless otherwise clearly explained in the study of drought type being investigated, and are based on their intended purpose, inputs, Droughts indices and time scale.

We plan our cities in the vicinity of water; we bathe in water; we play in water. The strength of water use in agriculture is our economic factor; all products that we purchase and sell are, one way or the other, partial water. It builds and shapes our daily lives on water. Otherwise, our lives would not be possible without the surrounding water – air humidity, the roughness of the river flow and the flow from the kitchen tap. Water is nature's precious gift and plays a key part in the promotion of civilisation. 80% of the human body consists of water and the 30% surface is covered by water: water is our culture, our life. Water is our culture. Human health has been demonstrated to improve up to 100 lpcd with water consumption (Dooge 2015). For development in the form of food production and industrial activity, water has always been essential. As the universal medium for the transport of nutrients and toxic elements, it is a key environmental factor. We acknowledge that water is a potential cause of war and can well be a critical factor for the outbreak of future regional wars, under current population pressures and regional disputes. The importance of waters in the Indian economy can be measured by the fact that the agricultural sector traditionally accounted for two-fifths of the GDP and two-thirds of the country's population. But late, due to several factors including the effect of the drought, it has experienced a decreasing trend.

Meteorological forecasting is one of the world’s most important and most demanding meteorological services operating tasks (Guhathakurata, 2006). In the past, the drought and flooding of Thailand were severe. The problems and the damage to the economy, agriculture and subsistence are expected to increase steadily. Effective water resources planning and management is needed to mitigate this. For successful crop selection and planning of crop rotation, forecasting rainfalls in various time scales is important for short- and long-term planning of agricultural production. For reservoir operation and flooding prevention, a precise and timely planned rainfall is essential because it can extend the flow forecast lead-times, more than the response time of the watershed, particularly in small and medium-sized mountain reservoirs. It needs to be a good idea of the next season in the short term. It needs realistic projections of future variability and change scenarios in the long term (Abraham et al., 2001). Forecasting of rainfall is very complex. It is far from an uncommon job to simulate the response by conventional approaches when modeling precipitation series since the hydrologic processes are inherently complex and involve different, still unclearly understood geomorphological and climatic factors. Statistical modeling is used to describe quantity variability and observational errors. These models, however, assume numbers or vectors are the observations. This assumption is not always realistic because continuous measurement results are always not accurate, but more or less inaccurate numbers. Such uncertainty differs from mistakes and variability. Whereas errors and variability can be modelled by stochastic variables and distributions of probability, imprecision, or fuzziness, is another type of uncertainty. The most up-to-date method is to apply fuzzy numbers and fuzzy vectors that are special fuzzy models for a quantitative description of these data. Since Lotfi Zadeh introduced the fuzzy theory and its application, the origin of the fugty logical approach dates back to 1965. It is possible to express tight intervals with fuzzy expressions, such as low, medium, high, good, moderate, poor etc. in terms of language subsets. In a fuzzy logic approach, here, the fuzzy theory of precipitation was recently used as an alternative method to develop an ambiguity/vagueness model of Forecasting. In order to model and predict data on local rainfall, Halide and Ridd(2002) used flush logic. The mean root squared error between the data and the model output is 319.0 mm, smaller than the local rain or niño. Wong et al. (2003) built the fuzzy rule bases using SOM and neural propagation networks and developed a predictive rainfall model for the spatial interpolation over Switzerland using the rule base. To predict precipitation in the west, Karamouz et al. (2004) have used a model of furious rule and neural networks. They showed that the same error occurred in both models. The neurofuzzy system was employed by Suwardi et al, (2006) to model the tropical rainfall in wet season. The low root mean squared error values of the models showed that the model Forecasting are reliable.

REVIEW OF LITERATURE

Hoyt (2014) defined Droughts with a yearly deficiency of precipitation of 15 per cent on wet and semi-arid areas. The Droughts has been defined, by Blumenstock (2010), as a period of rainfall within 48 hours of below 0.1 inch. The period of drought has been defined by Condra (2014) as high wind, low precipitation, high temperatures and unusually low relative humidity.

The drought of Ramdass and Malik (2018) was a period during which actual precipitation is equal to or below half the normal precipitation. When actual rainfall is less than twice as high as the standard deviation from standard long-term average rainfall, Ramdass defines Droughts.

Drought has been defined by Palmer (2015) as a situation where the actual precipitation is less than the precipitation that is climateally appropriate to existing conditions. The absolute drought was determined by Herbst et al. in 2014 by a minimum of 15 consecutive days without 0.01 inch rain for any day and a period of 29 consecutive days for a partial drought with a mean precipitation of not more than 0.01 inch per day.

Yevjevich (2017) discussed Droughts as rainfall deficiency in the mean (truncation level). The National Agriculture Commission (1976) has classified meteorology as a state of significant decrease (more than 25 percent) in the period from mid-May to mid-October from the normal four consecutive week period.

The drought defined by Gadgil and Yadamuni (2014) as a period of less than 10% probability of rainfall. Drought has been defined by Jorge Morban (2010) as a rainfall over a period of time less than its equivalent amount. The Indian Weather Department (IMD) is evaluating the drought on the basis of rainfall shifts from long-term average rainfall.

From the above, the time period of drought evaluation is varying in hours, days, weeks, months, season, and year from person to person, and country to country. Therefore, the literature does not make it clear to anyone how a meteorological drought can be evaluated precisely. In addition, in the context of a drought whose effects are felt over a long time, small periods such as hours, days and weeks can be insignificant. Therefore, for practical purposes, all of the above definitions based on precipitation alone may not be effective.

Hoyt (2014) defined Droughts has a small probability of occurrence as period in which the actual natural stream flows within a selected number of days. Drought is also identified in relation to the long-term mean flux as truncation level as the deficiency of stream flow (Yevjevich 2017). It was defined by Dracup (2010) as the flux deficience from a level that may be the median of long-term flows.

Drought was defined by Joseph (2010) for 14 consecutive days in climate-friendly years from the start of April as the lowest mean release at a certain measuring point in a stream. In the period of vegetation germination, Thambiannan (1990) cited Droughts as a three-month runoff deficit. Based on this, the criteria for the demarcation of the non-availability of the wastewater period and therefore the drought are any deficiency in streamflow, compared to the long-term medium, or an arbitrary value. Drought analysis can be insufficient only in view of the available flows without taking into consideration other types of water supplies and demand. The streamflow data collected from this particular measuring point may not really be the availability of water in a specific administrative area or border.

Thiruvengadachari (2017) Evaluated drought for two weekly talks on the vegetation index map analysis, greenhouse map and plant index statistics. The Droughts assessment of the vegetation status was carried out for every talouk for two months. The Droughts satellite assessment and monitoring were developed based on the relationship of the normalized vegetation difference index between the two consecutive years (NDVI). The fact is that all the vegetable cover in an area cannot be productive and some vegetation may not reflect the availability of water in this area.

FUZZY LOGIC MODELING OF METEOROLOGICAL FORECASTING

A fuzzy logic model is also called a fuzzy inference system or a fuzzy controller. Temperature, moisture, wind speed and solar radiation are part of the systems input. The rainfall data is the output. Four steps are taken to develop the following fuzzy model. The first step is for the membership, called the fuzzification process, to transform the crisp inputs into the flushy variable. The number and type of membership functions are based, in general, on the considering issue, on statistical data and engineering experience. The triangular member function was used to describe the variables of input and output. The second step, using historical data of 5 minutes of all parameters and fuzzy operator, is to create the fuzzy rule base. From each weather station, historical data have been collected. The fuzzy AND OR operators are used to combine the variables of input. The third step is the application of the membership features and rules to obtain the membership features. This step is done by means of the implication process, which produces a fuzzy output set when a single input number is given. Then each rule's output membership features are linked to a fuzzy output set called an aggregation process. Finally, a defuzzing process involves converting a fluffy output set into a single narrow value. The "centroid" assessment, which returns a center of the area under the curve, is the most common deflation method. In this work, each variable is provided with a small number of linguistic terms (e.g. high, medium or low), called fuzzy sets (e.g., temperature). These fluorescent sets overlap and cover the required variable size. A membership function is the level of affiliation (from 0 to 1) with an actual valued input (for example temperature) to a certain fuzzy set A (e.g. high). This transformation of true valuable inputs into a certain amount of membership is named "fuzzification." Language variables need to be subdivided into linguistic labels, and membership functions are assigrated for each variable. Temperature, humidity, wind speed and solar radiation are the four parameters used in this system. Each of these parameters is classified into linguistic labels as shown in table 1.

Table 1- Linguistic labels for fuzzy variables

No.	Parameters	Linguistic Labels
1	Temperature	Very high TM, High TM, Medium TM, Low TM, Very low TM
2	Humidity	Very high HU, High HU, Medium HU, Low HU, Very low HU
3	Wind speed	Very high WS, High WS, Medium WS, Low WS, Very low WS
4	Solar radiation	Very high SR, High SR, Medium SR, Low SR, Very low SR
5	Rain Fall	Very high RF, High RF, Medium RF, Low RF, Very low RF

Table 2. Linguistic values and their ranges

Linguistic Values	Notations	Numerical Ranges
Very Low	VL	[0, 0.3]
Low	L	[0, 0.4]
Medium	M	[0.3, 0.7]
High	H	[0.4, 0.8]
Very High	VH	[0.7, 1.0]

$$Var(x) = \text{var}(x) = \begin{cases} \text{"VL"} & \text{if } \text{var}(x) < 0.3 \\ \text{"L"} & \text{if } 0.0 \le \text{var}(x) < 0.4 \\ \text{"M"} & \text{if } 0.3 \le \text{var}(x) < 0.7 \\ \text{"H"} & \text{if } 0.4 \le \text{var}(x) < 0.8 \\ \text{"VH"} & \text{if } 0.7 \le \text{var}(x) < 1.0 \end{cases} \quad (1.1)$$

The linguistic expression for the variables and their membership functions are evaluated from the following triangular membership functions and it is defined by a lower limit a, an upper limit b, and a value m, where a < m < b.

$$\mu_A(x) = \begin{cases} 0, & x \le a \\ \dfrac{x-a}{m-a}, & a < x \le m \\ 1, & x \ge b \end{cases}$$

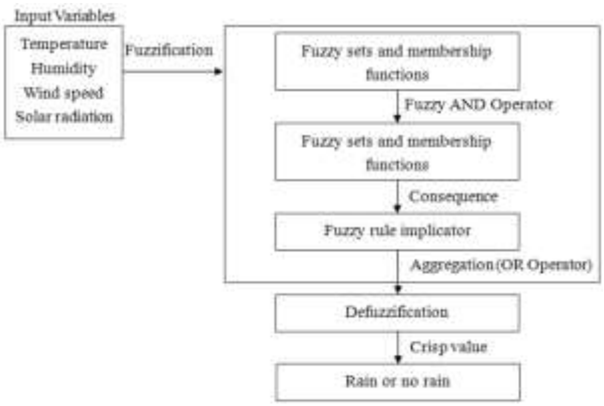

Figure 1. Fuzzy logic procedure of meteorological forecasting

1. Fuzzification

The mathematical approach to derive the membership functions and fuzzy levels of a fuzzy variable were shown in Fig. 2 and Table 2. For example, value of x of a fuzzy variable yields two membership functions (μ1) 0.3 and (μ2) 0.7 and fuzzy levels L and M (point of intersections), respectively. Construction of appropriate production rules that are comprised of antecedent and consequent parts of IF. Then algorithms with logic based on past experiences of the decision makers. IF (TP is low) and (HU is high) and (DP is Very high) and (WS is high) and (PR is very low), then (RF is high).

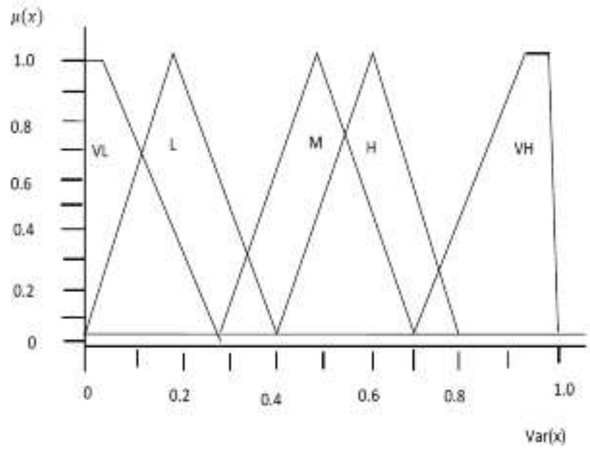

Figure 2. Graph of membership function

2. Min-Max Composition

From the rule definition, the AND operator is used. To evaluate the antecedent, the Mamdani min function is applied to determine the firing level (α) of the rule as follows:

$$\mu_{A\cap B(y)} = Min\left[\mu_{A(y)}, \mu_{B(y)}\right] \mid y \in Y$$

$$\alpha = Min\begin{bmatrix} \mu(TP = 0.3), \mu(HU = 0.7), \\ \mu(WS = 0.8), \mu(SR = 0.1) \end{bmatrix}$$

$$= Min[0.35, 0.76, 1.0, 0.88, 0.15] = 0.15$$

The value of the antecedent is multiplied by the weight factor to give a value which represents the degree of support (firing strength) for the rule $FV_i = \alpha_i w_i$ where $w_i = 1$ therefore $FV_i = \alpha_i$.

In the aggregation process, fused output sets of all rules are aggregated into one fuzzy set (produced by the implication method). For aggregating the fuzzy maximum (OR operator) function presented in the equation.

$$\mu_{A\cup B(y)} = Max\left[\mu_{A(y)}, \mu_{B(y)}\right] \mid y \in Y.$$

Suppose there are N rules for rainfall parameters and the fuzzy implication of each rule is represented as FV. Then is the fuzzy implication (firing strength) of the ith rule where i N = 1, 2,. , . K

Thus the final fuzzy value is the result of the aggregation operator

$$FV = Max\left[FV_1, FV_2, \ldots, FV_N\right]$$

3. Defuzzification

Defuzzification involves conversion of the linguistic variables to numerical or crisp values; this work adopts the centroid defuzzification method. This is given as follows:

$$Z = \frac{\sum_{i=1}^{n} \alpha_i y_i}{\sum_{i=1}^{n} \alpha_i}$$

where z is the crisp value and can be used for decision making, αi is the fuzzy implication (firing strength) of the ith rule μ (α) is the degree of membership of the ith route value, i y is the consequent of each rule.

DROUGHTS

Drought is a temporary, recurring natural disaster which results in significant economic losses due to lack of precipitation. Drought was a threat to society's survival throughout human existence. It has often caused mass migrations, famine and wars in human beings, and changed the course of history itself. Drought still affects the global community in countless ways despite massive development activities. Indeed, it continues to discover the complex interrelationships between drought and society and to work on response and mitigation strategies that reduce impacts on future generations to reduce vulnerability. Droughts cannot be prevented. However, preparations for drought can be developed and the effects of droughts reduced. The success of both depends, among others, on the well-defined nature of drought and the quantification of drought conditions. Drought in any given region has many facets and can (or may not) affect soil moisture, water streams, soil, water, ecosystems and humans as long as the precipitation is lacking. This led to the identification of various Droughts types (meteorological, hydrological, agricultural, socio-economic), which reflect the views on water shortages of different sectors. In effect, the drought types are various phases of the same natural and repetitive process (different extremes). Drought begins with the lack of rainfall. The longer and larger this deficiency spatially, the more likely other droughts are to occur. It may reflect in the first place on the availability of surface and ground waters, leading to hydrological drought, and then agricultural drought. Any external water sources (interbasin transfer) can mitigate the area's impact without hydrological and agricultural droughts. Droughts cannot be limited to a single all-embracing definition. This depends on regional, regional and disciplinary differences.

DROUGHTS IN INDIA

The large drought incidences in the South-West Monsoon Sea are one of the worst natural calamities for India (June to September). From 1901 to 1930 the Droughts season was frequent, with the frequency once in four years. Over the next 30 years, the drought in 1941 and 1951 was just two. However, 10 cases of drought occurred in the next 30 years; on average, a drought occurred once in three years. Karnataka, Tamil Nadu, Rajasthan, Gujarat, Andhra Pradesh and Maharashtra are the worst affected countries with drought. Over the 1970s, approximately 80% of the world's drought-affected victims were living in India. Droughts affected approximately one third of the country's geographical area, or 107 million hectares in 99 districts in 13 states, the National Agriculture Commission (1976) reported. Drought in 1987 was one of the worst, with a total precipitation deficiency of 19%. It affected 59-60% of the cultivated area and 285 million inhabitants. A dry drought assessment in Tamil Nadu State between 1977 and 1991 has shown that in many parts of the state, in particular Madras, there have been recurrent drinking water shortages. In the last 15 years, the worst drought years are 1980, 1982, 1983, 1987 and 1989. He talked about the 1987 drought that paralyzed the economy of the state. About six thousand villages have been affected, with 3 lakh hectares of crops and 108 lakh cattle. The drought of 1987 in Tamil Nadu serves as a model of chronic drought, and the study of its redemptive characteristics and management is of interest. There were 290 poor rainy days, 48 marginally rainy days and 27 good rainy days in the catchment areas without any water. The groundwater level dropped steeply to 11 m. (Nathan 2015). Everyone is still fresh in mind about the drought scenario of 2000. Droughts have affected more than 150 districts in eight states. The most recent drought, 2002, ranks fifth, but is unique in magnitude, spacing, dispersion and time when studied in general. The deficiency in precipitation increased up to 51 percent in July 2002, exceeding all previous droughts. Drought has spread to 56 percent of land mass and put 300 million people in 18 States in danger of surviving.

CONCLUSION

In the areas of meteorology, hydrology and agricultural systems and water resource systems, the study of modeling approaches is important for drought forecasting. Precise Forecasting is indeed necessary in order to improve the compulsory multi-stage Forecasting for the best management practices required. The analysis of regression is seen as one of the earliest and most straightforward methods to prevent future conditions of drought based on the link between the variables. The logistic and log-linear regressions are useful for forecasting the Droughts index. The assumption of linearity between predictor and forecast however reduced its ability to forecast for long-term results. There is no doubt that the hybrid model has been widely applied during the last decade as a consequence of a dramatic improvement in performance compared to the stand-alone model. A thorough review of the hybrid models shows in this article that the hybrid model can be classified as the hybrid of machine models or the hybrid of data pre-processing techniques and machinery models. Because a hybrid model combines the merits of each model, the accuracy of the Forecasting of the time-set with a shorter time and more long lead time is therefore improved. The hybrid models are extremely useful for short- and medium-term drought Forecasting and multi-stage forecast and should pave the way for further progress in climate-change drought projections. Dynamic modeling is a known method in the field of drought Forecasting in real time forecasting. Due to its ability to provide real-time data, remote sensing data is usually used as input for dynamic modelling. Remote sensing data can however contain partial information, and therefore Bayesian mixing with observed climatology is usually done to improve Forecasting. Real-time gauges and dynamic downscaling for dynamic modeling were also used other than remote sensing. The droughts are determined on the basis of various factors and their management mainly depends on the proper evaluation. Many research studies concentrate on only a few factors leading to unproductive results with no significant consequences for the planning of drought mitigation and finally for society.

REFERENCES

Dooge C.I. (2015), 'Water in Development and Environment', Report of Twelfth IHD Endowment Lecture, Centre for Water Resources, Anna University, India, pp. 15.

Hoyt I.C. (2014), 'Drought of 1936 with Discussion on the Significance of Drought in Relation to Climate', US Geological Survey Water Supply Paper No. 820.

Blumenstock (2010), 'Drought in US Analysed by means of Theory of Probability', Technical Bulletin No. 819, US Department of Agriculture.

Condra G.E. (2014), 'Droughts-Its Effects and Measures of Control in Nebrasca', Nebrasca Conservation Bulletin, No.25, Conservation and Survey Division, University of Nebrasca.

Ramdass L.A. and Malik A.K. (2018), 'Agricultural Situation in India', Technical Bulletin, Indian Council of Agricultural Research, New Delhi.

Palmer W.C. (2015), 'Meteorologic Drought', US Weather Bureau, Research Paper No. 45.

Yevjevich V. (2017), 'An Objective Approach to Definitions and Investigations of Continental Droughts', Hydrology Paper No. 23, Colorado State University, Fort Collins, USA.

Gadgil and Yadamuni (2014), 'Rainfall in Karnataka - Variability and Forecasting', Environmental Report of Karnataka State in 1985-86, Bangalore, India.

Yevjevich V. (2017), 'An Objective Approach to Definitions and Investigations of Continental Droughts', Hydrology Paper No.23, Colorado State University, Fort Collins, USA.

Joseph S. (2010), 'Probability Distribution of Annual Droughts', Journal of Irrigation and Drainage Division, ASCE, Vol. 96, No. IR4, pp. 461-474.

Thiruvengadachari S., Prasad T.S. and Harikishnan J. (2017), 'Satellite Monitoring of Agricultural Drought in Anantapur District in Andhra Pradesh State', Report No: RSAM-NRSA-DRM-TR-03/87, Drought Mission Team, Department of Space, Govt. of India, p. 35.

Corresponding Author

Mr. Ayub Shaikh*

Research Scholar, Shridhar University, Rajasthan

ayub24686@gmail.com