

# To develop a reasonable onset definition for Sabarmati basin and to predict arrival of monsoon in a region based on arrival of monsoon in neighboring region using Fuzzy Logic Approach

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## Abstract:

The agriculture statistics in Sabarmati basin depicts that major crop production depends on rain-fed farming or rain-related reservoir storages. As discussed, crop yield is highly dependent on arrival of monsoon in addition to rainfall amount and length of dry spells. Therefore, it is necessary to predict the onset of monsoon season at local scale considering a new approach. Here, a new approach of monsoon arrival based on fuzzy logic has been proposed considering three constraints namely, total amount of rainfall, number of rainy days and percentage of stations receiving rainfall. A monsoon arrival model based on fuzzy logic approach has been developed for parts of Sabarmati basin. The first two definition constraints are attached to a fuzzy membership function using triangular fuzzy numbers while the third constraint considers the threshold limit. Based on the Fuzzy logic algorithm, software for calculating the values of membership grades has been developed in FOXPRO. The basin has been classified into three regions based on terrain, amount of rainfall received and cluster of stations. The model results showed monsoon onset for region-1 on 14 th June, region-2 on 17 th June, and region-3 on 21th June. The model captures periodic variability in monsoon onset for various years. The model output was verified with Indian Meteorological Department's dates for monsoon arrival which shows good coherence. The performance of model may be improved using filter(s). The Linear Regression models have been developed to forecast monsoon arrival in region 2 based on onset in region 1 and for region 3 based on monsoon onset in region 2. The model parameters for targeted and independent region have been found to be 0.40 and 0.35 respectively.

**Key words:** Monsoon onset, prediction, Fuzzy logic

## Introduction:

In arid and semi-arid regions like Sabarmati basin, where rainfall is limited to a few months per year only, rainfall is the most critical factors for the ecological and environmental processes,. The amount of water available strongly depends on the rainy season's on-set, length and end in the areas where most of the agricultural production depends on rainfall. (Ati et al 2002) According to Steward (1991), the onset is the most important variable to which all other seasonal variables are related. Rainfall data is most important to hydrologists as it forms basis of many hydrological studies. The critical problem is the uneven distribution of rainfall during rainy season and the gap between the successive rainfall events. In order to get maximum yield, it is necessary to supply optimum quantity of water at right time which may not be possible every time. The total amount of rainfall in a particular area may be not sufficient or is not in time. The rainfall may be non-uniform over the crop period. There are sensitive periods of crop where proper amount of water is required .If sufficient moisture is not available, yield may be reduced. Due to very high spatial and temporal variability of rainfall and non-uniform distribution of rain during rainy season, farmers have problems to decide when to start with sowing of plants. Some of the strategies adopted by farmers to cope with the problems are re-sowing, dry seeding, crop rotation, exchanging information about rainfall with local workers and steps for sustaining soil fertility.

It is necessary to predict the onset of rainy season which is the most important factor and which coincide with the growing season of crops. Information of onset of rainy season, length and end of season imparts significant information in timely preparation of farmland, planting, preparation of equipment and manpower and also help in contingency planning to the government in the situation of drought.

Due to random distribution of local convection events and potential shifts of onset dates on site scales, this study will concentrate on determination and prediction on basin scale. It is focused on onset of monsoon for the different regions of Sabarmati basin.

The onset of rainy season (monsoon) is defined in different ways at present. The principal research areas are India, Australia and West Africa i.e. areas having water scarcity and rainfall is limited to rainy season. In general two types of definitions can be distinguished.

- 1) Definitions relying on the parameters measured on the surface.
- 2) Definitions using atmospheric dynamics.

The first group consists of number of methods applied for agro-climatologically purposes on local scale, while second group analyses the appearance of large-scale circulation patterns in combination with start of rains. Most researchers refer to rainfall itself in order to determine the onset and/or end of rainy season. The benefit of this approach is that precipitation tools are readily available and it exhibits the most direct relationship rather than some other related factors. For rainfall-alone definition, two sub groups can be found in literature, a definition based on certain threshold value(e.g. Stern et al.,1981) and a relative definition using a proportion relative to the total amount(Ilesanmi,1972)

The overall objectives of this investigation are:

- 1) To develop a reasonable onset definition for Sabarmati basin
- 2) To predict arrival of monsoon in a region based on arrival of monsoon in neighboring region.

An attempt has been also made to forecast the rainfall using Box-Jenkins approach of time series using ARIMA model. The description of model, methodology, data and performance model has been given in annexure-1.

### **Methodology & Description of model:**

For the statistical analysis performed, daily rainfall time series of 20 stations were applied. The meteorological data were obtained from State water data center. The data were checked for continuity by calculating monthly and annual totals. Table 6.1 represents the details of rain gauge stations used for analysis.

A Fuzzy logic approach has been developed to facilitate modeling. Fuzzy Logic (FL) is not a control methodology, but it is a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. This approach to set theory was not applied to control systems until the 70's due to insufficient small-computer capability prior to that time. Fuzzy logic is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input

information. The approach of fuzzy logic to control problems mimics how a person would make decisions, only much faster. Fuzzy logic incorporates a simple, rule-based “if x and y then z” approach to a solving control problem rather than attempting to model a system mathematically. The fuzzy logic model is empirically-based, relying on an operator's experience rather than their technical understanding of the system. Fuzzy logic requires some numerical parameters in order to operate such as what is considered significant error and significant rate-of-change-of-error, but exact values of these numbers are usually not critical unless very responsive performance is required in which case empirical tuning would determine them. Fuzzy logic was conceived as a better method for sorting and handling data but has proven to be an excellent choice for many control system applications since it mimics human control logic. It can be built into anything from small, hand-held products to large computerized process control systems. It uses an imprecise but very descriptive language to deal with input data more like a human operator. It is very robust and forgiving of operator and data input and often works when first implemented with little or no tuning.

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. In contrast with "crisp logic", where binary sets have binary logic, the fuzzy logic variables may have a membership value of not only 0 or 1 – that is, the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values of classic propositional logic. Furthermore, when linguistic variables are used, these degrees may be managed by specific functions.

The onset of monsoon has been defined considering three constraints namely, total amount of rainfall, number of rainy days and percentage of stations receiving rainfall. An artificial intelligence based fuzzy logic approach has been used to model the onset of rainy season. A fuzzy logic approach is important as it can incorporate the sternness of constraints which have to be fulfilled simultaneously. In this approach, each constraint is attached to a fuzzy membership function using triangular (subscript T) fuzzy numbers. The first two definition constraints are attached to a fuzzy membership function using triangular fuzzy numbers while the third constraint considers the threshold limit. For the first constraint dealing with total amount of rainfall within a 10 days spell, the triangular fuzzy numbers are  $(18, 25, +\infty)_T$ . This means that membership grade of rainfall totals less than 18 mm is attached to zero and total larger than 25 mm to one. Between

18 and 25 mm the membership grade is linearly interpolated. For the second constraint dealing with number of rainy day, the triangular fuzzy numbers are  $(1, 3, +\infty)$ . This means that membership grade of rainy days less than 1 is attached to zero and more than 3 to one. The membership grades between 1 and 3 are linearly interpolated and appropriate values are assigned. If  $\gamma_1, \gamma_2, \gamma_3$  are membership grades for amount of rainfall, number of rainy days and percentage of stations receiving rainfall then, the onset date is defined as the first day of year where the product  $\gamma = \gamma_1 * \gamma_2 * \gamma_3$  exceeds a defined threshold value.

$$\text{onset date} = \gamma = \gamma_1 * \gamma_2 * \gamma_3 \quad \text{-----}(4)$$

Where  $\gamma$  = Onset date,

$$\gamma_1 = 0, \text{ if } \sum R_f = 18 \text{ and } \gamma_1 = 1, \text{ if } \sum R_f = 25$$

$$\gamma_2 = 0 \text{ if } \sum R_d = 1 \text{ and } \gamma_2 = 1 \text{ if } \sum R_d = 3$$

$$\gamma_3 = 1 \text{ if } 60\% \text{ stations in a region met criteria 1 and 2}$$

Based on the Fuzzy logic algorithm, software for calculating the values of membership grades  $\gamma_1$  and  $\gamma_2$  has been developed in FOXPRO (Annexure-3). A filter was applied on onset date to make prediction relevance, in case the onset definition is beyond the stipulated monsoon duration.

## Analysis and Results

The daily rainfall values of all rainfall stations were used as input in order to derive past onset dates. The monsoon onset is the time when first spell of rains are being received. Therefore it is important to predict arrival of monsoon for a basin. A Fuzzy logic based approach was used to develop a reasonable onset definition. Three constraints namely, one- amount of rainfall in ten days, two- successive number of rainy days and three- percentage of stations receiving rainfall has been considered for defining onset. Fig 1 shows the three conditions used for

identifying the onset of monsoon using fuzzy logic approach. The arrows represent the direction for predicting the onset of rainy season of one region using the current onset date of another region. The entire basin is divided into three regions based on similar rainfall characteristics. The analysis of rainfall shows that the variability of rainfall is very high. The annual distribution of rainfall has been shown in Fig. 2 It shows that the all the regions received few amount of rainfall in the beginning of month of May. The region1 received around 10mm rainfall daily after mid of June which lasts upto first week of September, while region2 and region 3 receives average daily rainfall of around 10mm after third week of June which lasts upto end of September. The basin has been classified into three regions based on terrain, amount of rainfall received and cluster of stations. The model results showed monsoon onset for region-1 on 10th June, region-2 on 14th June, and region-3 on 17th June. The model captures periodic variability in monsoon onset for various years. The model output was verified with Indian Meteorological Department's dates for monsoon arrival which shows good coherence. The performance of model may be improved using filter(s). The Linear Regression models have been developed to forecast monsoon arrival in region 2 based on onset in region 1 and for region 3 based on onset in region 2. The model parameters for targeted and independent region have been found to be 0.40 and 0.35 respectively. The application of onset model will help farmers to decide crop to be sown and cropping pattern. Such type of simple tools may be used for advisory services.

## **Discussion and conclusion**

As the onset of rainy season is of major interest for managing farming strategies, it is required that before sowing of plants, farmers should be aware of the onset of rainy season .In this paper, for Sabarmati basin, based on the past data of daily rainfall (time period: year 1976 to 2007), analysis of past onset dates and mean rainfall amount is carried out. For this, Fuzzy logic approach is considered. The entire basin is divided into three regions based on similar rainfall characteristics. Region1 receives the rainfall in the second week of June and region 2 and Region 3 in the third week of June. This information is useful to the farmers for growing the seeds. The survival of seeding is key points for agriculturists (Sultan and Janicot, 2003). For sowing, it is important to know, whether, (1) the rain is continuous and sufficient to provide soil moisture during planting time, (2) level of soil moisture will be maintained or is there any change during

growing period to avoid crop failure (Walter, 1967). The data dependent model for defining monsoon onset using FL for Sabarmati basin has been developed.

There are methods to predict the rainfall using meteorological and /or atmospheric data. In this study, Linear Regression Analysis is used to find out onset dates of regions using the onset dates of one region. Here, region 1 is considered as the first region to receive onset and based on that linear regression models has been developed between regions, which can be useful for predicting inter-region monsoon onset. (Table 3).

As the Sabarmati basin is a semi arid area and most of the agriculture depends on rainfall in the basin, the analysis of past onset dates helps the farmers in planning their crop season. Knowing the start of rainy season, they can plan for type of the crop to be sown and date of sowing. The analysis also helps the farmer for drought contingency planning if the quantity of rain is less for a particular crop. An attempt has been made to predict rainfall using ARIMA methodology of time-series

Table 1: Details of rain gauge stations

Serial Number	NAME OF STATION	RAINFALL	REGION
1	AHD	780	S-W
2	RPW	709	
3	CDL	737	
4	VSI	749	
5	BRJ	811	
6	MHD	761	
7	SJT	738	
8	LML	726	N-W
9	MNS	718	
10	RSP	671	
11	VJA	800	

12	BDL	712	N-E
13	VRP	675	
14	DHR	758	
15	BHL	876	
16	CPW	906	
17	HMT	779	
18	IDR	875	
19	BYD	836	
20	TTI	784	

Table 2: Mean onset days and standard deviation

Definition 1	Mean onset date	Mean Onset day	Std. Dev.
Region 1(S-W)	14-Jun	45	17
Region 2(N-W)	17-Jun	48	15
Region 3(N-E)	21-Jun	52	14

Table  
regression models:

3 .Linear

Linear Regression equation, threshold values of  $\gamma$  for independent and target region. X represents independent region for respective target region .e.g. in.

regression equation  $y = -0.3683x + 53.795$ , x represents onset day of region 1 (S-W)

Fig 1 : Membership functions representing onset conditions

Fig 2: Mean rainfall behavior of three regions

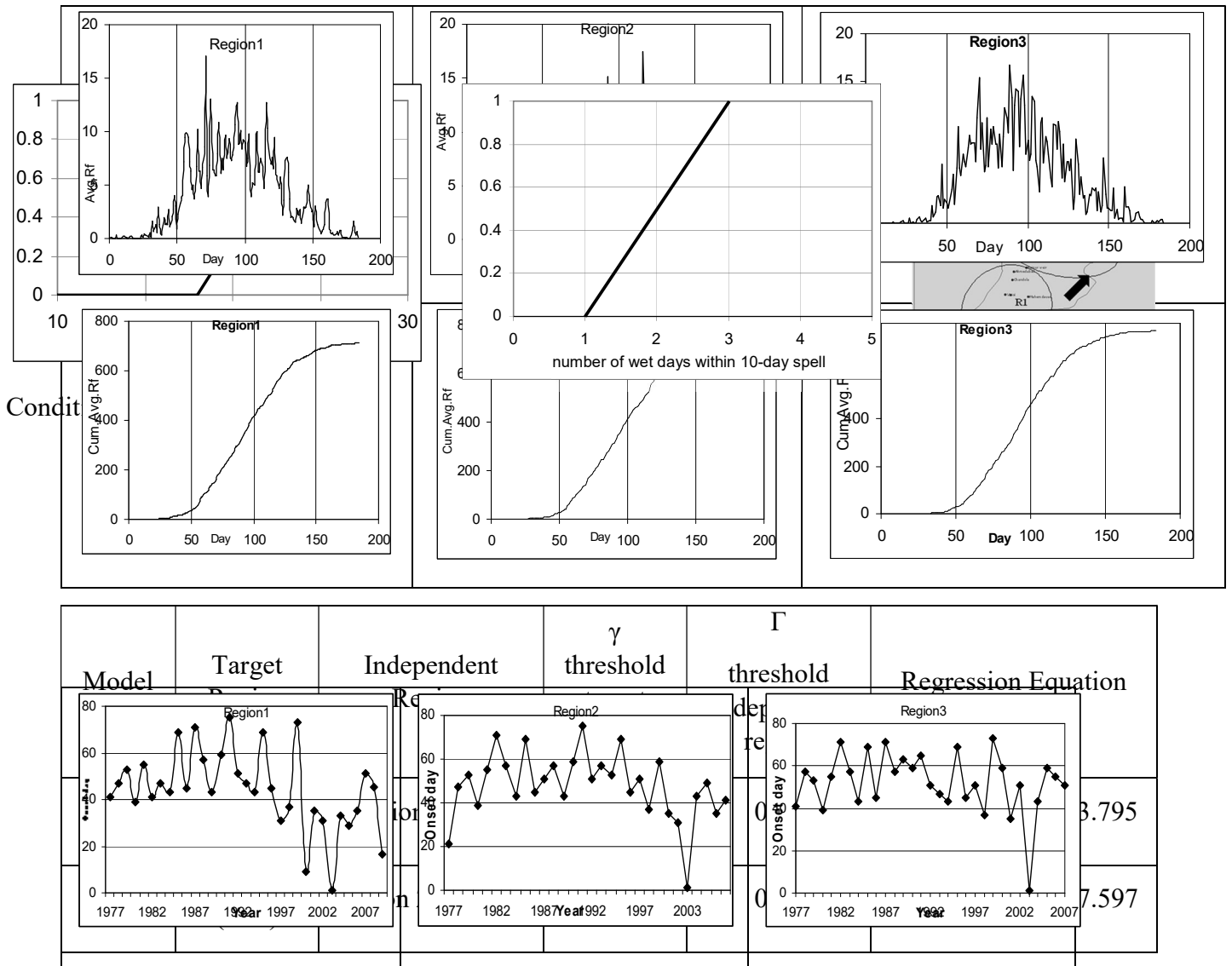


Fig 3: Onset days of three regions

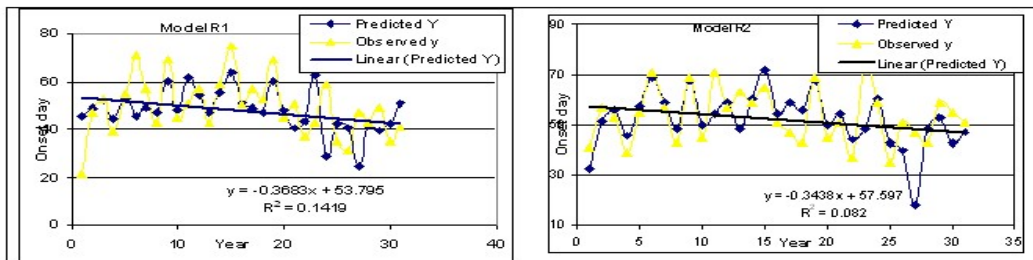


Fig 4: observed and predicted onset days using linear Regression Analysis and trends of onset.

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