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Rainfall prediction for the Kerala state of India using artificial intelligence approaches☆

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ABSTRACT

Three artificial intelligence approaches - K-nearest neighbor (KNN), artificial neural network (ANN), and extreme learning machine (ELM) - are used for the seasonal forecasting of summer monsoon (June-September) and post-monsoon (October-December) rainfall from 2011 to 2016 for the Kerala state of India and performance of these techniques are evaluated against observations. All the aforesaid techniques have performed reasonably well and in comparison, ELM technique has shown better performance with minimal mean absolute percentage error scores for summer monsoon (3.075) and post-monsoon (3.149) respectively than KNN and ANN techniques. The prediction accuracy is highly influenced by the number of hidden nodes in the hidden layer and more accurate results are provided by the ELM architecture (8-15-1). This study reveals that the proposed artificial intelligence approaches have the potential of predicting both summer monsoon and post-monsoon of the Kerala state of India with minimal prediction error scores.

1. Introduction

Accurate prediction of rainfall is highly desirable for states like Kerala where economy of the state and livelihood of people are highly sensitive to rainfall. Kerala receives approximately 2.5 times higher annual mean rainfall than the average of all India rainfall, nevertheless the state needs to resolve water scarcity issues in the upcoming years as the majority of the rainwater flows into the Arabian Sea within 48 to 72 hours of rainfall [1]. Summer monsoon and post-monsoon are the two rainfall seasons occur in the state. Summer monsoon occurs from June to September (JJAS) and is the primary rainy season of the state. Owing to wind reversal, the state has also received rainfall during the post-monsoon period which occurs from October to December (OND) [2].

Previous studies on Kerala have focused upon the spatial and temporal analysis, onset of rainfall, and trend analysis of rainfall for the state [3–10]. Rainfall is significantly influenced by the overall physiography of the state [5]. The decreased trend of rainfall over the southern part of the state has been observed [6]. Significantly increased rainfall trend during post-monsoon and decreased trend during summer monsoon were observed [7]. According to the recent studies, surface air temperature has shown an increasing trend and a decreasing trend has been observed for the annual rainfall over the state [10–13]. As per our previous study [14], the annual rainfall anomaly has shown a decreasing trend for the state.

Prediction of rainfall is a challenging task as it depends on various environmental factors. The regional climate and the economy of the Kerala state are highly influenced by the monsoon rainfall. Kerala has been affected by drought repeatedly in 2015 and 2016 [11]. Rainfall is classified into excess ($\geq 20\%$), normal ($\pm$ 19%), deficient (-20% to -59%), and scanty ($\leq 60\%$) [15]. The Kerala

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state has been severely affected by droughts due to deficient rainfall in JJAS and scanty rainfall in OND in 2016 (JJAS: 34% less than normal and OND: 62% less than normal) [12]. The severe shortage of drinking water, diminution of irrigational sources and lowering of the water levels adversely affect the hydropower generations in the state. These alarming issues motivated us for proposing artificial intelligence models to predict the rainfall for the Kerala state during the important monsoon seasons (JJAS and OND).

Artificial intelligence approaches have recently become popular and widely used for forecasting purpose in different domains of science and engineering. These methods are generalized data driven approaches which have the capability to model both linear and non-linear systems. These artificial intelligence models are capable of estimating the unseen data correctly with desired accuracy after completion of learning mechanism during the training period. So, these models are often referred as universal approximators. Therefore, it is necessary to apply these artificial intelligence approaches for prediction of the complex climate.

There are numerous studies based on rainfall onset and relation of rainfall with overall physiography of the Kerala state. However, there are limited numbers of studies to predict rainfall for the state using artificial intelligence techniques. Artificial neural network (ANN) approach has been implemented for the first time to predict rainfall for the Kerala state by Guhathakurta in 2006 [16]. Back-propagation based ANN technique has been applied for predicting rainfall for the state from 1992 to 2004 and author found better predictability of ANN model [16]. Another study by Nayagam et al. [17] in 2008 formulated a linear multiple regression model for long range forecasting of rainfall over Kerala using some ocean and atmospheric parameters. The present study is quite different from Guhathakurta and Nayagam et al. in the sense that instead of using a single method, performances of three artificial intelligence techniques were evaluated here for rainfall prediction over the Kerala state of India.

This paper is organized into different sections as follows. In section 2, the methodology is presented with short description of the dataset used, data normalization technique followed, and artificial intelligence approaches used. Section 3 represents prediction results of artificial intelligence techniques followed by the conclusion in section 4.

2. Methodology

2.1. Dataset used

The time series data was collected from Indian Institute of Tropical Meteorology (IITM), Pune for the Kerala subdivision for the period of 1871 to 2016 [18]. Preparation of the area weighted monthly data of rainfall has been performed by Mooley and Parthasarathy [19]. Summer monsoon (JJAS) and post-monsoon (OND) monthly mean time series were used for prediction purpose as the state receives maximum rainfall during these periods. In Fig. 1, the geographical location of the Kerala subdivision (study area) is shown.

2.1.1. Data normalization

Data normalization or data scaling is a pre-processing step which is necessary before initiation of the training phase of the neural network. Min-max normalization approach was used here for the data normalization process. In this study, the inputs to the neurons were normalized using the formula as presented in Eq. (1).

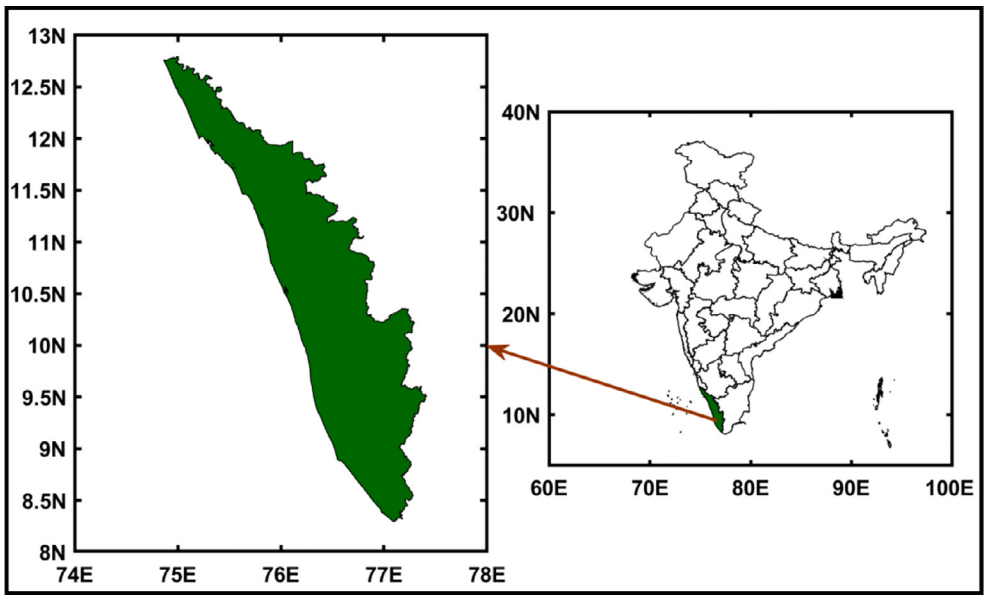

Fig. 1. Location of the area under study (Kerala subdivision).