ABSTRACT

Drought is considered as one of the most dangerous natural hazards in the today's world. Drought as an environmental disaster is associated with a deficit of water resources over a large geographical area, which extends for a significant period of time. It occurs in areas with high and low rainfall and all climate conditions. Drought occurs when precipitation is lower than normal. The drought can be classified into three categories viz. Meteorological, Hydrological and Agricultural drought. The Meteorological drought occur when actual rainfall is 25% less than the climatological mean, Hydrological drought occur when there is marked depletion of surface water causing very low stream flow and Agricultural drought occur when scarce soil moisture produces serious crop stress and affects the crop productivity.

Drought assessment is very important to manage water resources in lean period. It plays vital role in managing water demands especially in agriculture sector. In the present study North Gujarat region is chosen for study of different types of drought and its assessment using drought indices and development of drought forecasting model using soft computing techniques. The study covers five districts in North Gujarat viz., Banaskantha, Gandhinagar, Mehsana, Patan and Sabarkantha districts. Its geographical location makes it vulnerable to variations in the monsoon patterns, with rainfall being critical for agriculture in the region.

Various meteorological drought indices used to calculate number of drought years under various categories in the present study region using percent of normal (PN), percentage of departure from mean (PD), Deciles (DI), Rainfall anomaly index (RAI), standardized precipitation index (SPI), Reconnaissance drought index (RDI), China-Z index (CZI), modified china Z index (MCZI) and Z Score index. Also, precipitation concentration index and modified Fournier index is calculated for annual and seasonal basis for rainfall distribution and MFI used for identifying the years which having high and low rainfall erosivity. Aridity index viz., UNESCO Aridity index, De Martonne Aridity index, Erinc Aridity index, Thornthwaite Precipitation Effectiveness index, and Thornthwaite Moisture index are used in present study these indices helpful to determine the arid, semi-arid years. The results of all above indices was observed and analysed for assessment of droughts in North Gujarat districts using monthly rainfall, maximum temperature, minimum temperature, and potential evapotranspiration data for 1901 to 2002 years.

For Hydrological drought analysis is carried out using satellite-based remote sensing techniques to monitor hydrological droughts affected areas during 1992 to 2019 years. Different hydrological drought indices, namely Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI), Water Ratio Index (WRI), and Normalized difference salinity index (NDSI) used for surface water monitoring. These are most popular remote sensing indices used to assess water

bodies and changes in water content and can be valuable tools for hydrological drought assessment.

For Agricultural drought indices different Landsat data(Landsat5, 7 ETM+ and 8) during 1992 to 2019 years using Normalized difference vegetation index (NDVI), NDVI-deviation, Soil Adjusted Vegetation Index (SAVI), Vegetation Condition Index (VCI),Land surface temperature(LST), Temperature Condition Index (TCI), Vegetation Health Index (VHI) analysis over multiple years which enables the identification of changes associated with drought classification and the area affected under each category is analysed.

The trend analysis and correlation matrix analysis carried out also shows that there is highly correlation when time scale is increased and gives highly correlated between the different metrological drought indices. For prediction of drought severity class, drought forecasting model is developed using fuzzy logic approach and ANFIS approach for various combination of meteorological data for 70%-30% as training and validation period.

The monthly rainfall data of 102 years (1901-2002), analyzed and results shows that the months of January, February, March, April, May, November and December have been identified 68, 73, 78, 71, 68, 81, 79 times as drought months respectively in the 20^{th} century, indicating that these months must be provided with assured Irrigation. The study also reveals that 8%, 18% and 15% of extreme dry years, severe dry years and moderate dry years occur amongst drought years considered, which means 40% years are categorized into moderate to extreme drought years out of the total drought years using various drought indices over North Gujarat. Similarly, SPI, RDI and SPEI indices calculated for in various time scales (3, 6, 9 and 12 months) and results were analyzed. The percentage of drought years can provide valuable insights into the characteristics and trends of meteorological droughts and also rainfall variation in a North Gujarat region. The analysis of aridity index shows that North Gujarat districts is mostly arid in nature. It is revealed that almost 37% of the area possess semi-arid to 18% as arid zone and 48% as dry sub humid in the region. The trend analysis and correlation matrix also shows that there is highly correlation when time scale is increased and gives highly correlated between the different metrological drought indices. The results shows that SPI 3, SPI 6, SPI 9 and SPI 12 were well correlated with most of the other drought indices. Similarly, SPEI 3, SPEI 6, SPEI 9 and SPEI 12 showed a little less correlation with a similar time scale of other drought indices. Also, RDI 3, RDI 6, RDI 9 and RDI 12 showed a high correlation with a similar time scale of other drought indices.

The results of hydrological drought indices shows that Banaskantha district having 5.5% to 15.5%, Gandhinagar district having 1.5%-3.0%, Mehsana district having 2.5%-8.5%, Patan district having 1.5%-6.0% and Sabarkantha district having 1.2% to 4.0% water spread area in North Gujarat districts.

The average percentage of dry area in North Gujarat districts was 60.7%, 21.37%, 35.02%, 41.70% and 31.70% in Banaskantha, Gandhinagar, Mehsana, Patan, and Sabarkantha districts respectively. The results of NDVI index shows that dry area varies from 20% to 40% in North Gujarat districts. The maximum percentage variation was observed in Patan district from 30% to 42% during study period. This relationship revealed that when rainfall increases, NDVI, VCI also tends to decrease. Also there is increase in NDVI as a result, the event of agricultural drought increased. From the VCI analysis as extreme, high and moderate drought areas respectively in the study area. The LST analysis shows that Banaskantha and Gandhinagar district having 75% area under high temperature whereas Mehsana, Patan and Sabarkantha districts having more than 90% area. The analysis shows that NDVI decreased by 4% to 6% and NDWI decreased by 1 to 2% in the study area, while LST shows a significant increase by 1.5^{o}C –3.5°C. A consistent increase in LST, TCI can indicate prolonged periods of above-average land surface temperatures. Observe how TCI values correspond to changes in VHI. For instance, when TCI increases and VHI decreases, it suggests that elevated temperatures are negatively affecting vegetation health.

Various Indices are used to provide quantitative assessment of the severity, location, timing and duration of drought events. The analysis of agricultural drought in North Gujarat region it is clearly evident that the severity of drought increases year wise in the same time no drought condition decreased. Also, threshold values for different indices used to determine the drought affected areas in North Gujarat. The spatio temporal maps using all above indices were developed

Amongst developed models, the best Fuzzy and ANFIS model for RDI and SPI is Model 1 and 2, wherein model 1 represents annual rainfall as input and drought severity as output. model 2 represents annual rainfall and temperature as input and drought severity as output with the RMSE ranges between 0.03 to 0.015 for training and 0.0867 to 0.15 for validation period, and co efficient of determination value for training period is 0.9999 and for validation period is 0.9946 which are nearer to 1, which may be used for prediction of future drought conditions for the area considered under study for any amount of rainfall given.

Drought estimation helps water resource managers to assess the severity and duration of drought conditions. This information is crucial for planning water allocations, managing reservoir levels, and implementing water conservation measures. In summary, drought estimation is a critical tool for proactive planning and management in various sectors, helping to minimize the negative impacts of water scarcity on both natural and human systems. This study may help to improve the existing agricultural drought monitoring systems carried out in different parts of Gujarat. The results will be useful in future for planning, designing and operating irrigation system and crop planning too.