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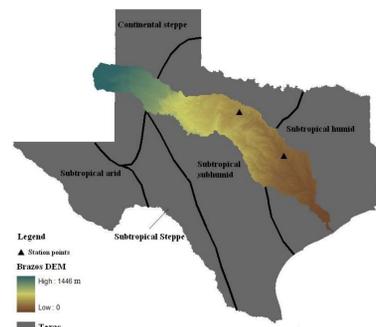
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Introduction

Assessment and understanding of past climate is an important step for drought mitigation and water resources planning. In this study, streamflow simulation obtained from the variable infiltration capacity (VIC) model was used for drought characterization, and subsequently regionalization was done based on the annual severity level, for the Brazos basin in Texas over a time span of 1949-2000. It is important to study drought characteristics within a regional context. Hence, identification of homogenous drought regions is a prerequisite, so that the drought characteristics can be studied within each of these regions. In this study, the concept of entropy was used for formation of homogenous regions based on drought severity. A standardized version of mutual information known as directional information transfer was used for station grouping. Results obtained were compared with the conventional k-means clustering method.

Objectives and Study Area



The objectives of the paper are:
 (1) Application of VIC model for streamflow drought analysis
 (2) Regionalization of Brazos basin based on the annual drought severity levels,
 (3) Identification of critical regions within the basin using entropy and comparison with the k means clustering method.

The area considered for this study is the Brazos River basin in Texas. It has a drainage area of 116,000 km² and average discharge of 300.2 m³/s.

Methodology

1. A large scale hydrological model known as VIC-3L (Liang et al., 1994) was used for simulation of daily streamflow on a 1/8th degree resolution over the Brazos basin.
2. Drought classification using Theory of runs. The index used for calculation of severity was standardized streamflow index (SSFI) (Modarres,2007).

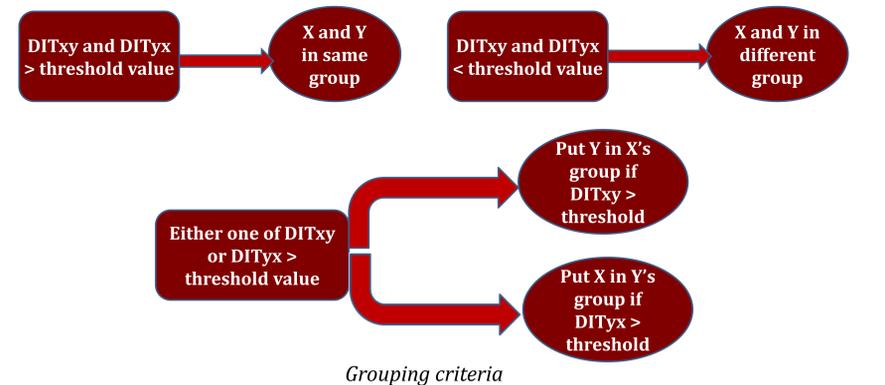
$$SSFI = \frac{F_i - \bar{F}}{\sigma}$$

3. Application of a mutual information based index: Directional information transfer (DIT) for regionalization based on drought severity (Yang and Burn,1994).
 1. Fraction of information transferred from one site to another.
 2. Value of DIT varies between 0 and 1.
 3. Not symmetric.

$$DIT_{xy} = \frac{T(X,Y)}{H(X)}; DIT_{yx} = \frac{T(X,Y)}{H(Y)}; DIT = (H - H_{lost}) / H = 1 - (H_{lost} / H)$$

4. Fixing a threshold value for DIT to control the group formation
5. Larger the threshold, higher the number of groups formed and vice versa

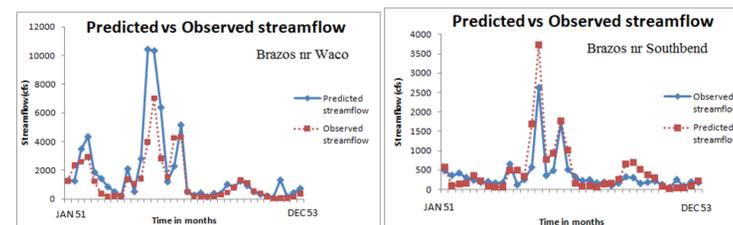
Methodology



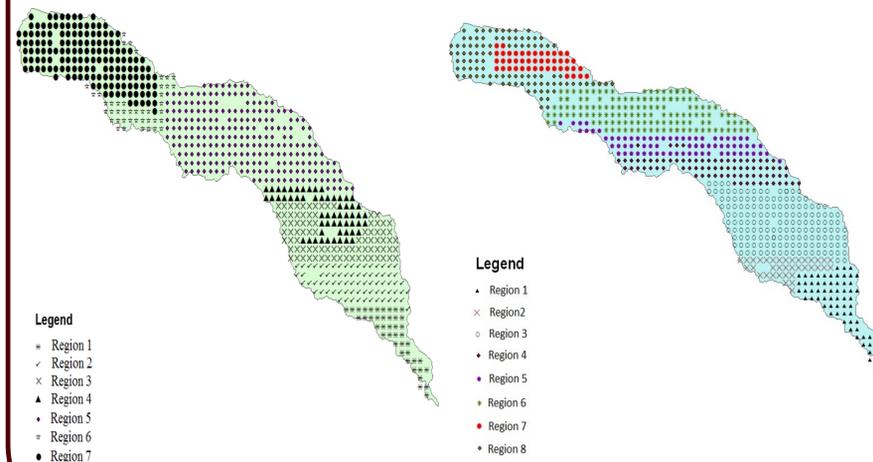
Grouping criteria

4. Comparison with the k-means clustering method. K-means is a hard clustering algorithm in which a collection of N vectors will be classified into K groups. The aim of the algorithm is to find the centre of clusters (also known as centroids) for each group. The algorithm minimizes the objective function which is essentially a dissimilarity function.

Results and Discussions



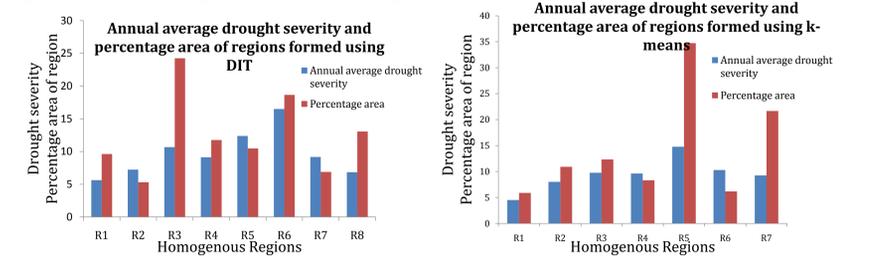
Validation results of the streamflow simulations from VIC model



Homogenous regions formed within Brazos River basin using (a) k-means (b) DIT

Results and Discussions

From the predicted versus observed streamflow plots it can be seen that the model has successfully simulated streamflow for Brazos basin. The homogenous regions based on the drought severity over the Brazos River basin using (a) entropy approach and (b) k-means approach can be seen from the respective figures. The percentage area coverage and average drought severity for each region formed using either method is given below:



Percentage area and average severity over each region

The drought severity pattern closely resembles the precipitation pattern over the basin. The middle Brazos basin showed relatively higher severity levels, and the lower Brazos region shows the least severity level, which could be attributed to the rainfall pattern over the area. The upper Brazos basin also showed relatively higher severity levels. The severity pattern of the regions formed using DIT and k-means clustering were found to be similar.

Concluding Remarks

- Entropy based DIT index was found to be an effective measure for the information connection between stations, and hence can be used for the grouping of the same.
- The average severity levels were found to be maximum in middle Brazos basin, and minimum in lower Brazos basin. This is consistent with the rainfall pattern within the basin.
- Similar results for regionalization using (1) DIT and (2) k-means clustering.

References

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<http://water.usgs.gov/wrri/09grants/national/2009TX334G.html>

