TEMPORAL AND SPATIAL CHARACTERISTICS OF SEASONAL AND ANNUAL RAINFALL IN MALAWI

Introduction

An understanding of the temporal and spatial characteristics of rainfall is central to water resources planning and management. Such information is often limited in many developing countries like Malawi, an agro-based economy where 60% of the agriculture is rain-fed. Most climate models project an overall decline of rainfall for the whole Southern Africa. However, some studies have observed changes in the mean rainfall, varying on relatively small spatial scales in the region. The main objective of this study was to investigate spatial and temporal characteristics of annual, seasonal and monthly rainfall in Malawi, a relatively lower spatial scale.

Methods

1. Data Quality Control

We used the Cumulative Deviations test for absolute testing (i.e. using stations own records) by Bisshard (1982). We further applied the widely used Standard Normal Homogeneity Test (SNHT) by Alexandersson (1986) for relative testing using neighboring stations.

2. Spatial characteristics

The spatial structure of rainfall between the various stations was examined using the Spatial Correlation Function (SCF) (Gen and Habib 2001):

\[ R(x, y) = \frac{1}{2\pi} \left( \frac{1}{n \sigma^2} \sum_{i=1}^{n} \frac{X_i - \mu}{\sigma} \right)^2 \]

where \( x \) is the distance between two stations and \( y \) with rainfall observations \( X \) and \( \mu \) respectively for any distance \( D \) between the two stations. A scatter plot of the \( x \) against \( y \) may reveal the underlying spatial correlation structure with distance among the stations.

3. Intra-annual rainfall Distribution

The Precipitation Concentration Index (PCI) was used to investigate monthly rainfall distribution (Oliveira 1988; De Louis et al. 2000):

\[ PCI_j = \frac{1}{N} \sum_{i=1}^{N} \frac{Z_{ij}}{Z_j} \]

Where \( Z_j^\prime \) is the monthly rainfall in mm, \( PCI \cdot 100 \) indicates uniform rainfall distribution in a year, while \( PCI \cdot 20 \) shows very high monthly variability.

4. Temporal Inteptions analysis

The nonparametric Mann-Kendall (MK) test statistic (Mann 1945; Kendall 1975) was used to analyse trends in the rainfall variables at a 0.05 level.

5. Krigging interpolations

Ordinary kriging interpolation was used to visualise the spatial patterns of the PCI.

Results

1. Spatial Correlations

Empirical spatial correlations (fig 2a) show a mixed correlation pattern. However, some structure in the spatial correlation is obtainable at other averaging intervals (fig 2b). Monthly rainfall series had the highest spatial correlations, with March and August having highest and lowest correlations, respectively (fig 2a and 2b). This spatial structure is typical of most tropical areas where rainfall occurs in fairly small convective storms than in the case of widespread rain (Jackson 1974).

2. Intra-annual rainfall distribution

The PCI showed that intra-annual rainfall is very variable countrywide. Areas with below intra-annual variability (PCI < 20) are in the Highlands to the north and south of the country (fig 3). Both areas are characterized by the south-easterly trade winds from Indian Ocean. In addition, the rainfall of the northern Highlands is also influenced by their proximity to Lake Malawi located on the east.

3. Temporal Rainfall Trends

Annual and seasonal (wet and dry) rainfall series exhibited localised trends with a 50%-50% countrywide distribution of negative and positive trends (not statistically significant at 0.05 level) (fig. 4A). The trends in the monthly rainfall series were negative at 86% of the stations (fig. 4B), though again not statistically significant. Positive trends dominate the January and February series, 12% and 8% respectively of which were significant (fig. 4B). The rest of the months had a predominance of negative trends, with January and April having the most number of significant negative trends. An increase in intra-annual variability is suggested as evidenced by the monthly positive trends of the PCI. 28% of which were significant at 0.05 level (Table 1).

Table 1: Summary of Mann-Kendall trends for individual months and PCI series as % of stations

<table>
<thead>
<tr>
<th>Trend/Variable</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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</thead>
<tbody>
<tr>
<td><strong>PCI</strong></td>
<td>12%</td>
<td>8%</td>
<td>9%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>14%</td>
<td>16%</td>
<td>14%</td>
<td>15%</td>
<td>13%</td>
</tr>
<tr>
<td><strong>Negative</strong></td>
<td>10%</td>
<td>10%</td>
<td>10%</td>
<td>12%</td>
<td>14%</td>
<td>14%</td>
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<tr>
<td><strong>Positive</strong></td>
<td>12%</td>
<td>8%</td>
<td>9%</td>
<td>8%</td>
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<td>6%</td>
<td>8%</td>
<td>6%</td>
<td>4%</td>
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</table>

**Correlation Function (SCF)**

\[ R(x, y) = \frac{1}{2\pi} \left( \frac{1}{n \sigma^2} \sum_{i=1}^{n} \frac{X_i - \mu}{\sigma} \right)^2 \]

**Location of Malawi in Africa and rainfall regimes of satellite stations**

![Fig. 2a: Empirical spatial correlations from top to bottom respectively for Annual, Seasonal, March and August monthly rainfall in Malawi.](image)

![Fig. 2b: Average spatial correlations from top to bottom respectively for Annual, Seasonal, March and August rainfall series in Malawi averaged at 20 km intervals.](image)

Conclusions

We observed from the low spatial correlations that rainfall in Malawi mostly occurs as localised events. Intra-annual variability is rather high with mean PCI > 20. Localised positive and negative non-significant trends dominate the wet and dry season series. Monthly rainfall on other hand had a clear dominance of negative trends countrywide. Rainfall increases in the months of January and February but the positive trends were coupled with negative trends for the rest of the months. Increased intra-annual variability is suggested by the monthly positive trends of the PCI.

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