TEMPORAL AND SPATIAL CHARACTERISTICS OF SEASONAL AND ANNUAL RAINFALL IN MALAWI

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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 90% 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 Buishand (1982). We further applied the widely used Standard Normal Homogeneity Test (SNHT) by Alexandersson (1986) for relative testing using neighbouring stations.

2. Spatial characteristics

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

$$R_{i,j} = \frac{\overline{(Z_i^0 - \bar{Z}_i)(Z_j^0 - \bar{Z}_j)}}{\overline{(Z_i^0 - \bar{Z}_i)(Z_j^0 - \bar{Z}_j)}} \qquad (1)$$

Where $R_{i,j}$ is the empirical SCF between two stations *i* and *j* with rainfall observations z_i^o and z_j^o with mean rainfall $\bar{z}_i$ and $\bar{z}_j$ respectively for any distance D_{ij} between the two stations. A scatter plot of the $R_{i,j}$ against $D_{i,j}$ 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 (Oliver 1980;De Louis et al 2000):

$$PCI = \left[\frac{\sum p_i^2}{\left(\sum p_i\right)^2}\right] \times 100 \qquad (2)$$

Where p_i is the monthly rainfall in mm. *PCI<10* indicates uniform rainfall distribution in a year, PCI<10<20 high monthly concentration and seasonality, while PCI>20 shows very high monthly variability.

4. Temporal trend analysis

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

5. Krigging Interpolations

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

References

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Study area and data

In Malawi (Fig. 1), both rainfall and temperature are altitude dependent. Rainfall ranges from 700 mm in the semi-arid low lying parts to 2500 mm in the highlands whereas temperature ranges between 10–40ºC countrywide. Two main rain bearing systems dominate the rainfall of Malawi and the Southern Africa region: (1) The Inter tropical Convergence Zone (ITCZ) marked by convergence of north easterly monsoon and south easterly trade winds and (2) The Congo air boundary- the northwest winter monsoons comprised of recurving tropical Atlantic air that reaches Malawi through the Congo basin. The Congo Air is normally active in the central and northern parts of the country.

Data from 42 stations between the period 1960-2006 were obtained from the Malawi Department of Climate Change and Meterological services. Various rainfall variables were derived including, annual, seasonal (i.e. wet and dry season totals)and monthly rainfall (i.e month to month and individual months).

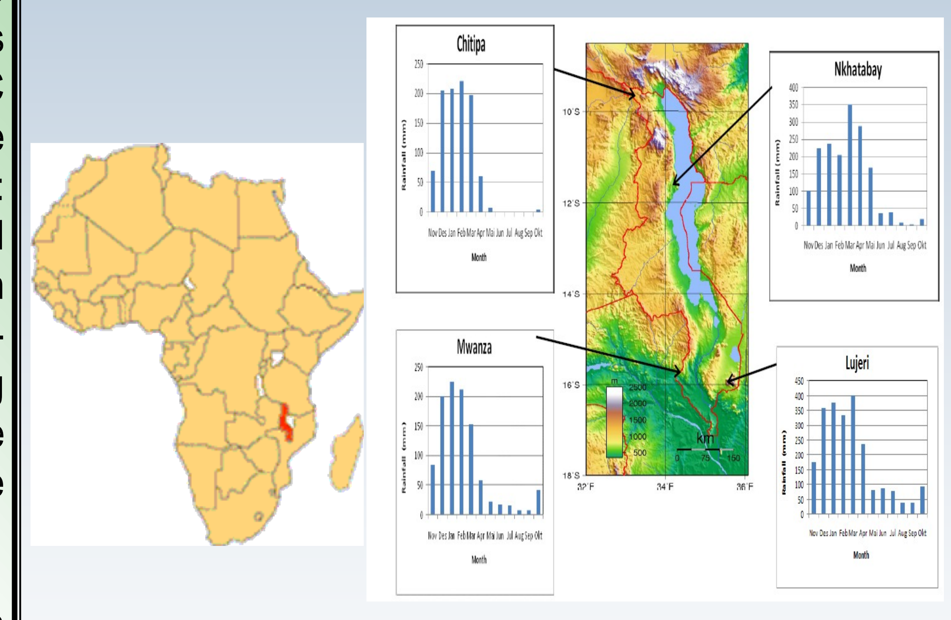

Fig1. "Location of Malawi in Africa and rainfall regimes of selected stations"

Results

1. Spatial Correlations

Empirical spatial correlations (fig 2a) show a mixed correlation pattern. However, some structure in the spatial correlations is obtainable at 20km averaging intervals (fig 2b). Monthly rainfall series had the highest spatial correlations , with March and August having highest and lowest correlations, respectively (Figs 2a and 2b) . This spatial structure is typical of most tropical areas where rainfall occur within fairy small convective storms than in the case of widespread rain (Jackson 1974).

2. Intra-annual rainfall distribution

The PCI show that intra-annual rainfall is very variable countrywide. Areas with lowest intra-annual variability (PCI~20) are in the highlands to the north and south of the country (Fig 3). Both areas are windward of the south easterlies from Indian Ocean. In addition, the rainfall of the northern highlands is also influenced by their proximity to Lake Malawi located on their 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 α=0.05), indicating the absence of large scale patterns (Fig 4a-4c). The trends for monthly rainfall series were negative at 88% of the stations (Fig 4d), though again not statistically significant. Positive trends dominate the January and February series, 21% and 5% respectively of which were significant (Table1). The rest of the months had a predominance of negative trends, with June and April having the most number of significant negative trends. An increase in intra-annual rainfall variability is suggested as evidenced by the mostly positive trends of the PCI, 26% 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

Trend/Variable	Nov	Dec	Jan	Feb	Mar	Apr	Mai	Jun	Jul	Aug	Sep	Oct	PCI
NegTrend*	69	83	26	45	60	83	81	79	57	64	55	52	8
SigNeg**	5	5	0	0	2	19	12	21	5	5	2	7	0
PosTren***	31	17	74	52	38	14	19	19	38	33	45	48	92
SigPos****	0	0	21	5	0	2	0	0	0	0	0	0	26

NegTrend*-Negative trends; SigNeg**-Significant negative trends ; PosTren***-Positive trends; SigPos****-significant positive trends

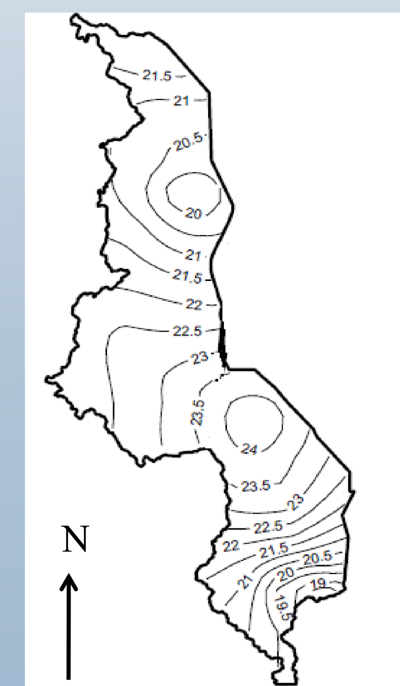

Fig 3. PCI spatial distribution

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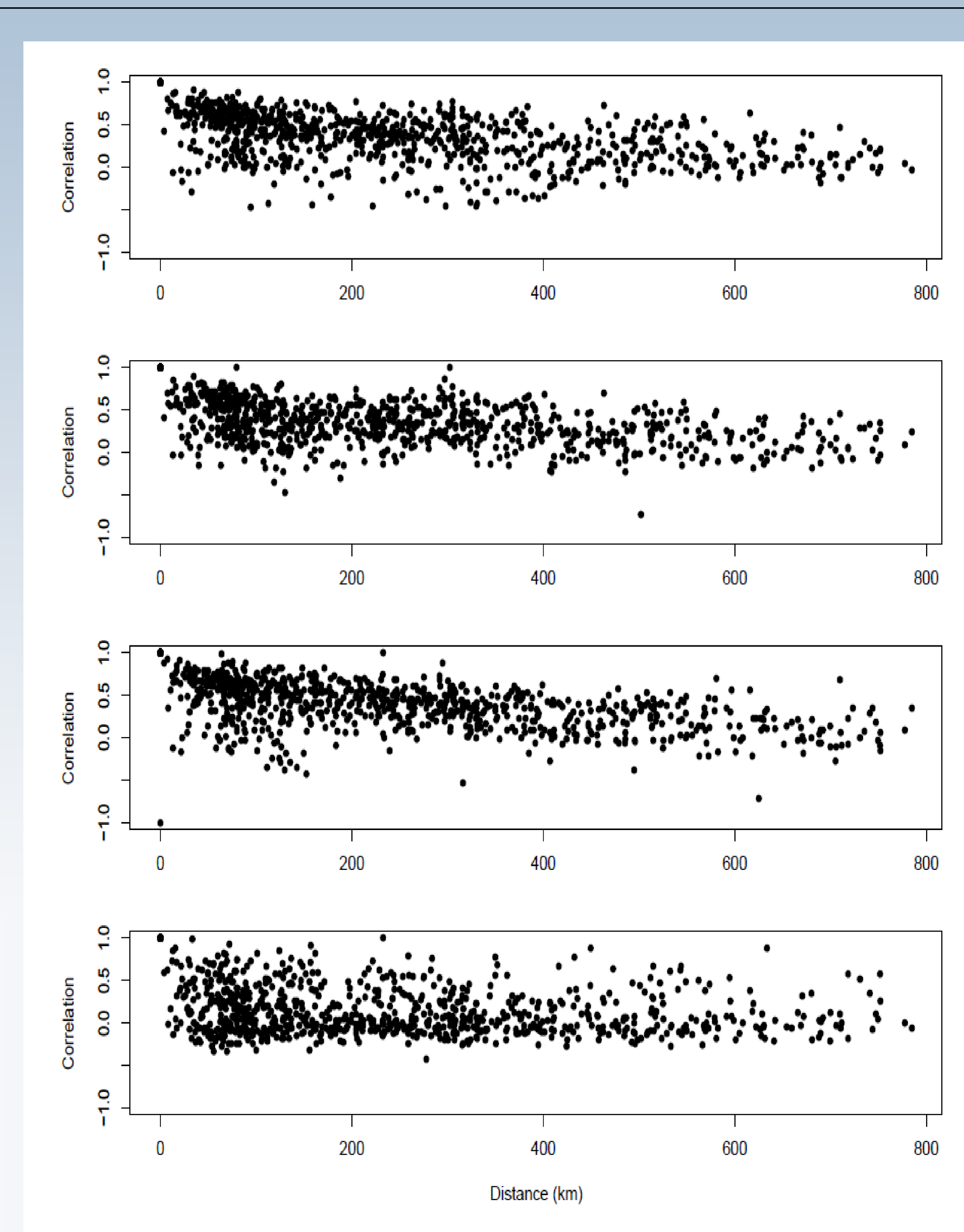

Fig 2a. Empirical spatial correlations from top to bottom respectively for Annual, Seasonal, March and August monthly rainfall in Malawi.

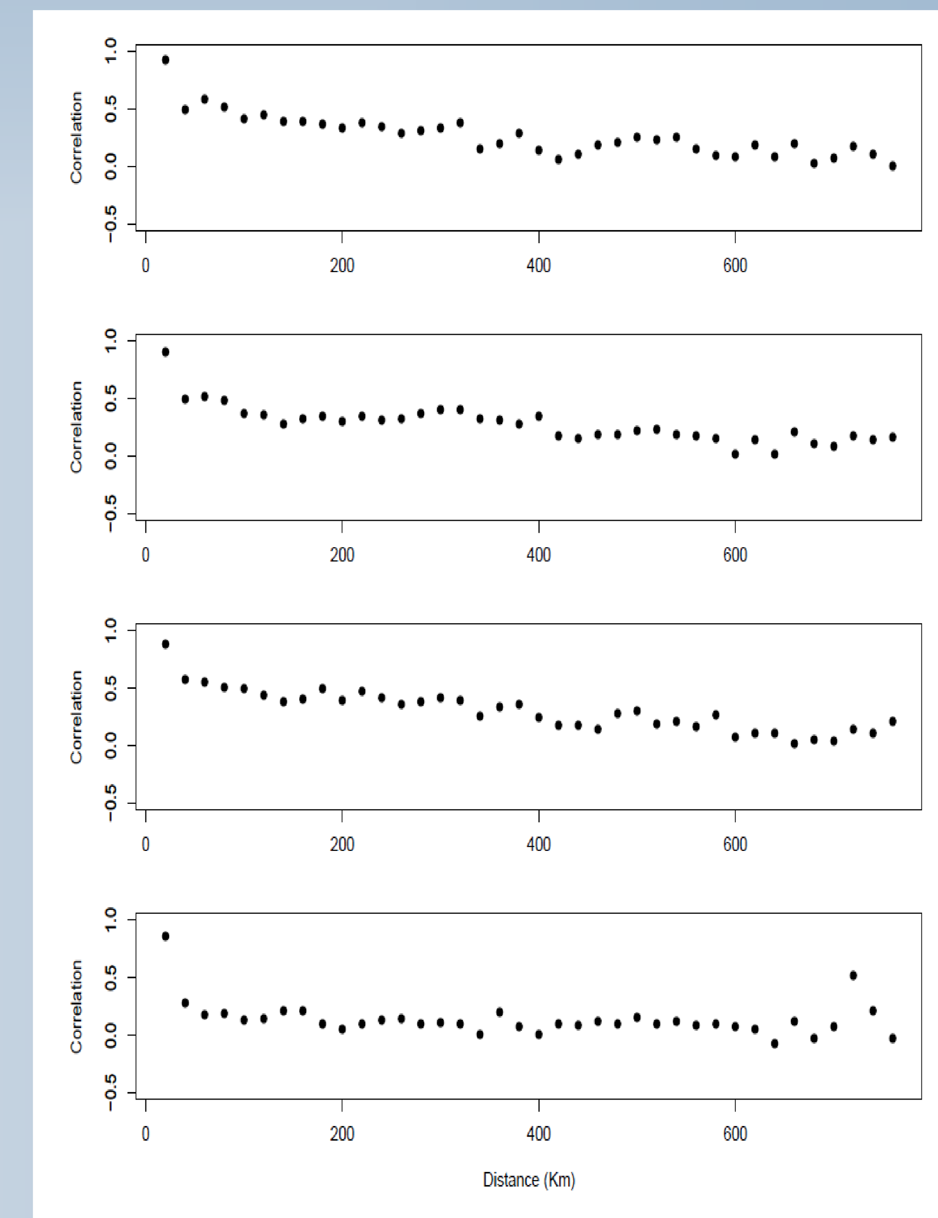

Fig 2b. Average spatial correlations from top to bottom respectively for Annual, Seasonal, March and August rainfall series in Malawi averaged at 20 km intervals.

Fig 4.Mann-kendall rainfall trends (a) Annual (b) Wet Season (c) Dry Season (d) Monthly △ = Positive ▽ = Negative ○ = No trend

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 annual ,wet and dry season series. Monthly rainfall on other hand had a clear dominance of negative trends countrywide. Rainfall increased 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 mostly positive trends of the PCI.

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