CHANGES IN RAINFALL SEASONALITY (1889-2015) AT GROOTFONTEIN, SOUTH AFRICA

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INTRODUCTION

Rainfall seasonality (the time of year when rainfall peaks) is an important abiotic driver in natural and ecological ecosystems for many reasons, including affecting direct effects on and competitive interactions between plants (Dean et al., 1995; Whitford, 2002) , altering fire regimes (Cochrane, 2010), and influencing crop and livestock production (Richardson & Hahn, 2007; Van Oudtshoorn, 2007). South Africa generally experiences a single rainy season which, for most of the country, is during summer, except in the south western regions when it is during winter (Nicholson, 2000). In the Karoo, rainfall amount and rainfall seasonality have likely interacted for thousands of years to influence the balance between dwarf shrubs and grasses (Mucina et al., 2006). The general understanding is that mid-summer rains promote C_4 grasses, while rain during other times of the year promote slower-growing, frost-hardy C_3 shrubs (Roux & Vorster, 1983; Kraaij & Milton, 2006), although further work is required to better understand the relation between these two life forms (O'Connor & Roux, 1995; Masubelele et al., 2014). At Grootfontein, in the eastern Karoo, du Toit & O'Connor (2014) reported on the cyclical nature of rainfall seasonality from 1888 to 2012. The objective of this study was to provide an updated and expanded analysis of changes and patterns of rainfall seasonality at Grootfontein.

METHODS

A dataset of monthly rainfall from 1889 to 2015 was available for analysis. Data were filtered using a 10-year running mean, to reduce variation, to generate a dataset of monthly data for the seasons (July of year x to June of year x+1) 1898-2014e. Each season's data were then fitted with a rational model regression (Equation 1; see Figure 1 as an example). Rainfall seasonality for each year was defined as the time of year at which the regression peaked. To determine the position of the peak, the derivative of the rational function was calculated (Equation 2) and solved for each year's regression.

Seasonality data were smoothed using Lowess regression (α=0.25), a robust technique that protects against the effect of outlying points (Cleveland 1979), using dedicated software (Peltier 2015).

$$y = \frac{a + bx}{1 + cx + dx^2}$$ Equation 1

$$x = \frac{\sqrt{a^2d^2 + (b^2 - abc)d} - ad}{bd}$$ Equation 2

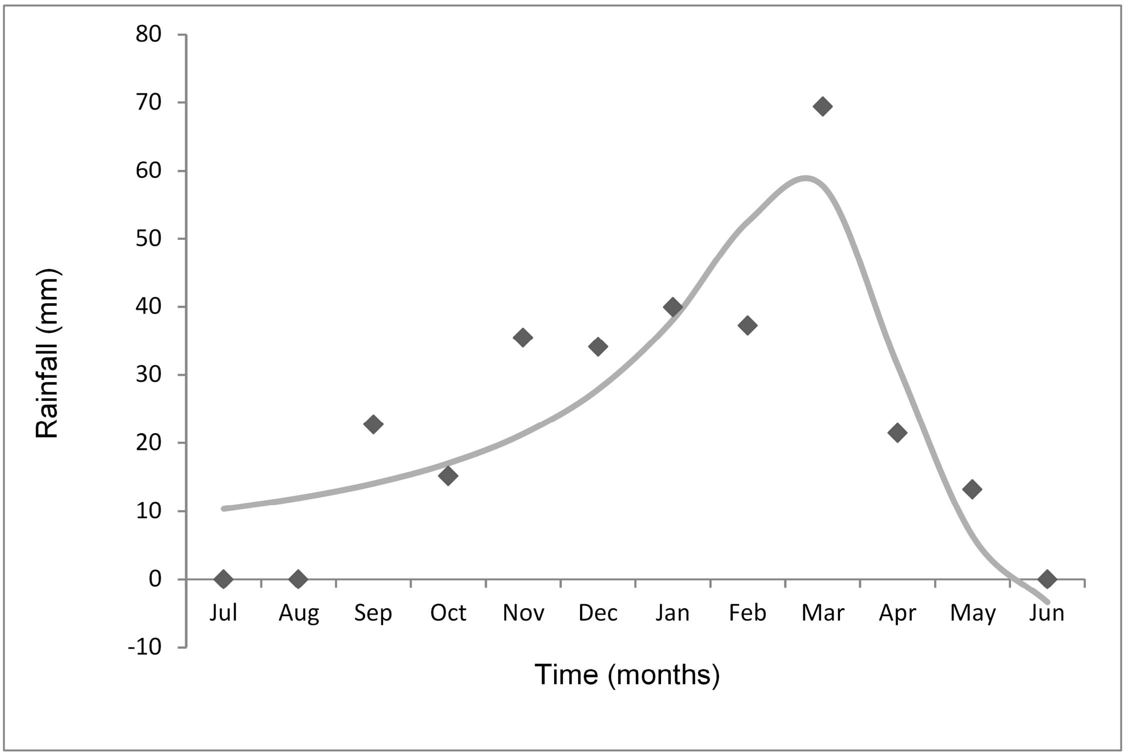

Figure 1. Ten-year running mean monthly rainfall values (dots) from 1922-1931 fitted with a rational function (line).

RESULTS AND DISCUSSION

Rainfall seasonality ranged from early January to early March (Figure 2). From the beginning of the 20th century rains became increasingly late until the late 1920s, after which they began falling increasingly earlier until the mid-1960s. At this point there was an abrupt transition to very late rains, since which time rains have tended again to being early. There is a strong inverse linear relation between rainfall amount and rainfall season, i.e. early rains are correlated with wet seasons ($F_{1,115}$=44.5; $P<0.0001$; R^2=28.1%) (Figure 3).

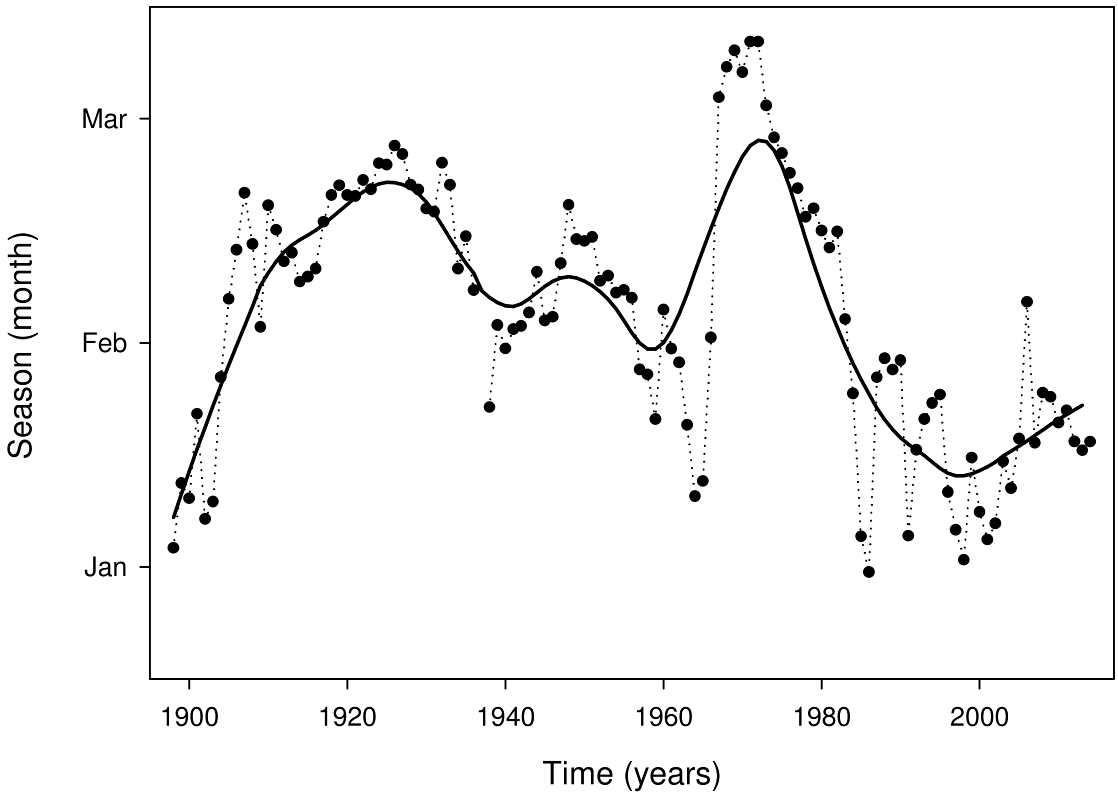

Figure 2. Rainfall seasonality (dots and dashed line) fitted with a Lowess function (solid line) at Grootfontein

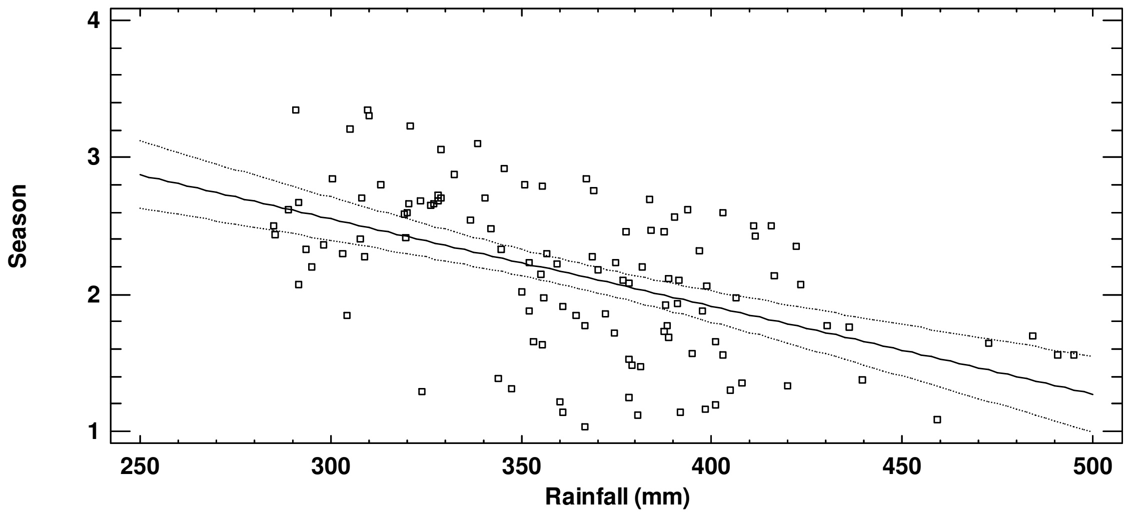

Figure 3. Relation between rainfall amount and season at Grootfontein. Solid line is linear regression; dotted lines are 95% confidence intervals. For season, 1=1 January, 2 = 1 February, etc.

Because seasonality ranges broadly over the months of January and February, rains are further defined as being ‘early’ if before 31 January and ‘late’ if after 1 February. From 1905 until 1983 rains were mainly late with an average of 350 mm. Before 1906 the average rainfall was slightly higher than this but importantly, since 1984, the rains have been consistently early with a high average (405 mm). Heavy early rains would be expected to favour the growth of C_4 grasses, which is consistent with the common trend of increased grassiness in the region, and possibly with reports of a more grassy Karoo in the late 1800s (Dickie & Parsons, 2012).

Table 1. Periods of early and late rains at Grootfontein

Period	Early/late	Average rainfall (mm)
1898-1905	Early	372
1906-1956	Late	345
1957-1961	Early	358
1962-1983	Late	356
1984-2014	Early	405

CONCLUSION

Seasonality of rainfall has varied over time from early January to early March. Wet years tend to be associated with early rains, and this may provide an explanation for the increased grassiness in the Karoo.

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