Changes in rainfall pattern in the eastern Karoo, South Africa, over the past 123 years

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ABSTRACT

Rainfall is a key driver of ecosystem processes, especially vegetation dynamics, in semi-arid regions. Rainfall amount, including droughts and extended wet periods, seasonality, and, possibly, concentration, influence vegetation composition in the eastern Karoo. A monthly rainfall record of 123 years from Grootfontein was analysed to search for evidence of cyclicity in rainfall amount, seasonality, and concentration. Rainfall was substantially higher during the late 1800s and after 1990 than it was during the rest of the 20th century. Extended sequential below-average runs of years characterised the drought periods of the early 20th century and the 1960s. There was strong evidence of an approximately 20-year rainfall cycle, except for spring rain. Additionally, annual and seasonal rainfall showed evidence of a longer cycle, between 44 and 77 years, which may be related to the southern oscillation index. The additive effects of the two cycles described annual and seasonal rainfall with R^2 values typically > 0.5. Rainfall seasonality was also related to the longer-term cycle, while rainfall concentration showed some evidence of having entered a new, more concentrated state since 1988. The analysis reveals that rainfall at Grootfontein is not a random process, but rather appears driven by cyclical processes. Rainfall at the site is predicted to decline over the next approximately 20 years, and the high levels of variation and complex causal factors will make it difficult to discriminate between natural variation and possible effects of climate change on rainfall.

Keywords: semi-arid, rainfall concentration, rainfall seasonality, periodicity, cyclicity

INTRODUCTION

Rainfall is a primary driver of the structure, composition and functioning of semi-arid vegetation communities (Gentry, 1988; Anderson et al., 2007; Belsky, 1990). In semi-arid rangelands rainfall amount may be highly variable over years and decades, although seasonal patterns (e.g., wet summers) may be relatively predictable. High rainfall variability can lead to droughts, which can significantly alter community composition through the die-off of plants (Westoby et al., 1989). Extended periods, rather than single years, of above-average rainfall may induce significant ecological changes, such as the recruitment of woody plants (Kraaij and Ward, 2006), or increased grassiness leading to increased likelihood of fire (Scholes et al., 2003). In the eastern Karoo, South Africa, vegetation composition is strongly related to rainfall amount and seasonality (Roux, 1966; Roux and Vorster, 1983; Hoffman et al., 1990; O'Connor and Roux, 1995). Rainfall amount in semi-arid regions increases plant growth, and rainfall seasonality is a potentially strong driver of vegetation composition in the eastern Karoo (Roux, 1966; Roux and Vorster, 1983; O'Connor and Roux, 1995) because of the differential response of plant growth forms (importantly C_3 shrub and C_4 grass forms) to water availability across seasons (Epstein et al., 1997). Similarly, rainfall concentration (how rainfall is distributed over the year) may control vegetation composition to some extent, as low-concentration rainfall (rainfall spread across much of the year) would presumably favour perennial plants that grow more or less continuously, while high-concentration rainfall (rainfall concentrated within a few months) would favour plants adapted to long periods of dry weather such as succulents and ephemerals. Therefore, changes in rainfall amount, seasonality, and concentration in the eastern Karoo would be expected to have a marked influence on vegetation and ecosystem functioning. Furthermore, understanding cyclical or directional changes in rainfall parameters, especially in the face of predicted increases in rainfall variability (Mason et al., 1999) and amount (Hewitson and Crane, 2006), is necessary for understanding and managing this ecosystem.

In Africa, considerable research effort has been focused on identifying patterns in rainfall over time, and particularly cycles, at continental (Nicholson, 2000), regional (e.g. Tyson, 1971 in South Africa), and local (e.g. Gertenbach, 1980 in the Kruger National Park) scales. In South Africa a range of short-period cycles, in the order of 2–7 years, have been identified (Vines, 1980; Jury and Levey, 1993; Kane, 2009), although of greater interest has been a cycle with a period of approximately 20 years (Tyson, 1971; Dyer, 1975; Dyer, 1976; Hall, 1976; Dyer and Tyson, 1977; Vines, 1980; Jury and Levey, 1993; Alexander et al., 2007; Kane, 2009). Because data series are limited in length (usually <100 years), identifying cycles with a longer period is often impossible, although Kane (2009), using data from 1990, did find evidence of 32–35 and 55–66 year cycles for parts of South Africa. Rainfall patterns have been linked to the Southern Oscillation Index (SOI) (Nicholson and Entekhabi, 1986; Kane 2009), and the sunspot cycle (Dyer, 1976; Thresher, 2002; Alexander et al., 2007), or a combination of the two (Stager, 2007). Sunspots have been identified as having an 11-year cycle, while frequencies ranging from months to a few years (Nicholson and Entekhabi, 1986; An and Wang, 2000), 10–15 years (Sun and Yu, 2009), and 12–20 years (Torrence and

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Received 12 September 2013; accepted in revised form 10 June 2014.

http://dx.doi.org/10.4314/wsa.v40i3.8
Available on website http://www.wrc.org.za
ISSN 0378-4738 (Print) = Water SA Vol. 40 No. 3 July 2014
ISSN 1816-7950 (On-line) = Water SA Vol. 40 No. 3 July 2014