Journal of Arid Environments 91 (2013) 88–94

Contents lists available at SciVerse ScienceDirect

Journal of Arid Environments

journal homepage: www.elsevier.com/locate/jaridenv

Runoff responses to long-term rainfall variability in a shrub-dominated catchment

L. Turnbull [a,*], A.J. Parsons [b], J. Wainwright [c], J.P. Anderson [d]

[a] Institute of Hazards, Risk and Resilience, Department of Geography, University of Durham, Science Laboratories, South Road, Durham DH1 3LE, UK
[b] Department of Geography, University of Sheffield, UK
[c] Department of Geography, University of Durham, UK
[d] Jornada Basin Long Term Ecological Research Program, New Mexico State University, Las Cruces, NM, USA

ARTICLE INFO

Article history:
Received 10 January 2012
Received in revised form
28 November 2012
Accepted 12 December 2012
Available online 26 January 2013

Keywords:
Climate change
Frequency
Magnitude
Rainfall
Runoff response

ABSTRACT

In this study we investigate how rainfall has changed between two nine year periods (1977–1985 and 2003–2011), and evaluate the effects of changes in rainfall on runoff from a shrub-dominated catchment in the southwestern USA. Analysis of rainfall characteristics shows that between these two periods there is an overall increase in annual rainfall, which corresponds with a long-term increase in rainfall in this region. Analysis of the frequency–magnitude distribution of rainfall events during these two periods indicates that there has not been a significant change in the return period of daily rainfall totals, whereas there has been a significant change in the return period of runoff-generating rainfall events. Between the two periods, there has been a large increase in the return period for a runoff event of a given magnitude. Although there has been an increase in rainfall between the two periods, results show that, contrary to what might be expected, an overall increase in rainfall has not resulted in an increase in runoff because of a change in the frequency–magnitude distribution of runoff-generating rainfall events. We anticipate that this reduction in runoff is due to a reduction in rainfall intensities between the two periods.

1. Introduction

Over the past century or more, there has been profound vegetation change in the southwestern USA, from native desert grassland to shrubland (Brown et al., 1997; Van Auken, 2000), which is associated with an increase in runoff and erosion (Parsons et al., 1996; Turnbull et al., 2010; Wainwright et al., 2000). This vegetation change is widely considered to be driven by changes in climate, overgrazing and changes in fire regimes (e.g. Buffington and Herbel, 1965; Brown and Archer, 1999; Gao and Reynolds, 2003; Neilson, 1986). At the Jornada Experimental Range in southern New Mexico, between 1914 and 2011 there has been a significant increase in annual rainfall at a rate of 0.7 mm a^{-1} ($p = 0.02$; Fig. 1). This increase in annual rainfall is manifest as an increase in summer rainfall at a rate of 0.58 mm a^{-1} ($p = 0.03$) and an increase in winter rainfall at a rate of 0.17 mm a^{-1} ($p = 0.17$).

Rainfall characteristics are important drivers of runoff dynamics in drylands, especially in terms of the frequency and magnitude of rainfall events. Larger, more extreme events are more likely to exceed the infiltration capacity of the soil and generate runoff, while the reverse will be true of less intense rainfall events. Therefore, changes in the frequency and magnitude of rainfall events that drive changes in the frequency and magnitude of runoff events will alter the characteristics of runoff, erosion and nutrient redistribution in drylands.

Increasingly, rainfall-manipulation experiments are being undertaken to uncover the effects of changes in rainfall characteristics on ecosystem processes (e.g. Reynolds et al., 2000; Sala and Lauenroth, 1982; Thomey et al., 2011; Wainwright et al., 2000). However, the direct effects of long-term changes in rainfall on runoff dynamics remain poorly understood. Projections of future climate change in the southwestern USA are for a decrease in annual rainfall due to the northward displacement of the subtropical anticyclone (Christensen et al., 2007: 888), and that the transition to a drier climate should already be underway (Seager et al., 2007). However, there is considerable uncertainty in these predictions for the southwestern USA, with some Atmospheric General Circulation Models predicting an increase in rainfall over this region (Christensen et al., 2007: 891). Several studies have used regional climate models to investigate the effects of predicted climate change on extreme events, with general consensus that the anticipated decrease in rainfall will lead to an increase in extreme events (Christensen et al., 2007). However, there is perhaps

* Corresponding author. Tel.: +44 (0) 191 33 41957.
E-mail address: Laura.turnbull@durham.ac.uk (L. Turnbull).

0140-1963/$ – see front matter
http://dx.doi.org/10.1016/j.jaridenv.2012.12.002

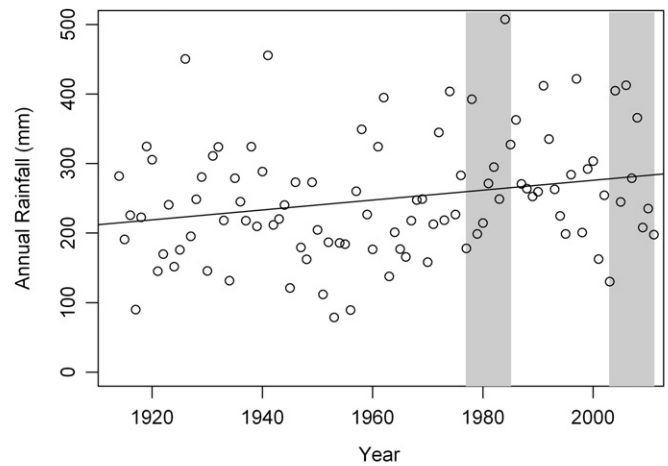

Fig. 1. Long-term rainfall record from the Jornada Experimental Range (1914–2011; Jornada Headquarters rain gauge) shows an overall increase in annual rainfall of 0.7 mm a^{-1} ($p = 0.02$). Highlighted segments show the two time periods that are investigated in this paper: period 1 (1977–1985) and period 2 (2003–2011).

even more uncertainty over these projections of changes in the frequency–magnitude distribution of rainfall events and the occurrence of extreme events, largely because much of the summer rainfall in this region is controlled by convective-scale rainfall events which are harder to simulate (Giorgi et al., 2001; Leung et al., 2003).

Changes in frequency–magnitude distributions of rainfall have long been recognized as important controls on geomorphic processes (Cooke and Reeves, 1976; Leopold, 1951). Analysis of long-term daily rainfall records from four sites across New Mexico showed a progressive increase in the frequency of small rainfall events (<12.5 mm) between 1850 and 1930 (Leopold, 1951). For example, in the semi-arid southwestern USA, there has been debate concerning impacts of extreme rainfall events on arroyo downcutting. Cooke and Reeves (1976) suggest that recent and historic episodes of arroyo downcutting have occurred as a result of unusually large rainfall events that cause particularly large flood events. Others argue that arroyo downcutting is driven by changes in vegetation cover and composition induced by factors such as drought which reduces vegetation cover, or by overgrazing (Antevs, 1952; Bull, 1997; Graf, 1983). The effects of changes in the

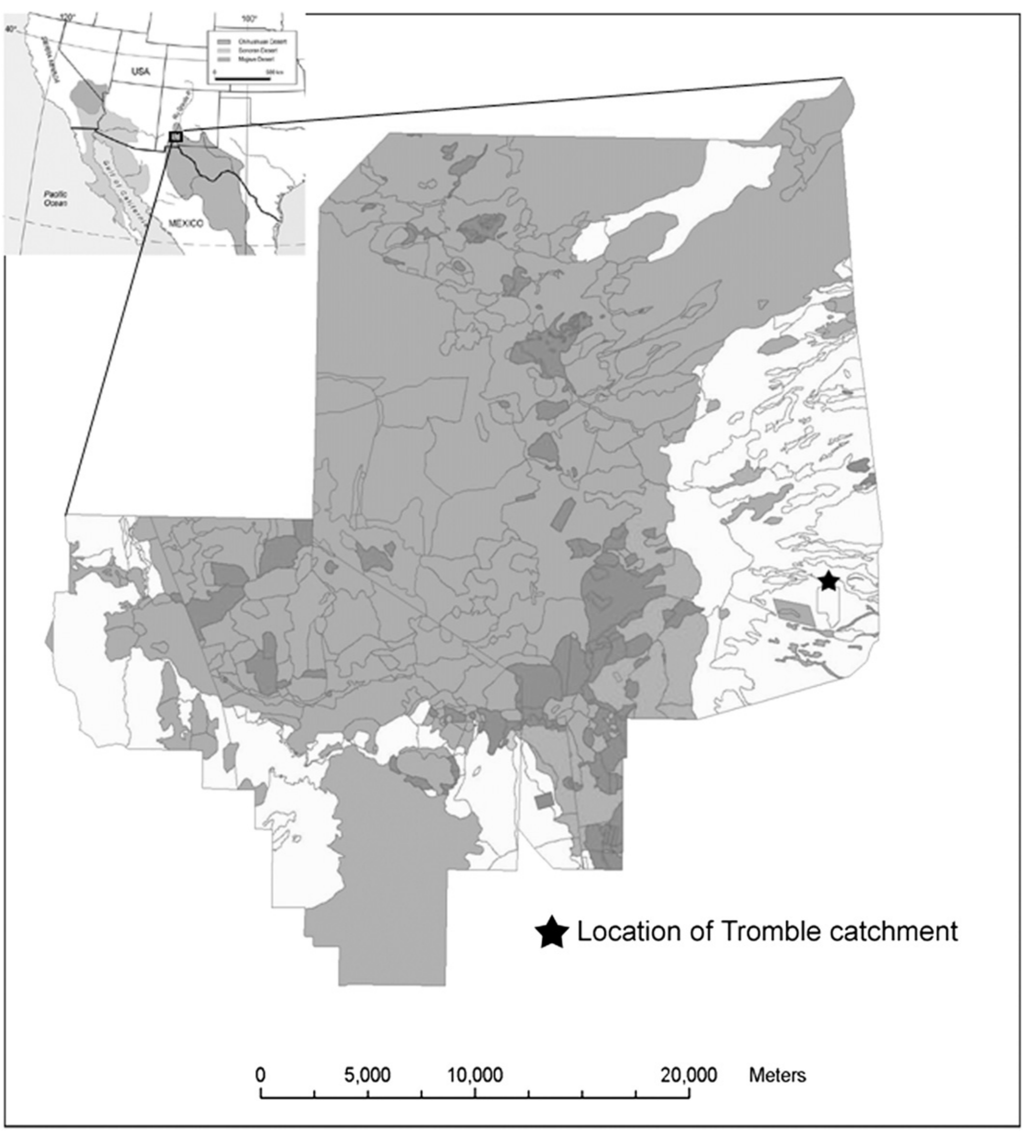

Fig. 2. Location of the Tromble catchment in the Jornada Experimental Range, New Mexico, USA. Within the Jornada Experimental Range (larger map), areas shaded in dark gray are dominated by grasses, areas shaded in light gray are dominated by mesquite and tarbush and areas in white are dominated by creosotebush (adapted from Gibbens et al., 2005).