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Spatio-temporal trends in precipitation and their implications for water resources management in climate-sensitive Nepal

John M.A. Duncan*, Eloise M. Biggs, Jadunandan Dash, Peter M. Atkinson

Geography and Environment, University of Southampton, University Road, Southampton SO17 1BJ, United Kingdom

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A B S T R A C T

As one of the world's most water-abundant countries Nepal has plenty of water, yet resources are unevenly distributed, both spatially and temporally. Limited accessibility and poorly managed water resources continue to inhibit socioeconomic development. Poverty levels are high across the nation (57% of the population lives below the international poverty line) and population expansion, coupled with rapid environmental change, is thought to be placing substantial pressure on water resources; an irrefutable asset for sustaining livelihoods and an essential contributing factor for alleviating poverty. Precipitation is a vital water resource for much of the rural population, 80% of which are dependent on rain-fed agriculture for their livelihoods, and fluctuations in which can give rise to changing states of poverty. Here we provide a comprehensive spatiotemporal analysis of precipitation time-series data for Nepal and discuss the contribution of precipitation change to water resources management for this land-locked Himalayan nation. We show that precipitation totals have predominantly remained stable; precipitation extremes and variability indicate widespread decrease; and no clear variation in monsoon onset date is reported. Based on these results, we suggest that water resources management needs to focus on population and environmental pressures, rather than specifically mitigating for precipitation change.

Introduction

Precipitation is an essential natural asset for much of Nepal's population as reflected in the large proportion of livelihoods reliant on subsistence agriculture. On average, 80% of Nepal's precipitation falls in the monsoon season (Duncan & Biggs, 2012) and this leads to a problematic temporal heterogeneity in water resources. In addition, the spatial distribution of precipitation favours populations closest to perennial water sources, with communities located furthest away the most vulnerable to climatic trends and fluctuations (Gentle & Maraseni, 2012). The livelihoods of these (largely rural) populations are often entirely dependent on precipitation such that deviations in the system (e.g. more frequent extremes; a delayed monsoon) can impact greatly upon water resources for food and water security (Agrawala et al., 2003; Biggs, Watmough, & Hutton, 2011). Communities throughout the Himalayas are particularly vulnerable to climatic variability because of amplification of regional warming trends by the mountainous terrain (Shrestha, Wake, Dibb, & Mayewski, 2000). Population distribution (Fig. 1a) is highly spatially correlated with agricultural land use (Fig. 1b) and average monsoon precipitation totals (Fig. 2a), indicating strong interdependence between livelihoods, environment and climate. For remote rural communities this trilateral reliance postulates a delicate balance, with the potential for unmitigated environmental and climatic changes to substantially impact upon livelihoods.

Annual fluctuations in the duration of the monsoon coupled with local and regional variation in topography create marked spatial variation in the amounts and timing of precipitation events in Nepal (Anders et al., 2006; Barros, Joshi, Putkonen, & Burbank, 2000; Barros & Lang, 2003; Kansakar, Hannah, Gerrard, & Rees, 2004). Generally, peak precipitation reaches southern and eastern Nepal before dissipating to the north and west (Ichiyanagi, Yamanaka, & Kumar, 2007; Kansakar et al., 2004). Winter precipitation (December to February) is greatest in western Nepal and the High Himalayan regions to the north (Kansakar et al., 2004).

Studies to date do not detect any long-term trends in national or regional precipitation totals, but have revealed significant interannual and decadal variability (Ichiyanagi et al., 2007; Shrestha et al., 2000). These studies are limited for several reasons: research has only used relatively short precipitation time-

* Corresponding author. Tel.: +44 (0)23 8059 9655.
E-mail address: jmad1v07@soton.ac.uk (J.M.A. Duncan).

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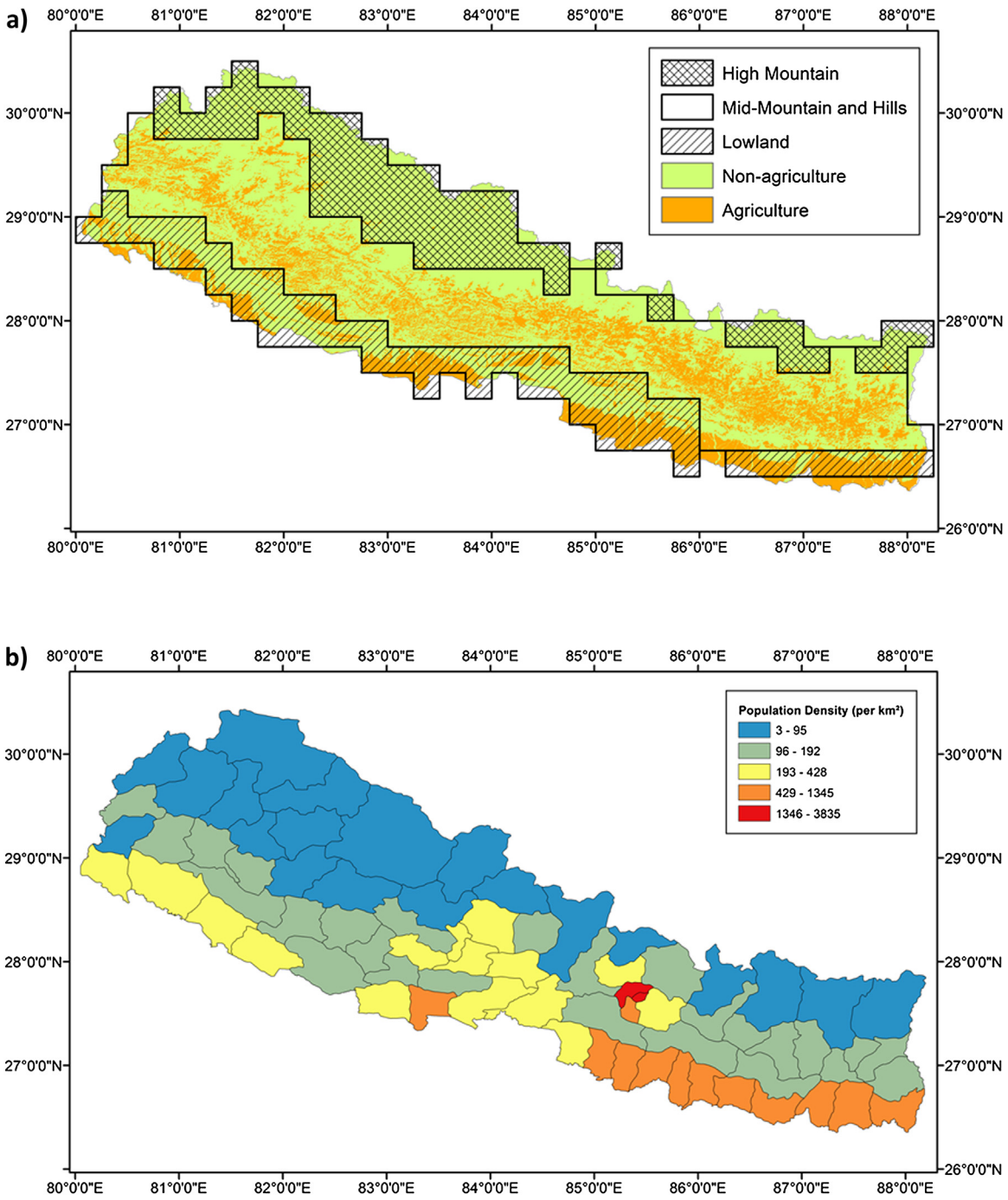

Fig. 1. (a) Classification of agricultural and non-agricultural lands from the FAO Land Cover of Himalaya Region product; the three main physiographic zones are also indicated. (b) Population density per district from Central Bureau of Statistics 2011 census data.

series data (e.g. Ichiyanagi et al., 2007); focus has a limited spatial extent (e.g. Manandhar, Pandey, Ishidiara, & Kazama, 2012a, Manandhar, Pandey, & Kazama, 2012b); limited coverage by station data over large regions has been aggregated (e.g. Shrestha et al., 2000); and some fail to consider facets of precipitation other than precipitation amount (e.g. extreme events or onset date) which significantly impact water resources and livelihoods in Nepal (e.g. Manandhar, Pandey, & Kazama, 2011; Pandey, Manandhar, & Kazama, 2012). The ability to predict the timing of the monsoon onset dominates agricultural planning, especially in areas with intensive cropping cycles (Webster et al., 1998). Failure to plant crops at the optimum time can reduce the length of the growing season and subsequently reduce yields (Gupta & Seth, 2007; Saharawat et al., 2010). Extreme precipitation events and flooding can also negatively impact crop yields through crop damage (Revadekar & Preethi, 2010).

Water is a substantially underused (and poorly managed) resource in Nepal. As a result several medium-sized river basins are turned into water poor (Pandey et al., 2012) and more effective water use would provide the potential to improve livelihoods. Detailed trend analysis of observational data is essential to evaluate climate change impacts on water resources (Manandhar