Rain on the rangelands: how intense is it?

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Abstract

Sub-daily rainfall intensity has a significant impact on runoff and erosion rates in northern Australian rangelands. It is therefore important to accurately represent sub-daily rainfall intensity in rangeland systems models (e.g. GRASP), which are used to investigate management impacts on runoff and soil erosion processes. We describe a new equation to calculate daily maximum 15-minute rainfall intensities (I15) for any location in Australia, using readily available daily rainfall and climate data. The new I15 model accounted for 46% ($P < 0.01$) of the variation in observed daily I15 for an independent validation data set derived from 67 Australia-wide pluviograph stations and represented both geographical and seasonal variability in I15. The model also accounted for 70% ($P < 0.01$) of the variation in the observed historical trend in I15 for the full record period (average record period was 37 years) of 73 Australia-wide pluviograph stations. The new I15 equation represents a significant improvement on the existing equation incorporated in GRASP, which needs to be calibrated for a given location.

Introduction

Soil erosion is a major cause of degradation in Australia's rangelands (e.g. Rogers et al. 1999). Soil erosion can lead to reduced on-site pasture productivity (e.g. Silburn et al. 2010), sedimentation of inland waterways (Bartley et al. 2005) and also increases in sediment loads to near shore reefs (Brodie et al. 2003).

Significant soil erosion events are often the result of high intensity rainfall events occurring when surface cover is low (Scanlan et al. 1996). It is therefore important that rangelands are managed to maintain critical levels of ground cover in the order of 30% (e.g. Silburn et al. 2010). Maintaining high cover levels is difficult given the high level of variability in rainfall, particularly on year-to-year and decadal timescales. One approach to developing sustainable management practices is to assess management options using grazing systems models. These models can assess the impacts of grazing management on runoff and soil erosion over long timeframes (approximately 100 years) and therefore account for long term climate variability (McKeon et al. 2000).

Rainfall intensity and, in particular, I15 (the maximum 15 minute rainfall in a day, expressed in mm/hr) is a key factor in determining hillslope scale runoff and soil erosion in northern Australian rangelands (e.g. Scanlan et al. 1996). I15 is a critical component of runoff models in GRASP and has been represented by an empirical equation (Equation 1, Scanlan et al. 1996), which will now be referred to here as the ‘time of year’ I15 equation.

Equation 1.

I15 = daily rainfall × (intensity_intercept + intensity_slope × time_of_year)

Where:
intensity_intercept is a user defined coefficient
intensity_slope is a user defined coefficient

$$time\_of\_year = \mathrm{COS}\left(\frac{2\pi(day + 15)}{365}\right)$$

Scanlan’s I15 equation has been used within the GRASP model to simulate soil erosion processes in northern Australia (e.g. McIntosh et al. 2005). However, the equation needs to be parameterised for a given location and there are limited long- term pluviograph data available in Australia. A study has been conducted to develop alternative models of I15 for the available pluviograph records in Australia (Fraser et al. in press). We report here the major findings of that study, in particular a more generic rainfall intensity equation that has now been included in the GRASP model.

Development of a new rainfall intensity equation

The Bureau of Meteorology holds records for 184 long-term pluviograph stations (>30 years records) in Australia up until 2005. Daily I15 values were extracted for 79 of these locations for days when daily rainfall was greater than 15 mm. A subset of 11 sites (Figure 1) from northern Australia (north of latitude −27° 28' S) and one site from Tasmania were used in the development of a new empirical equation for daily I15.

We tested a number of empirical relationships settling on an equation, which accounted for 42% of the variability in rainfall intensity across the 12 calibration sites. This equation (Equation 2), referred to here as the 'temperature I15' model, is based on readily available daily rainfall and climate variables (minimum and maximum temperature).

Equation 2.

I15 (potential) = Minimum Temperature × minimum (100, Daily Rainfall) × Diurnal Temperature Range/K
I15 (potential) = minimum (4 × Daily Rainfall, I15 (potential))
I15 = maximum (0.25 × Daily Rainfall, I15 (potential))

Where:

I15 (potential) is an estimate of daily 15-minute peak rainfall intensity in mm/hr prior to applying all the model constraints
Minimum Temperature is the daily minimum temperature in ^{o}C
Diurnal Temperature Range is the daily temperature range in ^{o}C
K is a coefficient which was found to be 150 when optimising to minimise the root mean square error between measured and estimated I15

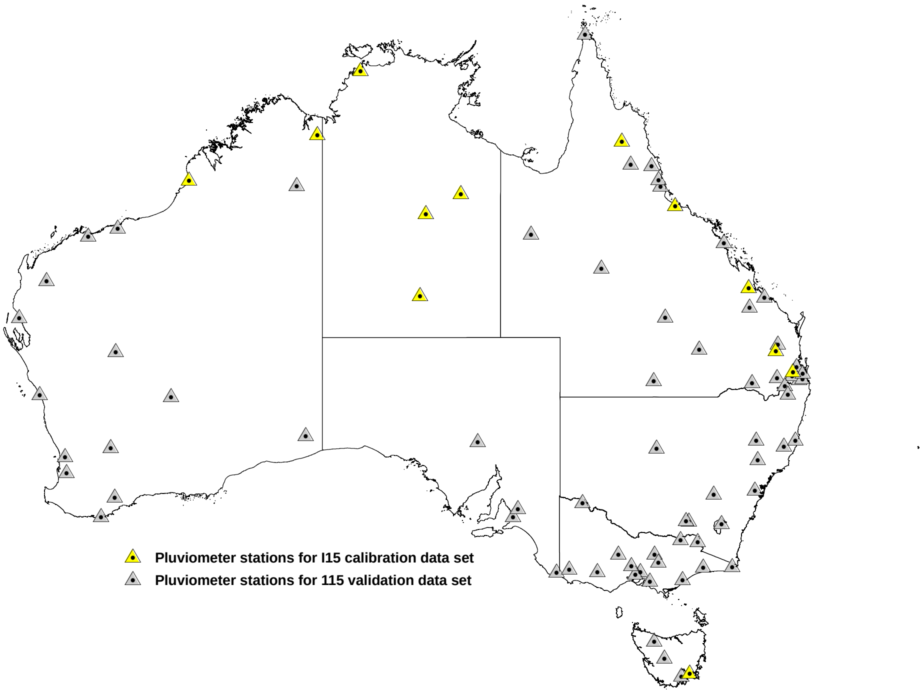

Figure 1. Pluviometer stations used in this study.

The model was tested on independent data comprising 67 of the long-term pluviograph stations (Figure 1). The model accounted for 46% of the variation in daily I15 for these stations. Whilst this correlation would appear low, we compared this equation (which is not calibrated) with the calibrated 'time of year' I15 equation at four locations (Townsville, Rockhampton, Kingaroy and Hobart), representing a wide range of climatic zones. For these four stations the optimised 'time of year' I15 model accounted for 25, 20, 40 and 5% of the variation in I15 respectively, whilst the new 'temperature I15' model accounted for more of the variation (35, 41, 55 and 18% respectively). The major improvement was found to be that the 'temperature I15' model better represented the 'event size distributions' (e.g. Figure 2). The results at these four locations suggest that the 'temperature I15' model performs as well, if not better, than the 'time of year' model with the important benefit that the model does not need to be parameterised and can be applied using readily available climate data.

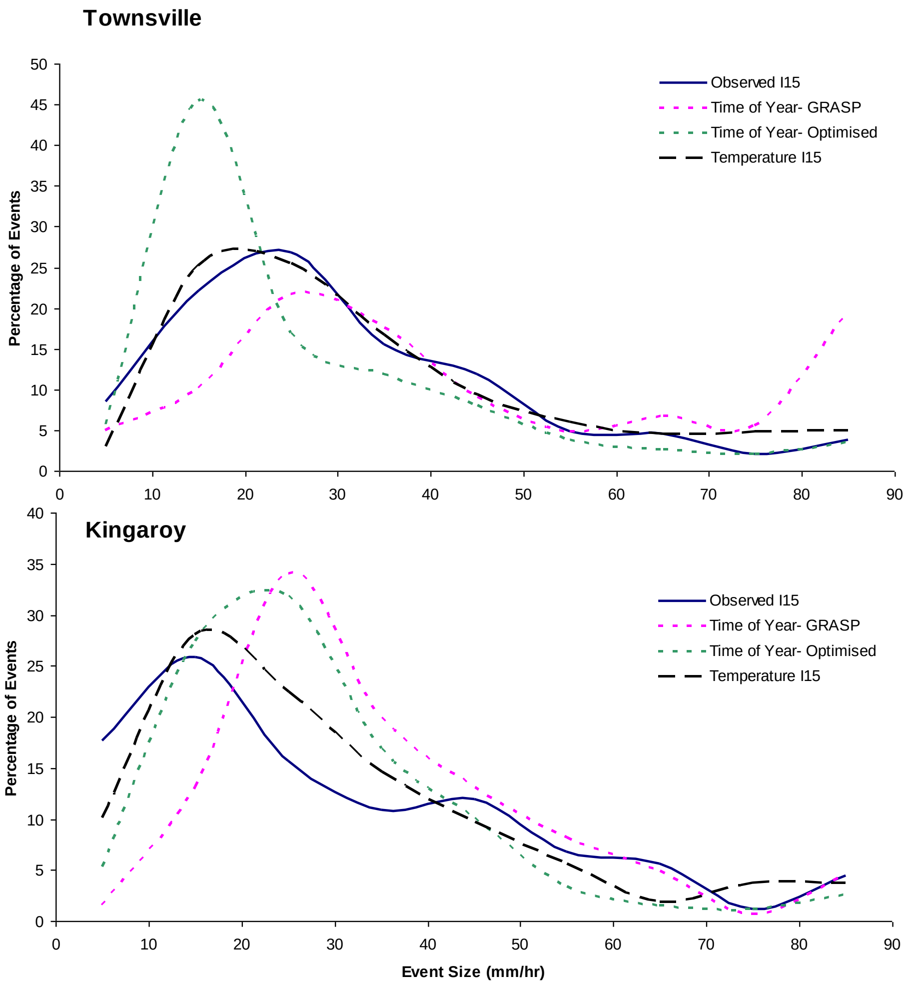

Figure 2. A comparison of the event size distributions for: a) historical observed I15, b) 'time of year I15' using GRASP parameters; c) 'time of year I15' using optimised parameters; and d) the general 'temperature I15' equation. Note events at 85 mm/hr include all events > 85 mm/hr.

The 'temperature I15' equation was also evaluated against historical time series of I15 data for 73 locations. At the majority (91%) of these locations, observed I15 has been trending upwards for the full recording period (on average 37 years). Unlike the 'time of year' equation, the 'temperature I15' equation has the potential to change over time, and thus may represent observed I15 trends. It was found that the 'temperature I15' model accounted for 70% of the observed trends in I15 for these locations.

A major question is whether the observed trends in rainfall intensity are a manifestation of anthropogenic climate change. If so, it is important that grazing systems models such as GRASP can adequately represent climate change impacts on I15. The 'temperature I15' model has the potential to capture a changing rainfall intensity regime, which is currently being explored. We recommend that the equation be applied in daily time-step biophysical models on timeframes exceeding five years given the relatively low correlation ($r^2 = 0.46$) with observations.

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