Real time analysis of rainfall, soil water content and surface runoff

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ABSTRACT

Real time monitoring of rainfall, soil water status and surface runoff have the potential to provide valuable information in understanding the dynamics of runoff generation and runoff control. Runoff plots were established in high (>70%) and low (<45%) ground cover grazing areas on the North-West Slopes of NSW, plots were equipped with data loggers to record rainfall and runoff at 1 minute intervals, and soil water content every 4 minutes. Data are presented for a single storm event in September 1998 of 64.6 mm. The high ground cover plot had higher water infiltration (28.6 mm) and low runoff (2.1 mm). Low ground cover reduced water infiltration (26.4 mm) and increased surface runoff (30.0 mm). Data are presented to show the relationships between rainfall intensity, change in soil water content and surface runoff. The results support previous evidence that increased ground cover reduced the amount of surface runoff on the North-West Slopes of NSW.

KEY WORDS

Surface runoff, rainfall intensity, ground cover, soil water content, pastures, grazing

Introduction

Grazing lands on the North-West Slopes of NSW are dominated by native pastures and are mainly used for wool, mutton and beef production. These pasture systems can have production limitations as a result of water loss from surface runoff. Rainfall is summer dominant and high intensity short duration storms occur frequently in the warmer months (3). Surface runoff not only removes valuable water from the system but also sediment and essential nutrients. Previous studies (4) have shown that losses from surface runoff may be as high as 160 mm (22.6% of a.a.r.) per year on the North-West Slopes. Pasture plants are frequently in water stressed conditions leading to reduced production and lower stocking rates. Surface runoff control and soil water recharge is crucial to maximise pasture and animal production.

A range of studies has found that runoff control is linked to variable thresholds of ground cover for several different pasture systems. Costin (1) found that 70% cover controlled surface runoff on improved pastures on the Southern Tablelands of NSW and that wet soil conditions increased surface runoff. In sub-tropical pastures, McIvor et al. (6) suggested that 40% ground cover was required to control runoff and limit erosion but higher levels were required as rainfall event size increased. Studies by Lang (4) suggested that maintaining cover above 75% would provide surface runoff control on the North-West Slopes of NSW for most rainfall events. Gifford (2) conducted infiltrometer studies in rangelands and found that hydrologic processes are complex and vary with cover, antecedent soil moisture status and soil type. Two key processes initiate runoff in most events (9). Where rainfall intensity exceeds the surface infiltration capacity of the soil, runoff is generated by ‘infiltration excess’. In contrast, where the soil surface becomes locally saturated, runoff is generated by ‘saturation excess’.

All surface runoff events will not be controlled by a single threshold of ground cover. With dry soil conditions, the threshold may be lower, but for wet conditions threshold levels may be higher (6). To further understand the dynamics between rainfall, soil water content and surface runoff an accurate real time record of these interrelated factors is required. This paper outlines the methods used to collect rainfall, surface runoff and soil water data in real time, while exploring the dynamic relationship between these factors and ground cover.

METHODS

An experimental site was established as part of the Sustainable Grazing Systems National Experiment (5), located 22 km north of Manilla NSW on “Springmount” (30°34’S, 150°38’E, 510 m a.s.l.). The site was gently sloping (3.4%), with a southeasterly aspect. Soils were deep Red Chromosols with a hard setting surface, derived from colluvial deposits at the foot of the Nandewar Range. Red grass (*Bothriochloa macra*), wallaby grass (*Austrodanthonia spp*) and wiregrass (*Aristida ramosa*) dominated the native pasture. The community was a typical tussock grassland, with tufted perennial grasses interspersed with areas of bare soil.

The low ground cover plot was continuously grazed at six sheep/ha while the high cover plot was rotational grazed at four sheep/ha. The rotation was defined as four weeks of grazing at 16 sheep/ha followed by 12 weeks of rest. Plots were approximately 0.5 ha in area. Ground cover was estimated visually in ten quadrats on each runoff plot, monthly between March 1998 and September 2001. BOTANAL (8) was used to estimate total herbage mass and species composition every 13 weeks at the beginning of each season.

Rainfall was measured by a “Monitor Sensors” (200 mm diameter) tipping bucket pluviometer (0.2 mm per bucket tip). Rainfall was recorded on a data logger at one minute intervals. Rainfall intensity was calculated from the sum of rainfall in the previous four minute period.

One bounded runoff plot (approximately 100 m^2 in area, 33 m long by 3 m wide) was established within each grazing treatment with a galvanised steel trough to collect runoff water at the toe. Each runoff trough (4 m long by 0.4 m wide by 0.4 m deep, 1.6 m^2 in area) was manufactured from folded galvanised steel plate, one mm thick. The leading edge had a horizontal flap six cm wide that lay flat on the soil surface to direct runoff water into the trough and provide a stable edge to the runoff plot.

Runoff water flowed through a baffle and into a calibrated tipping bucket pluviometer (between 5 and 7 litres per tip). Tips of the pluviometer were recorded on a manual pulse counter and on an automatic data logger at four minute intervals.

Soil water content for the top 20 cm of soil profile was monitored using Watermark gypsum blocks (7.5 cm long and 2.5 cm diameter) installed at depths of 2.5, 5.0, 7.5, 10.0, 15.0 and 20.0 cm. Data were recorded at four minute intervals on a data logger, and converted to volumetric water content using a calibration equation developed for each block.

Data loggers used were “Tain Micropower Automatic 8 channel Mark III”. Raw data was collected on the loggers and transferred to spreadsheet and a relational database for analysis. The database was used to calculate and plot rainfall, soil water content and runoff for concurrent times. All volumes were calculated in mm of equivalent rainfall.

Results

The data presented were from a rainfall event on the 4 and 5 September 1998 when a total of 64.6 mm of rainfall was recorded with a peak intensity of 63 mm/hr (22:56 on 4 September, Fig. 1). Ground cover was about 50% and 90% in the low and high ground cover plots, respectively. Total herbage mass was about 1500 kg/ha in the low ground cover plot and 3000 kg/ha where cover was high. The high ground cover plot had a total of 2.1 mm of runoff while the low cover plot had 30 mm (Fig. 2). For 1998, the low ground cover plot had a total of 74.1 mm of runoff from 15 events and the high cover plot only 2.1 mm from one event.

A plot of soil water content over time (Fig. 3), showed that with high ground cover there was a slow initial wetting of the soil (215 minutes), but a greater net change in soil water content (28.6 mm) during the rainfall event. In contrast, the low ground cover plot wet up more rapidly in the initial phase (107 minutes), but had a lower net change (26.4 mm).

Peak runoff volumes were generated at least four minutes after peak rainfall intensity. With low ground cover, peak runoff was recorded at 23:04 on 4 September and with high cover it peaked a further four minutes later. Approximately 50% of total runoff (15.6 mm low ground cover, 0.9 mm high ground cover) was generated in a 35 minute period following peak rainfall intensity. Substantial runoff was generated from the low ground cover plot later in the rainfall event (06:00, 6 mm and 12:00, 5.2 mm on 5 September) which was associated with higher rainfall intensity.

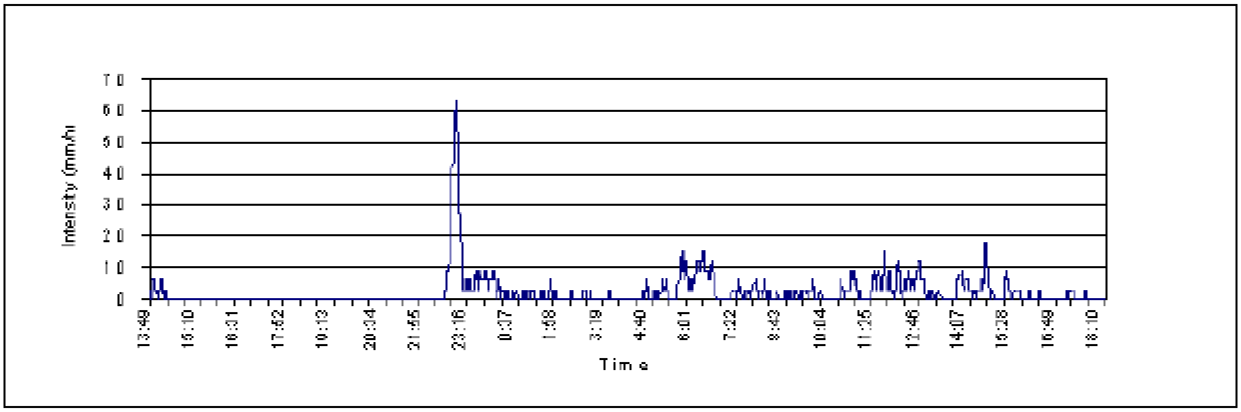

Figure 1. Rainfall intensity (mm/hr, 4 minute) recorded on 4 and 5 September 1998.

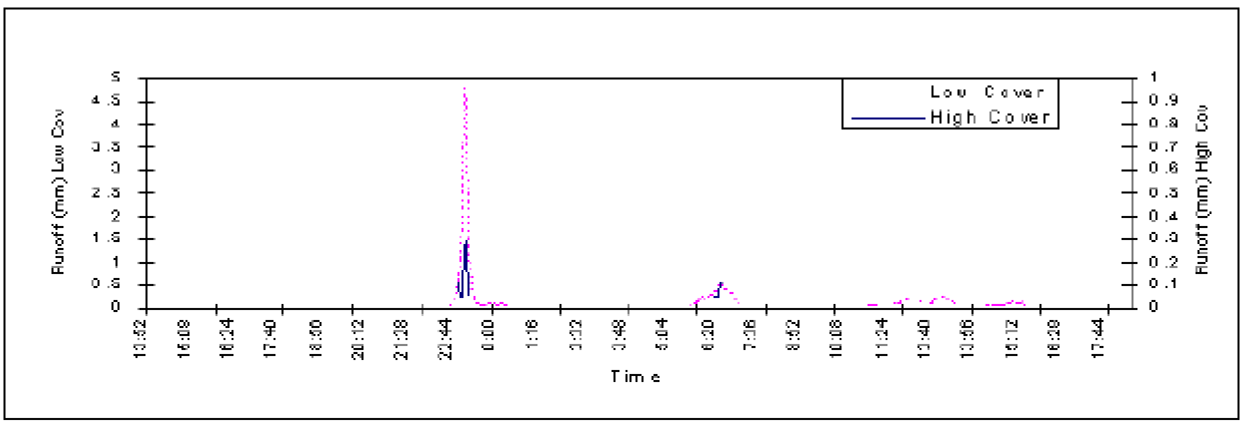

Figure 2. Surface runoff (mm) recorded from low and high ground cover plots on 4 and 5 September 1998.

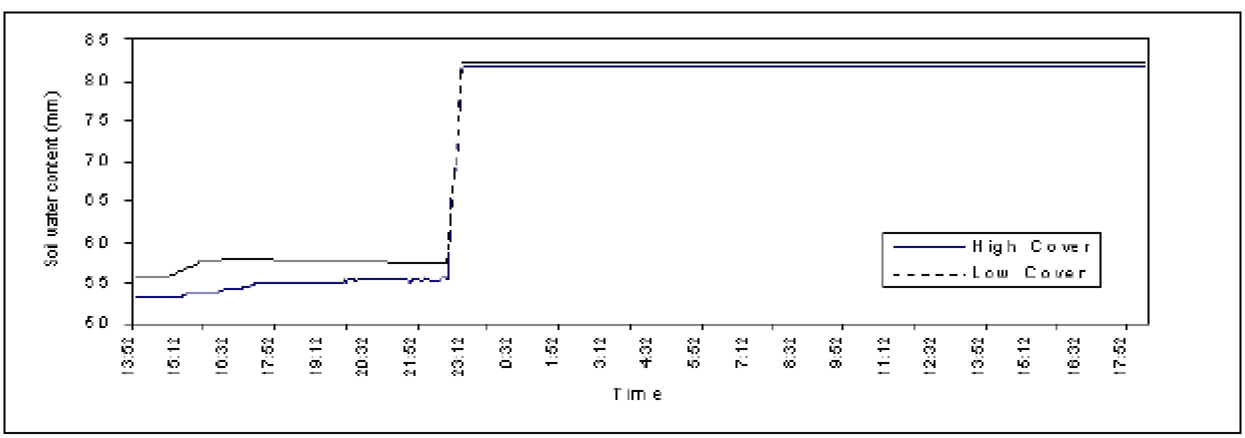

Figure 3. Volumetric soil water content (mm) recorded in the top 22.5cm of soil for low and high ground cover plots on 4 and 5 September 1998.

DISCUSSION

These data showed recording in real time for rainfall, soil water content and surface runoff allowed a detailed analysis of the event. These data were complemented by ground cover and herbage mass information at the time of the runoff event. This method was successfully used to record and analyse the details of other runoff events in 1998-2000. Each runoff event behaved differently dependent upon rainfall intensity and duration, soil surface conditions, soil water content, ground cover and herbage mass. Data collected using the methodology outlined here should allow a detailed examination of the importance of these factors influencing runoff under different conditions.

Various authors (1, 2, 4, 6, 7) have suggested ground cover threshold values for pasture lands following runoff plot or rainfall simulator studies. Some collected information on soil water content prior to and at the completion of simulator studies. Scanlan et al. (7) showed the important role that soil water deficit played in reducing runoff in small rainfall events, with higher deficits increasing the available soil water storage. However, many runoff studies do not have soil water content data. The technique presented in this paper recorded the soil water content at short intervals during the rainfall event to trace water infiltration into the soil. The data showed that as the surface soil reached its highest soil water content, the low infiltration capacity resulted in more runoff being generated on the low ground cover plot. These soils have a hard setting surface and are likely to surface seal, which would result in a reduced infiltration capacity on low ground cover areas. After this time small increases in rainfall intensity produced relatively large amounts of runoff on the low ground cover plot.

Where rainfall intensity exceeds the storage capacity or infiltration capacity of the soil surface, runoff will be generated. The level of herbage mass and ground cover can moderate the intensity of rainfall reaching the soil surface. Standing herbage mass can also dissipate rainfall kinetic energy and provided further storage volume. Under low ground cover conditions with low herbage mass, rainfall kinetic energy is not reduced resulting in rainfall reaching the soil surface with high intensities that may exceed infiltration capacity. The instrumentation described in this study has the potential to link rainfall intensity with surface infiltration rates and surface storage values. These data highlight the importance of ground cover (litter and herbage mass) in reducing surface runoff on the North-West Slopes of NSW.

Conclusion

A technique has been described for the real time monitoring of rainfall, soil water content and surface runoff on bounded plots on the North-West Slopes of NSW. The amount of surface runoff was influenced by these factors at different times. These techniques showed the relative importance of these factors in the attempt to control surface runoff across a wide range of rainfall intensity and ground cover conditions. Further studies using these methods should provide valuable data for the interpretation of runoff generation and control.

ACKNOWLEDGMENTS

Experiments were performed as part of the Sustainable Grazing Systems Key Program an initiative of Meat and Livestock Australia, the Land and Water Resources Research Development Corporation, the Murray Darling Basin Commission and collaborating agencies. We gratefully acknowledge the assistance of Brian Roworth and Michael Honess in collecting and analysing the data and the willing co-operation of the landholders, Ross and June Wicks. Colin Lord, University of New England, Armidale, wrote the relational database.

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