Assessing Rainfall Variability and Runoff Characteristics in a Dry Savanna Catchment, Queensland, Australia

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Background:

High spatial and temporal variability of rainfall is an overriding characteristic of semi-arid savanna environments (Jarihani et al. 2017). This has been associated with land degradation processes occurring in many of the heavily grazed catchments in Queensland, Australia. These catchments are believed to be the main sources of runoff and sediment to the Great Barrier Reef (GBR) (Images 1 & 2). There is limited understanding of the influence that rainfall variability has on runoff and sediment generation processes.

Image 1: Erosion in the Upper Burdekin Catchment (Koci 2016)

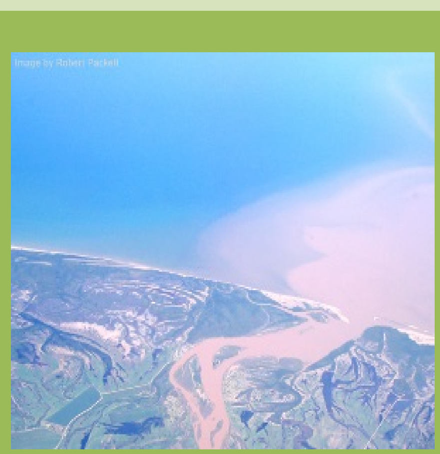

Image 2: Burdekin River Flood Plume near the GBR (Packett 2012)

Aim:

To identify how rainfall varies spatially and temporally at the small catchment scale (i.e., Weany Creek Catchment; Fig. 1) and how this variability in rainfall influences the runoff generation processes.

Objectives:

1. To describe the spatial and temporal variability of rainfall in Weany Creek catchment; and
2. To construct, calibrate, and test a simple hydrological model (HEC-HMS) to demonstrate the relationship between rainfall variability and runoff.

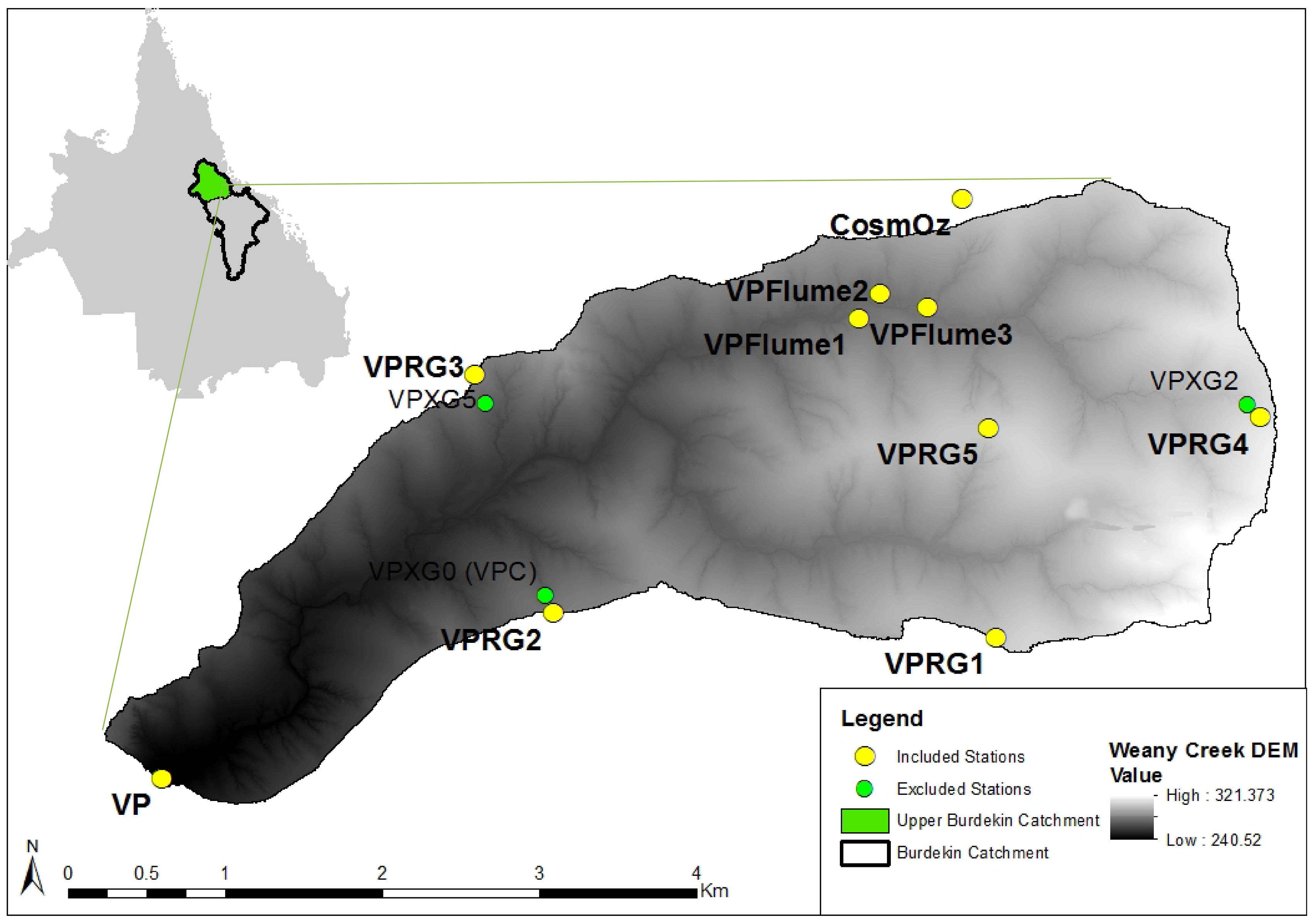

Fig. 1: Weany Creek Catchment study site within the Upper Burdekin sub-catchment of the Burdekin Basin, Queensland, Australia; locations of the rain gauge stations are shown.

Datasets:

The study uses secondary quantitative rainfall and runoff data. It includes runoff data from a stream gauge at the outlet of the catchment and 13 tipping bucket rain gauges that provide rainfall amount and intensity information for specific dates and time intervals. Additionally, Intensity-Frequency-Duration (IFD) data from the Australia Government Bureau of Meteorology (BOM) was incorporated. The study focused on data between 07/31/2010 and 05/31/2017.

Methods:

Stage 1a:
A python code was used to organise the rainfall data into regular time intervals. These data were then used to derive daily, monthly, and annual statistics to portray the temporal variability of rainfall.

Stage 1b:
The raw rainfall data were then processed using the Rainfall Intensity Summarisation Tool (RIST) to derive data for individual storm events. The RIST output was applied to an assessment framework that combines the Coefficient of Variance (CV) and Moran's I to present the spatial variability of rainfall.

Stage 2:
A lumped rainfall-runoff model was constructed using the Hydrological Modelling System developed by the Hydrologic Engineering Center (HEC-HMS). The model was calibrated and tested using data from three storm events. Observed and simulated hydrographs of these events were compared and the model parameters were adjusted accordingly to allow the model to portray realistic outputs.

The IFD and annual exceedance probability (AEP) information from BOM was then entered into the model to simulate runoff. Three land surface scenarios were tested by altering the infiltration loss rates. The model outputs represent how rainfall variability and land surface conditions can influence runoff .

Results and Discussion:

Stage 1a: Temporal Variability of Rainfall

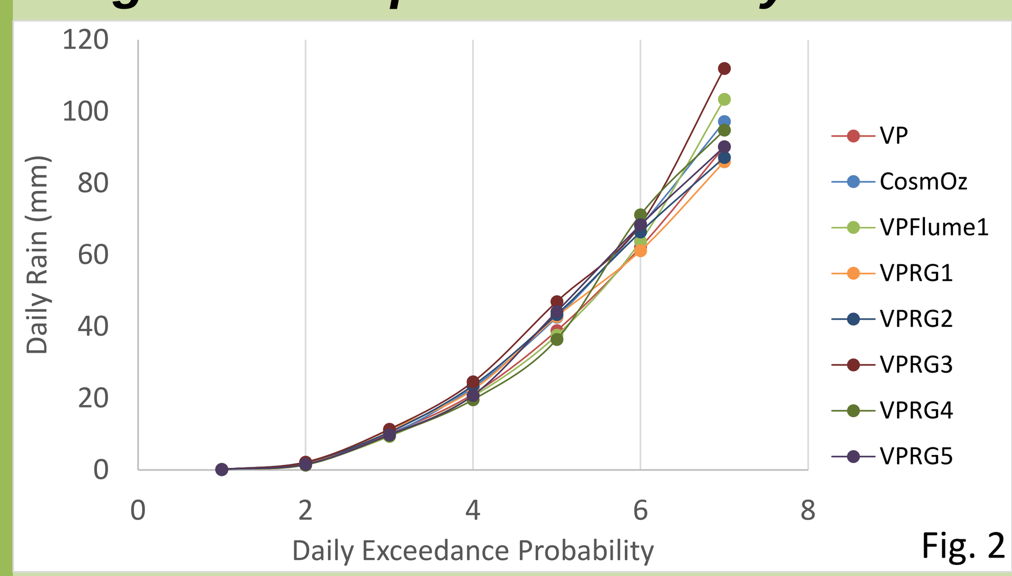

Fig. 2

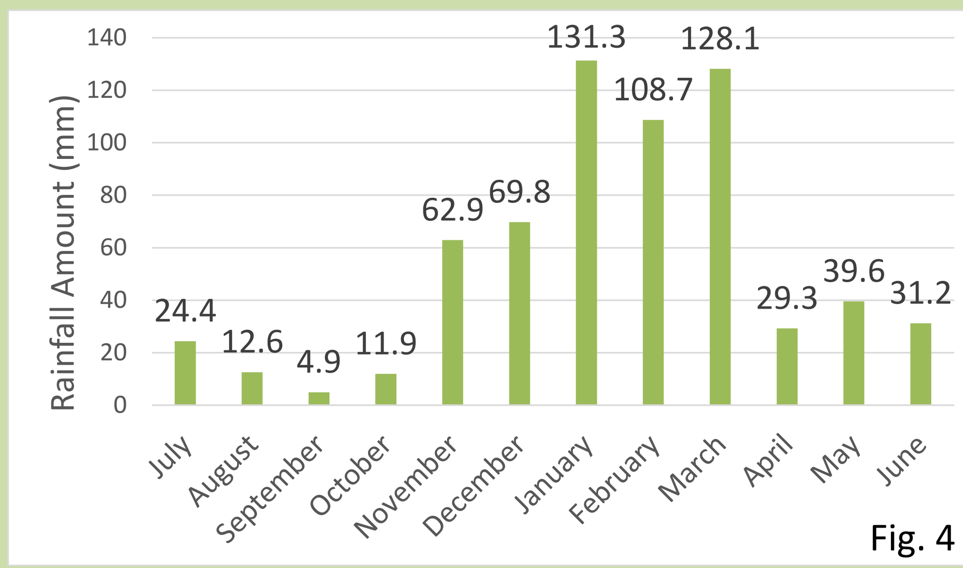

Fig. 4

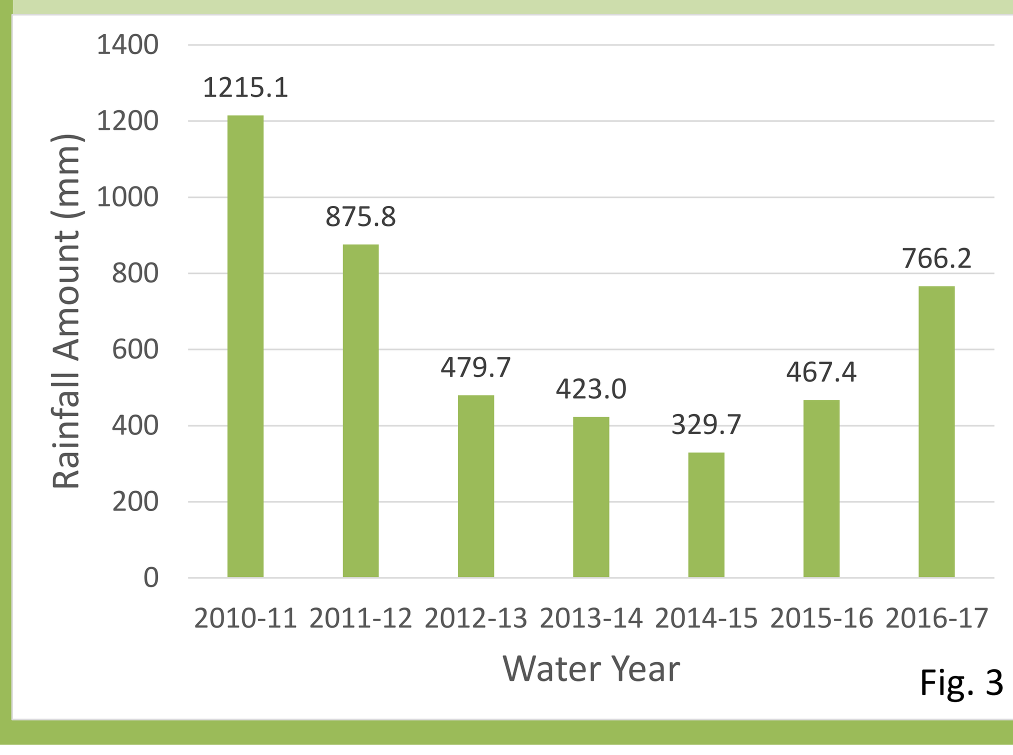

Fig. 3

- The daily rainfall statistics showed high temporal variability at all rain gauge stations (Fig. 2).
- Considerable variations in the average annual rainfall occurred during the 7-year period of record, accentuated by El Niño and La Niña events, associated changes in rainfall patterns, and extreme weather events occurring in the region (Fig. 3).
- The temporal variability of mean monthly rainfall exhibited distinct wet and dry seasons corresponding to the Australia summer monsoon season (Fig. 4).
- Therefore, whilst the Weany Creek catchment receives large amounts of rain in individual events, the temporal variability is rather complex.

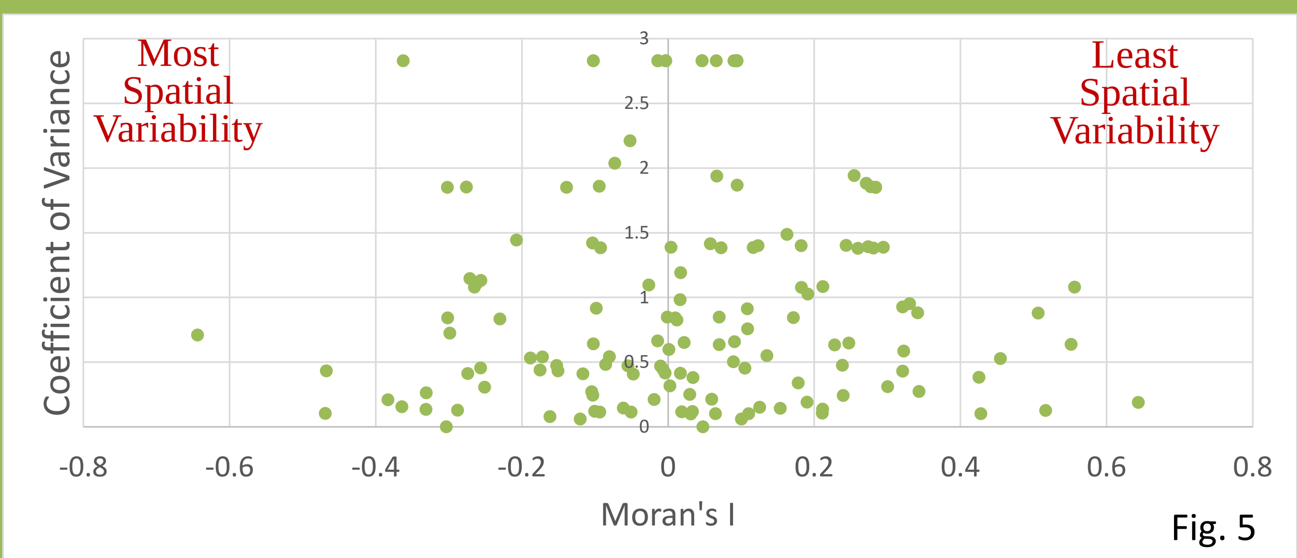

Fig. 5

Stage 1b: Spatial Variability of Rainfall

- The majority of storm events had a Morans I value close to zero corresponding to a random spatial pattern (Fig. 5).
- The CV values for most storms were <0.75 and only approximately 5% of the events had CVs >2.
- Collectively, the CV and Moran's I results show that similar amounts of rain can be witnessed across the catchment during storms; however, the spatial footprint of individual storms is diverse and slightly random where there is no definite clustered or dispersed spatial pattern.
- The storm patterns are influenced by the variable size, speed, and direction of rain events which play a significant role in the spatial distribution of rainfall including which gauges receive these amounts.
- The spatial variability among the 155 storm events is significant.

Stage 2: Modelling

- In all three scenarios, the modelling results indicate that as rainfall magnitude and intensity increase, runoff amounts and, consequently, the runoff ratios increase (Fig. 6).
- The effects of land cover on runoff generation is greater for lower rainfall intensities. By increasing rainfall intensity, the influence on land cover decreases, however, this relationship is not linear.
- Poor soil conditions are associated with higher runoff ratios due to heavy grazing, compacted soils, and lower cover and organic matter. Comparatively, high-very high land cover is associated with better soil conditions and, subsequently, experiences less runoff.

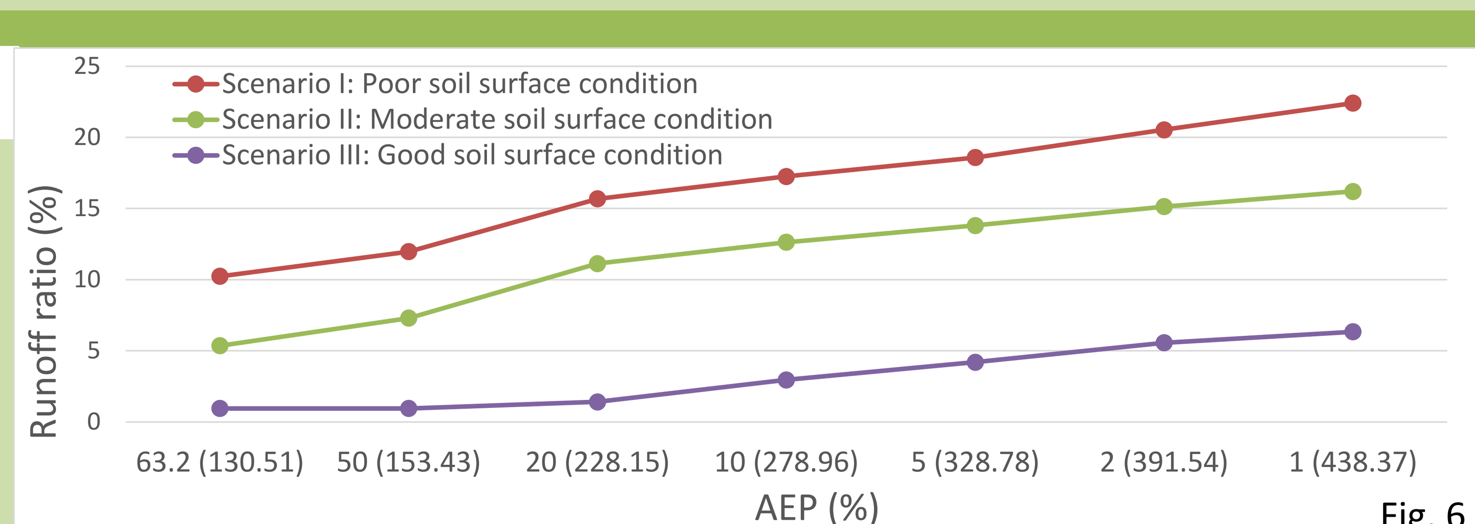

Fig. 6

Conclusions:

- Whilst some trends could be identified, the temporal and spatial variability of rainfall in the catchment remains rather complex and inconsistent particularly across shorter time intervals
- Hydrological models are useful for assessing the effects of changes in rainfall and land cover on runoff generation in the catchment.

References:

- Jarihani, B., Sidle, R.C., Bartley, R., Rother, C.H. & Wilkinson, S.W., 2017, 'Characterisation of Hydrological Response to Rainfall at Multi Spatio-Temporal Scales in Savannas of Semi-Arid Australia', *Water*, vol. 9(7), p. 540.
- Koci, J. 2016, *Key factors and processes controlling hillslope gully erosion and associated fluxes of sediment and nutrients in grazed dry-tropical savannas tributary to the Great Barrier Reef.*
- Packett, R. 2012, Great Barrier Reef case study, viewed 22 March 2018, https://ewater.org.au/casestudies/catchments-case-studies/great-barrier-reef-case-study/.

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