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Spatial and temporal patterns of bank failure during extreme flood events: Evidence of nonlinearity and self-organised criticality at the basin scale?

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Non-linearity in physical systems provides a conceptual framework to explain complex patterns and form that are derived from complex internal dynamics rather than external forcings, and can be used to inform modeling and improve landscape management.

One process that has been investigated previously to explore the existence of self-organised critical system (SOC) in river systems at the basin-scale is bank failure. Spatial trends in bank failure have been previously quantified to determine if the distribution of bank failures at the basin scale exhibit the necessary power law magnitude/frequency distributions. More commonly bank failures are investigated at a small-scale using several cross-sections with strong emphasis on local-scale factors such as bank height, cohesion and hydraulic properties. Advancing our understanding of non-linearity in such processes, however, requires many more studies where both the spatial and temporal measurements of the process can be used to investigate the existence or otherwise of non-linearity and self-organised criticality.

This study presents measurements of bank failure throughout the Lockyer catchment in southeast Queensland, Australia, which experienced an extreme flood event in January 2011 resulting in the loss of human lives and geomorphic channel change. The most dominant form of fluvial adjustment consisted of changes in channel geometry and notably widespread bank failures, which were readily identifiable as ‘scalloped’ shaped failure scarps. The spatial extents of these were mapped using high-resolution LiDAR derived digital elevation model and were verified by field surveys and air photos. Pre-flood event LiDAR coverage for the catchment also existed allowing direct comparison of the magnitude and frequency of bank failures from both pre and post-flood time periods. Data were collected and analysed within a GIS framework and investigated for power-law relationships. Bank failures appeared random and occurred throughout the basin but plots of magnitude and frequency did display power-law scaling of failures. In addition, there was a lack of site specific correlations between bank failure and other factors such channel width, bank height and stream power. The data are used here to discuss the existence of SOC in fluvial systems and the relative role of local and basin-wide processes in influencing their distribution in space and time.