Distributed Modelling of Stormflow Generation: Assessing the Effect of Ground Cover

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Introduction and Objectives

Understanding the effects of grazing management and land cover changes on surface hydrology is important for water resources, controlling erosion and land management. A distributed hydrological modelling platform, Wflow, that was developed as part of Deltares's OpenStreams project, is used to assess the effect of land management practices on runoff generation processes. The model was applied to Weany Creek, a small catchment (13.6 km^2) of the Burdekin Basin, North Australia, which is being studied to understand sources of sediment and nutrients to the Great Barrier Reef.

Satellite-based ground cover data, high resolution topography from LiDAR, soil properties, and distributed rainfall data were used to parameterise the model. Wflow was used to predict total runoff, peak runoff, time of rise, and lag time for several events of varying magnitudes and antecedent moisture conditions (Table 1).

The results show that a process-based distributed model can be calibrated to simulate spatial and temporal patterns of runoff generation mechanisms, to help identify the dominant processes that can be incorporated into land management practices to improve rainfall retention. The model will be used to assess the effects of ground cover changes due to management practices in grazed lands on storm runoff.

Study Site

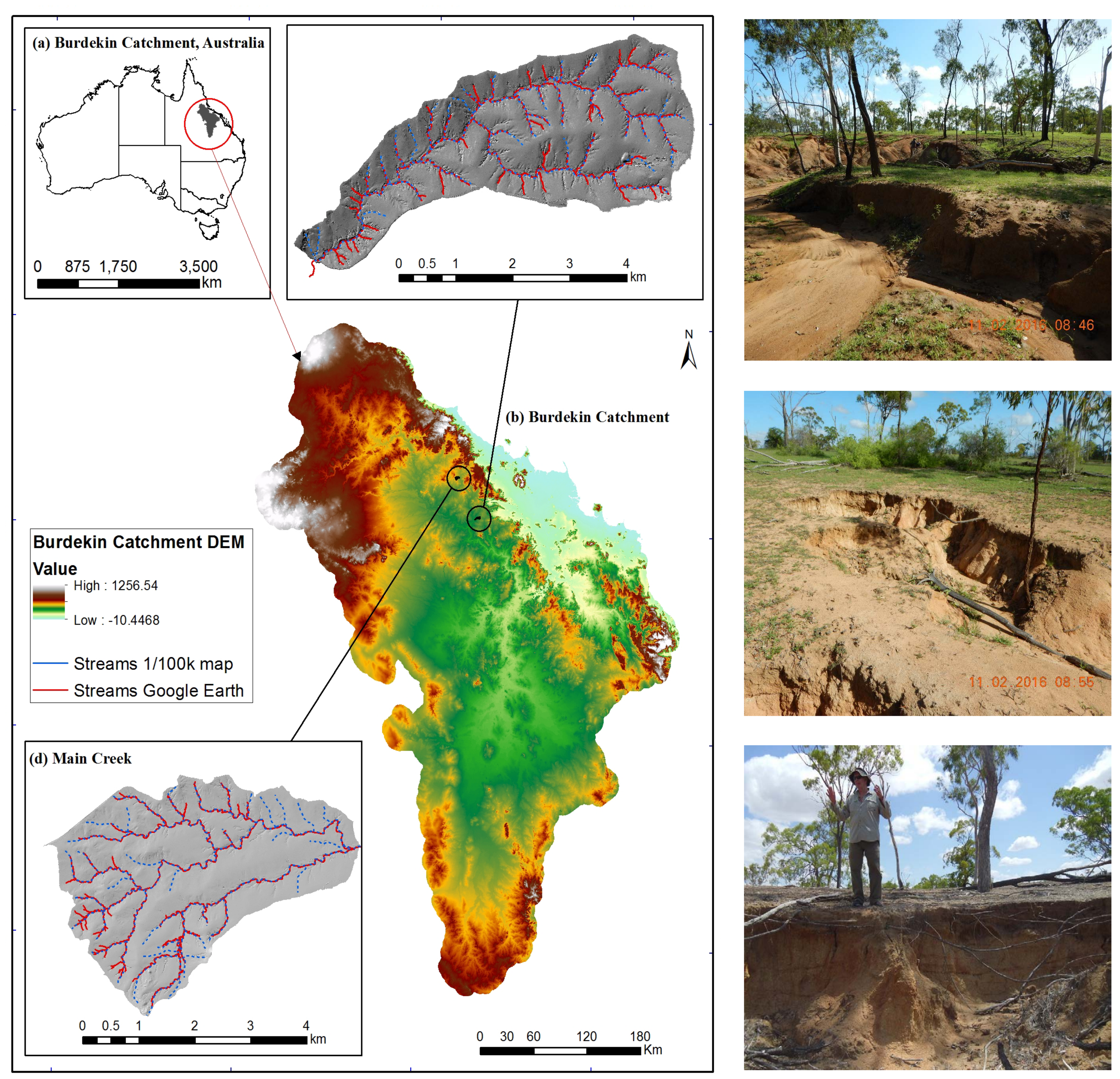

Figure 1: Study area, Weany sub-catchment of Burdekin River Catchment, Queensland Australia.

Wflow model

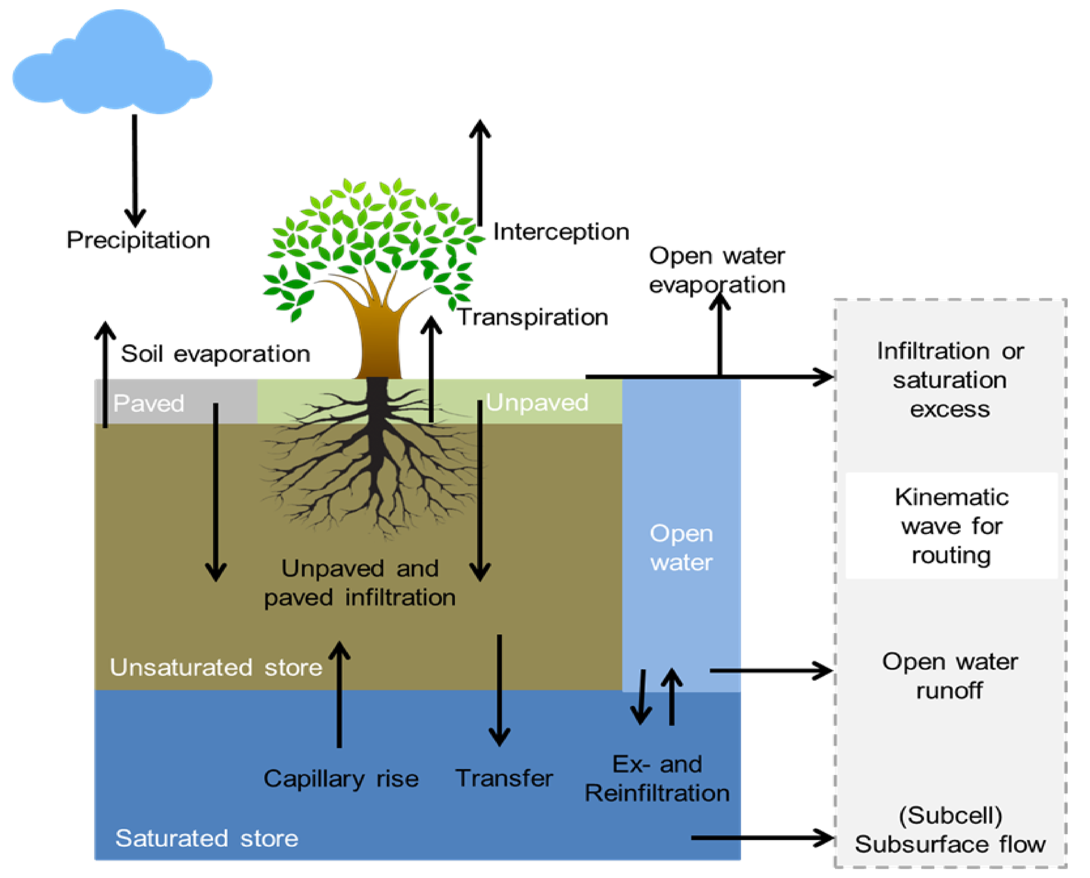

Figure 2: Overview of the different processes and fluxes in the Wflow_sbm model (http://wflow.readthedocs.io/en/2017.01/wflow_sbm.html)

Processes

- **Interception** is modelled using the Gash model (Gash, 1979 and Gash et al., 1995);
- The model uses potential **evapotranspiration** as input time series and derives the actual evaporation based on soil water content and vegetation type;
- The **soil is represented using a simple bucket model** that assumes an exponential decay of the saturated conductivity (Ksat) with depth (M parameter);
- **Lateral subsurface flow is modelled using the Darcy equation**. Soil depth is specified for different land-use types and subsequently scaled using the Topographic Wetness Index;
- A sub-cell parameterization is present that allows a fraction of a cell to represent a compacted soil surface with reduced infiltration capacity. This is also used to represent the effects of urban areas;
- **Surface runoff is modelled using a kinematic wave routine**;
- **The model can run with any time step**. However, the model uses a simple explicit solution for most processes. As such, changing the time step may call for recalibration.

Workflow Diagram

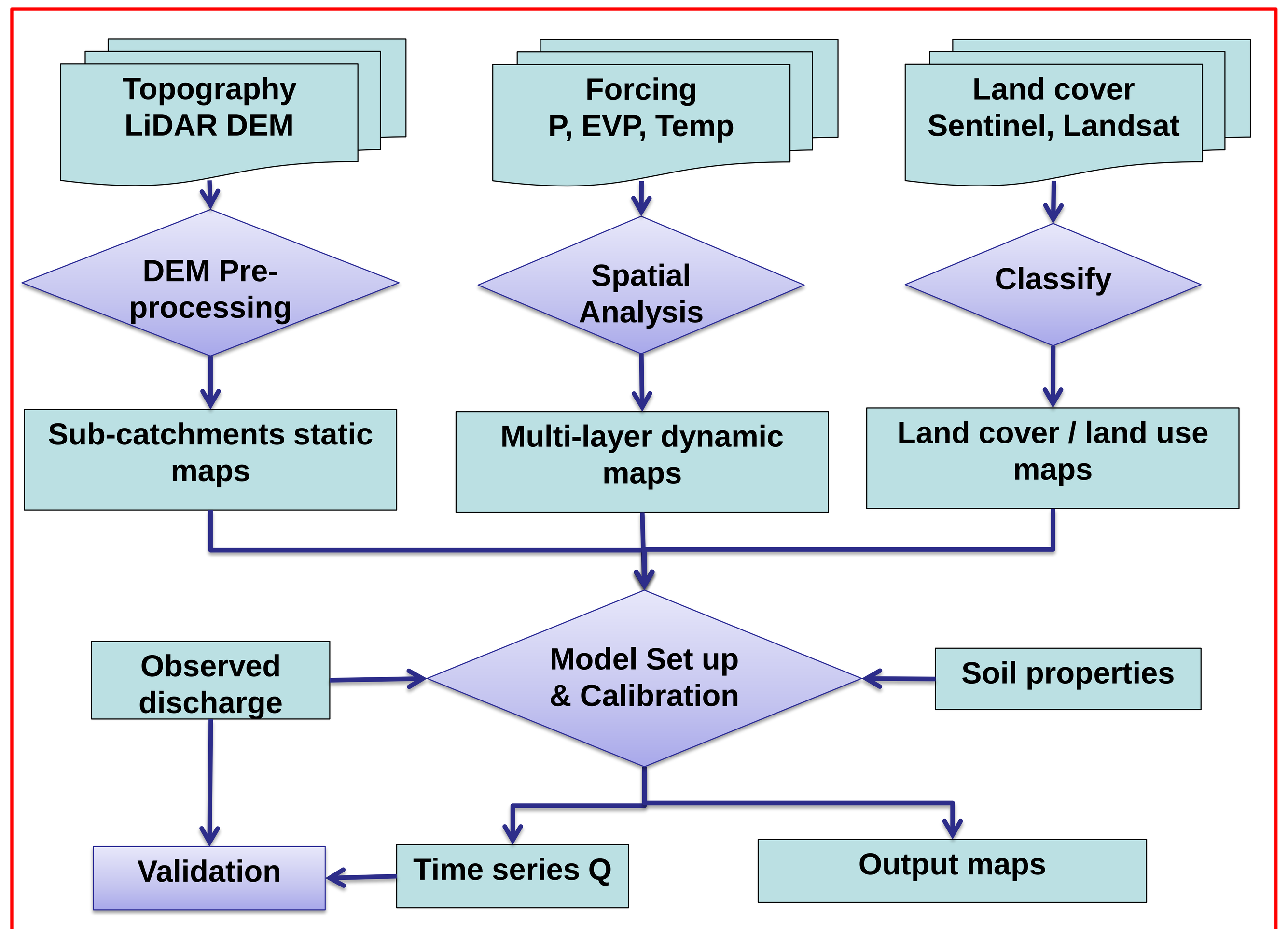

Figure 3: Workflow diagram.

Results

Table 1: Selected storm event with different magnitudes for model set up and calibration.

Event #	Rainfall starts	Runoff finishes	Total rain & antecedent 3-daily rain (mm)	Total runoff (mm)	Max 15min rain (mm)	Peak discharge 10 min (m^3/s)	Runoff ratio	Sentinel &(Landsat) Image
11	11/12/2016 18:00	11/13/2016 08:00	45 (0)	1.5	18	4.65	3.3	11/15/2016
22	01/03/2016 19:45	01/05/2016 06:00	84 (0)	7	14.5	10.31	8.3	12/11/2015
33	01/06/2017 16:15	01/07/2017 15:00	77 (60)	8.2	13.5	14.06	10.6	12/05/2016
44	03/01/2016 01:30	03/02/2016 05:00	112 (0)	33	36	92.87	29.5	02/19/2016
42	02/12/2009 21:45	02/13/2009 09:00	125 (16.6)	50.26	21.5	91.5	40.2	12/04/2008
43	02/24/2009 16:00	02/25/2009 12:30	144.6 (80)	81.22	22.8	150.2	56.4	12/04/2008

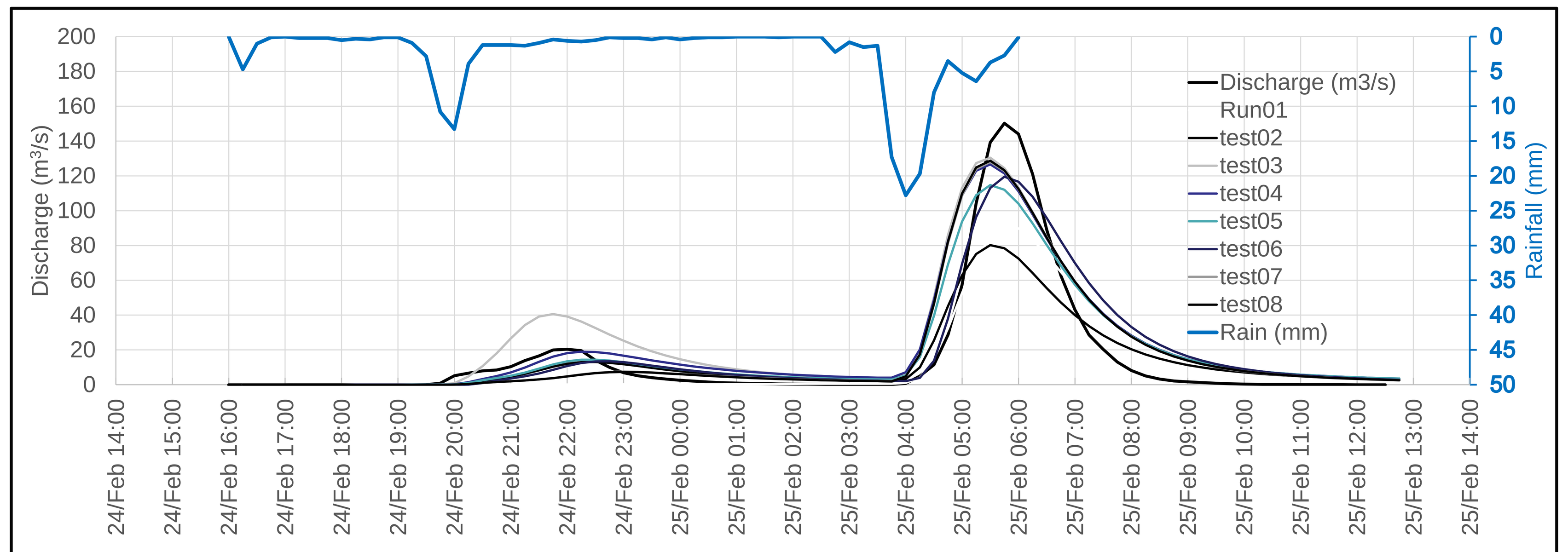

Figure 4: Rainfall, discharge and calibration process of the storm event # 43, biggest storm event since 2000.

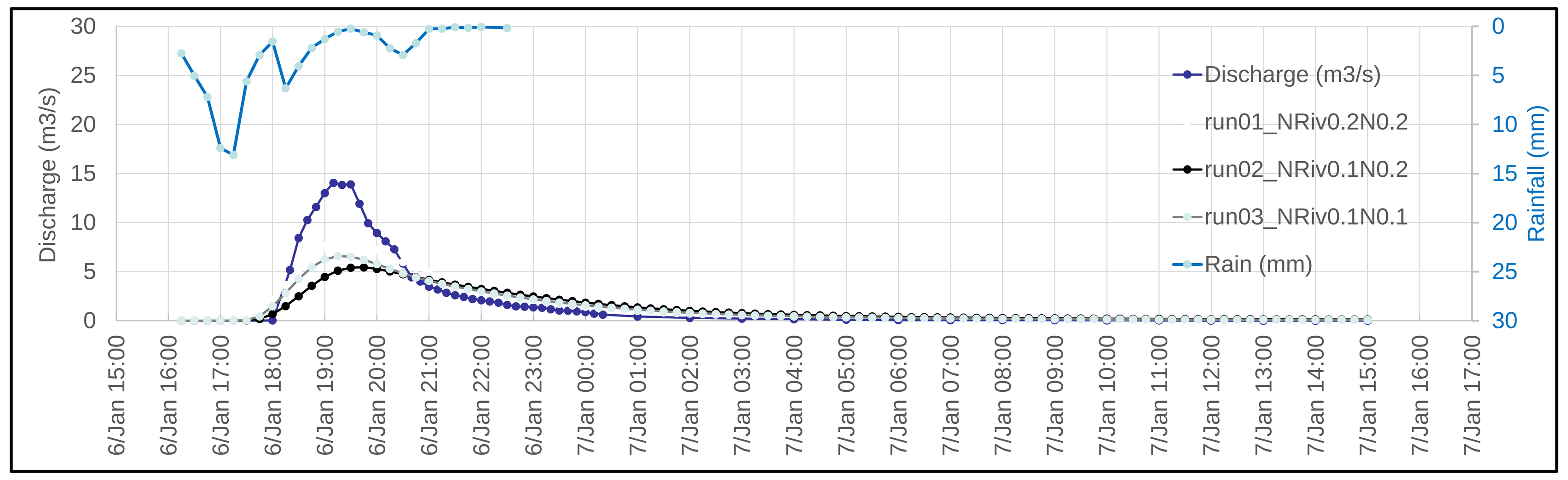

Figure 5: Rainfall, discharge and calibration process of event # 33 – a moderate storm event

Table 2: Land cover scenarios and related model parameters

Scenario	landcover	canopy gap fraction	KsatVer (mm/d)	M	max canopy storage (mm)	N	thetaS	Path fraction
C								
C1	0	1	360	2000	1	0.1	0.1	1
C2	25	0.75	480	1550	2	0.11	0.15	0.75
C3	50	0.5	600	1100	3	0.12	0.2	0.5
C4	75	0.25	720	650	4	0.13	0.25	0.25
C5	100	0	840	200	5	0.15	0.3	0

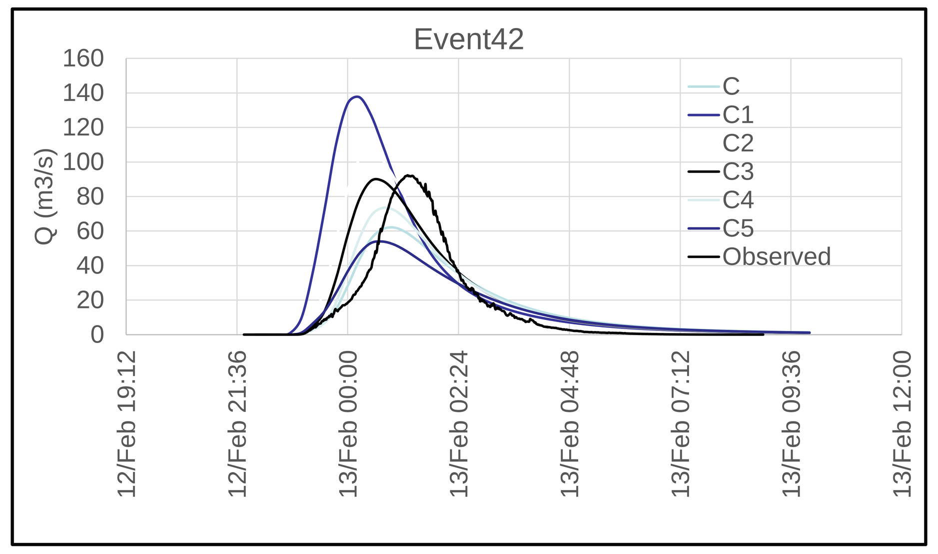

Figure 6: discharge of 5 tested land cover scenarios

Table 3: Land cover scenarios analysis results

	C	C1	C2	C3	C4	C5
runoff (mm)	54.33	87.06	75.09	66.45	58.06	49.98
runoff ratio	0.43	0.70	0.60	0.53	0.46	0.40
runoff ratio (obs)	0.40	0.40	0.40	0.40	0.40	0.40
difference (%)	8	73	49	32	16	-1

Conclusions

- The results of the hydrological model indicate that streamflow is affected by land cover changes in Weany Creek - the relationship between runoff ratio and ground cover is non-linear.
- Remote sensing over estimates ground cover and consequently discharge peaks are underestimated.
- The distributed Wflow model can be used to understand runoff generation processes in more detail throughout the catchment area.

References:

Wflow-sbm model documentation version 1.0.master 2017.1 accessible at http://wflow.readthedocs.io/en/2017.01/wflow_sbm.html

Wflow rainfall runoff model public wiki page accessible at https://publicwiki.deltares.nl/display/OpenS/WFlow+rainfall-runoff+model

Jaap Schellekens, Willem van Verseveld, Tanja Euser, Hessel Winsemius, Christophe Thiange, Laurène Bouaziz, Daniel Tollenaar, Sander de Vries, 2016. openstreams/wflow: 2016.03. doi:10.5281/zenodo.155389