Assessing surface flow pathway connectivity in semi-natural unimproved grasslands using structure from motion

Nicola Ellis[1], R Brazier[1] and K Anderson[2]

[1]University of Exeter, College of Life and Environmental Sciences, Geography, Exeter, United Kingdom of Great Britain and Northern Ireland

[2]University of Exeter, Environment and Sustainability Institute, Penryn Campus, Penryn, Cornwall, United Kingdom of Great Britain and Northern Ireland

ne240@exeter.ac.uk @enicola21

Background

- Unimproved grassland has potential as a form of natural flood management. But there is little research on unimproved grassland hydrological processes, especially overland flow generation once soil is saturated.
- One hypothesised mechanism is the low connectivity of flow pathways. Tussocks may slow surface pathways through longer, disrupted flow pathways in comparison to the flatter, lower roughness, intensely managed perennial ryegrass fields.
- Current geospatial data (e.g. LiDAR) is incapable of mapping microtopographic features which are present in unimproved grasslands. SFM can offer superior data for mapping fine scale surface hydrological connectivity.
- **Study site:** A field of *Molinia Caerulea* and intensely managed grassland (control) in North Devon, UK (**Fig.1**). 95% of *M. caerulea* has been lost in North Devon area since 1950.
- **Research aim:** Develop an understanding of structural connectivity within unimproved grassland fields in comparison to intensely managed grassland.

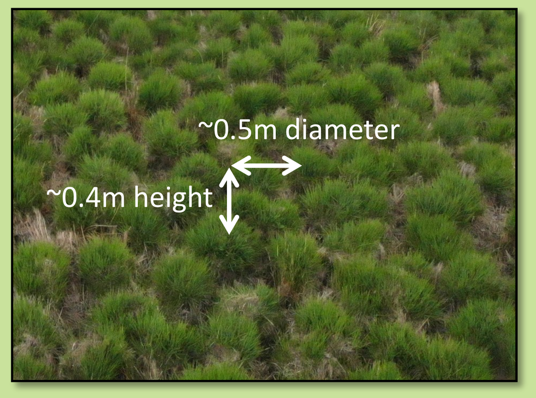


Fig 1: Purple moor grass *(Molinia caerulea)* tussocks (left) and intensely managed grassland (right).

Method

UAV flight

DJI Mavic Air: Overlap/sidelap of 85%, pixel ground resolution avg. 1.6cm/pix, flight height 40m. Combination of nadir and oblique photos

Differential GPS survey of ground control points: 12 ground control points evenly spread across the field, GNSS accuracy ~0.03m

SFM processing:

Create sparse point cloud: Tie point density 7.71 points per m²

Bundle adjustment and optimisation (9 CGPs and 3 check points, RMSE of control and check points below)

Create dense point cloud (pixel density 1492 pix/m) (**DPC**)(**Fig.2**)

Error (cm)	X	Y	Z
M. caerulea	1.14	1.65	2.19
Intensely managed	1.38	1.145	3.52

Create DEM (spherical kriging), 0.03m resolution

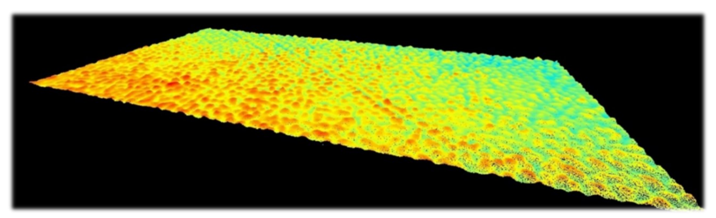


Fig. 2: DPC section of tussocks

Classify tussocks Use DPC error and tussock height in R to extract tussock shapefile (**Fig.3**)

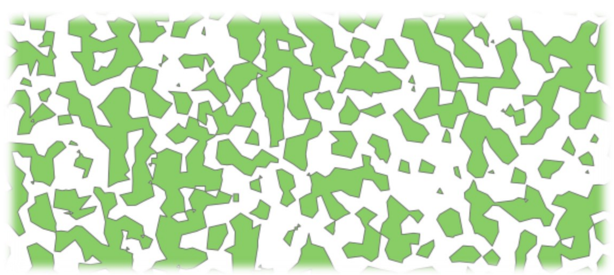


Fig. 3: Sample of shapefile of tussocks extracted from DPC

Quantify surface flow pathway length using drainage density (flow pathway length per unit area)

Optimised pit removal and Arc GIS flow routing algorithm

Results: SFM

The results of flow pathway analysis for *M. caerulea* and intensely managed grassland are shown below.

Fig 4: ***M. caerulea*** had longer, tenuous flow pathways which were disrupted by the soil forming tussocks. Drainage density (m flow pathway length per m²) averaged 2.54m m⁻¹. The grassland also had a greater roughness with the greater vegetation species diversity.

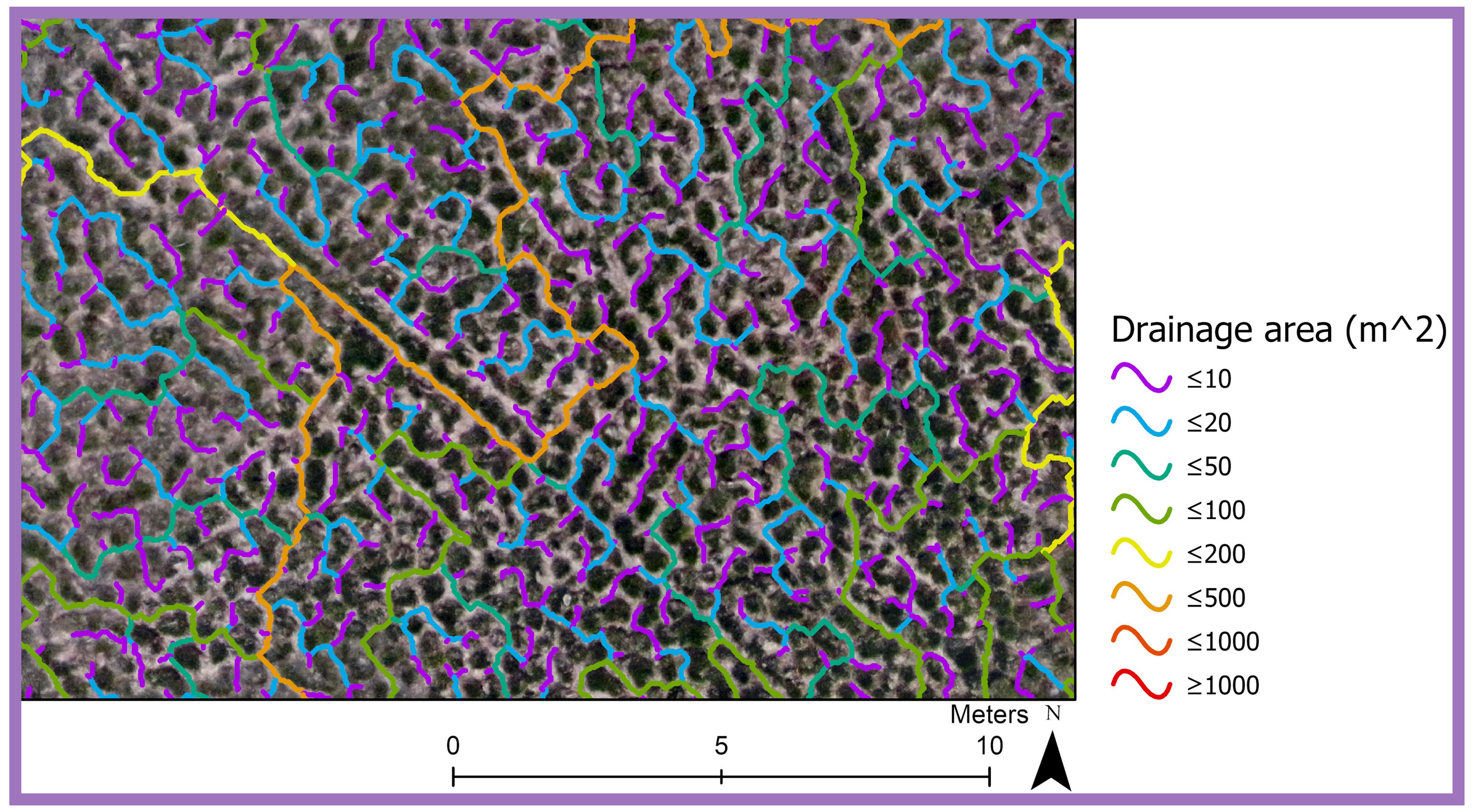
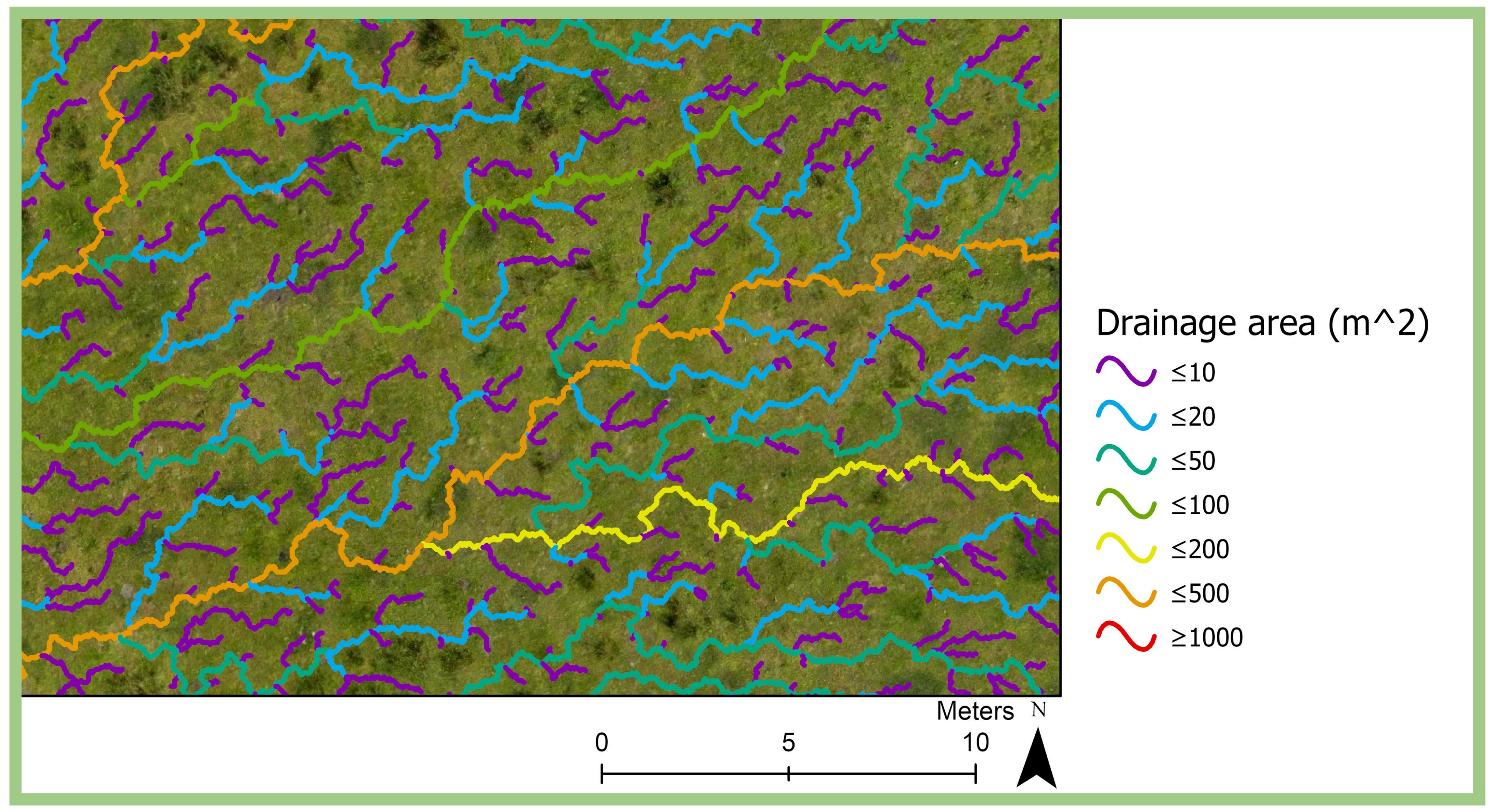


Fig 5: Intensely managed grassland had a drainage density of 1.82m m⁻², which were straighter and more in line with slope. The monoculture grassland had lower surface roughness and often followed degradation features such as wheel tracks or through gateways.



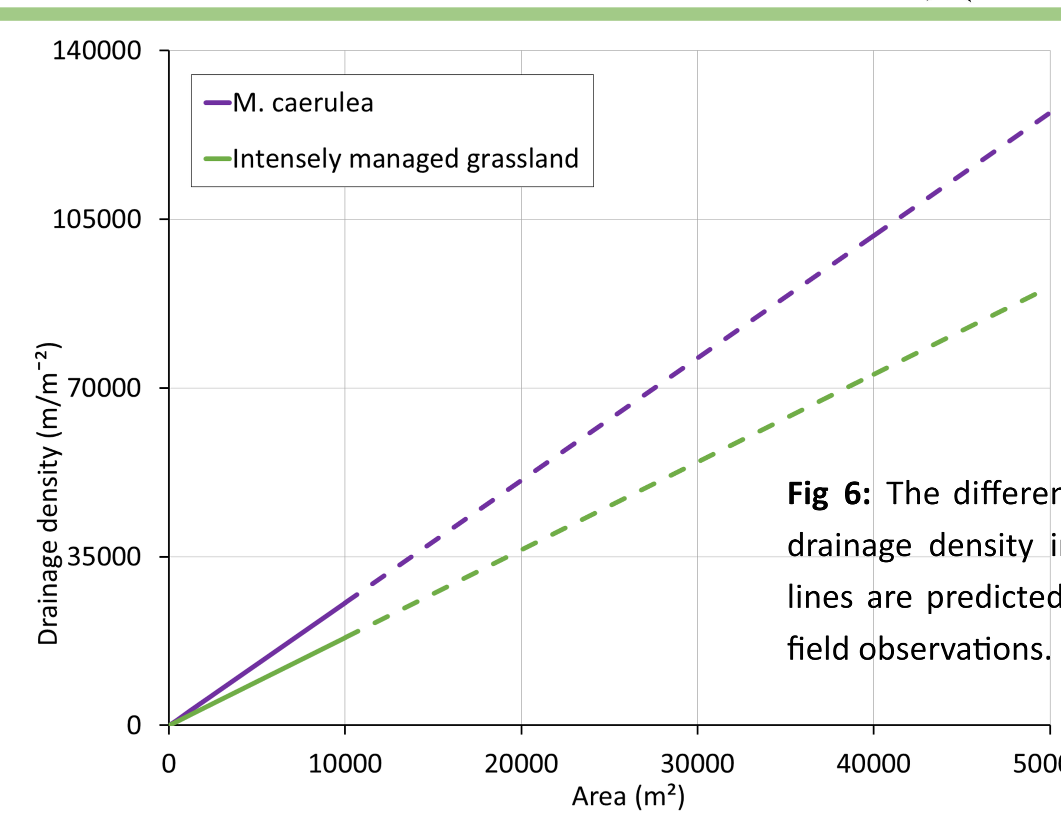


Fig 6: The difference in surface flow pathway drainage density increases with area. Dashed lines are predicted flow pathways based upon field observations.

Results: LiDAR

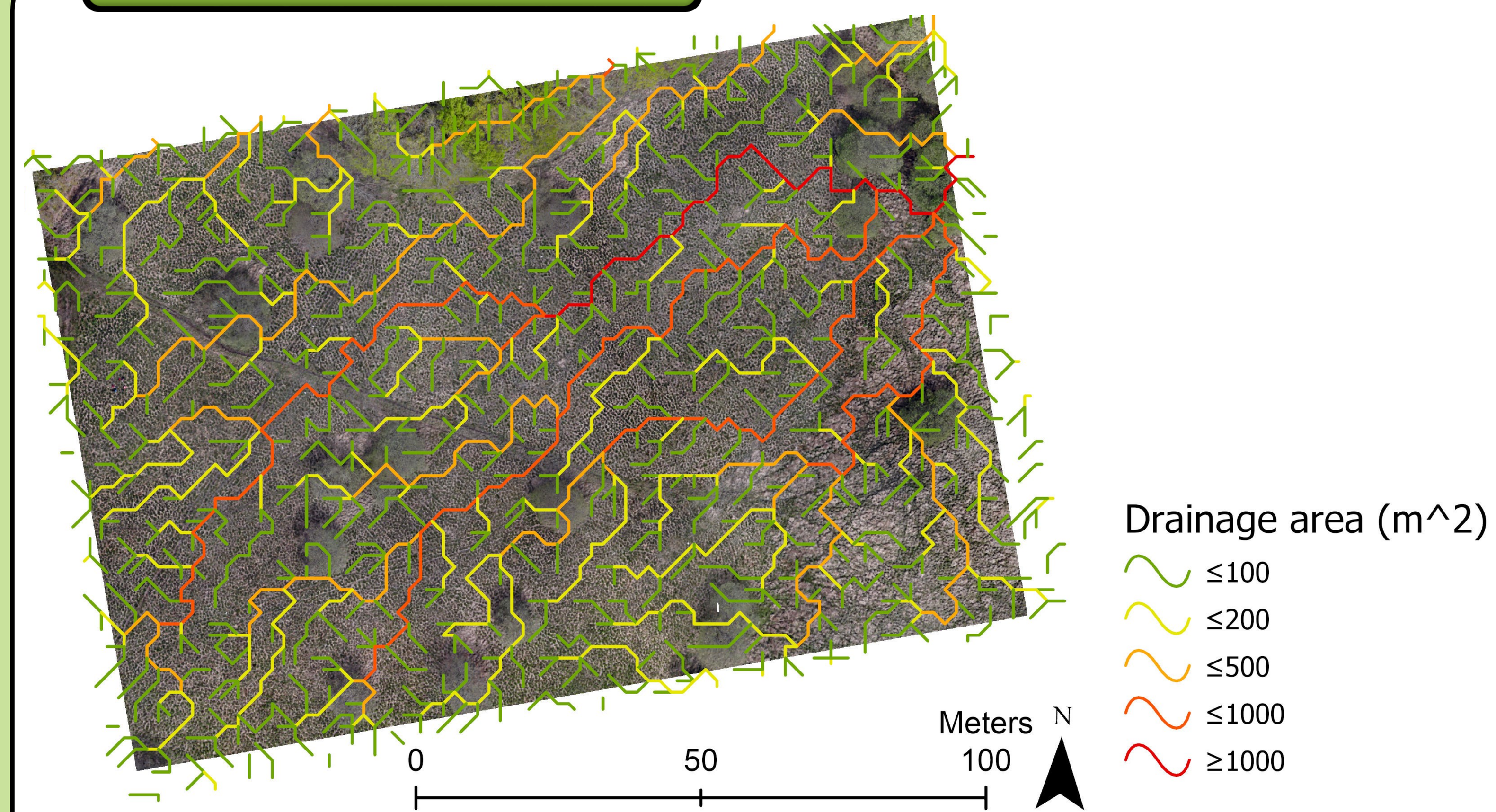


Fig 7: Flow pathway algorithm used on a 2m **LiDAR DEM** of the same *M. caerulea* field.

Flow pathway drainage is limited to ≥100m² in contrast to SFM data which can model flow pathways ≤10m². The superior resolution of the SFM DEM (0.03m versus 2m) means fine scale features such as grass tussocks can be assessed. SFM is able to assess surface connectivity where LiDAR would miss microtopographic feature impact upon surface flow pathways.

Research Implications

- *M. caerulea* was shown to have decreased connectivity when using drainage density as a metric, in comparison to intensely managed grassland which had greater surface connectivity.
- Longer, tenuous flow pathways with reduced connectivity in *M. caerulea* sites theoretically results in: slower flow velocity, reduced soil erosion, greater evapotranspiration and root uptake than intensely managed grassland sites. These attributes imply the dis-connectivity of *M. caerulea* may result in natural flood management properties.
- Understanding can be coupled with field results of unimproved grassland hydrological properties investigated as part of this PhD, such as a field rainfall simulations to study runoff generation and volume and ongoing in situ monitoring of water above and below surface water storage capacity.
- SFM is highly effective at capturing intricate structures and hydrological processes in grasslands, especially in comparison to available data such as LiDAR.
- It is critical that this enhanced flow pathway model is used within hydrological models to explore the role of grasslands within flood mitigation or flood generation processes.

Key discussion points

The following are points of discussion for furthering the study of unimproved grassland flood mitigation properties and the method used to assess this.

- **Connectivity within grasslands:** How do unimproved grasslands fit into the concept of (dis) connectivity, particularly in regards to providing natural flood management services?
- **SFM as a method of assessing grassland microtopographic features:** Discussion of structure from motion as a method of assessing grassland features and connectivity of surface flow pathways, particularly in comparison to current available geospatial datasets.