The relationship of soil and woodland cover on soil hydraulic conductivity at a hillslope scale and local flood management in the Scottish Borders

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Introduction

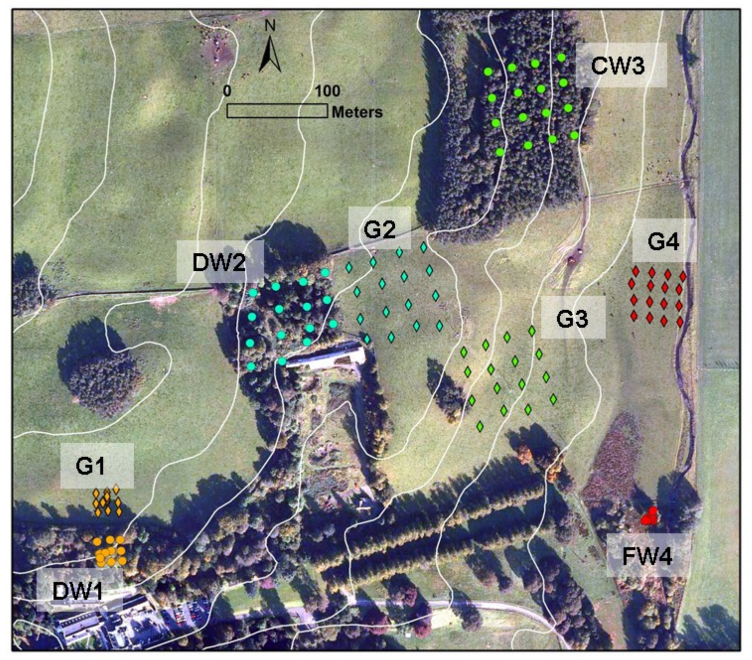
An important criteria in Natural Flood Management (NFM) is understanding and improving the surface soil permeability (or field, saturated hydraulic conductivity, *Kfs*; Talsma, 1987) of natural ground surfaces with the view of increasing rainfall infiltration and storage capacity (Marshall *et al.*, 2009). At the local scale infiltrability and soil hydraulic conductivity (Ks) are key soil properties as they activate surface and near-surface flow paths that influence runoff generation (Elsenbeer, 2001; Bonell *et al.*, 2010).

Aims

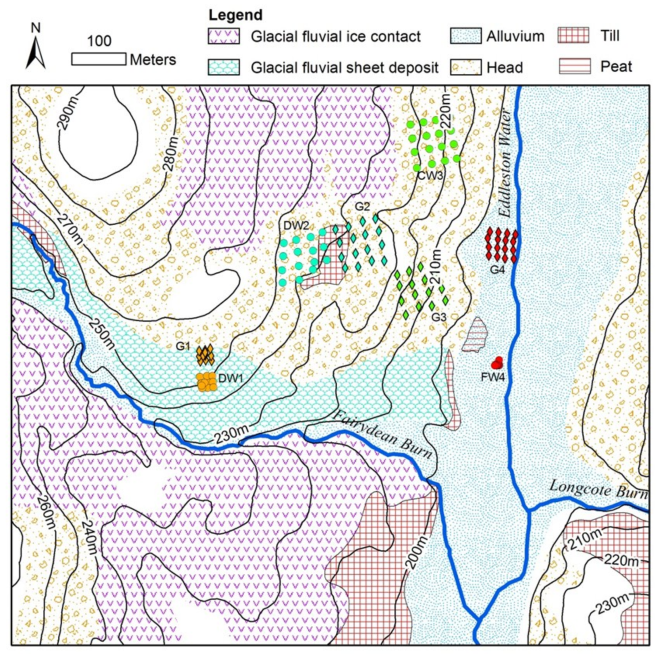
1) To evaluate the impacts of landcover in relation to superficial geology and soils on soil permeability. This will be done by measuring *Kfs* of adjacent grassland and woodland areas on similar superficial geology and soil types.
2) The results of measured Kfs of grassland and woodland will be compared with maximum rainfall intensities of 15 minute duration (I_{max15}) to infer whether infiltration-excess overland flow is generated within the study area.
3) The presence of woodland in relation to soil permeability will be discussed in terms of reducing infiltration excess overland flow.

Site area

The site is located on a hillslope that extends to the floodplain of the Eddleston Water, a tributary of the River Tweed in the Scottish Borders (55°42.9'N, 3°13'W). It has an altitudinal range from 192 m to 255 m above Ordnance Datum (OD) with a slope gradient varying from 1 to 22 %. .



Aerial photo of site area



Superficial geology of site area

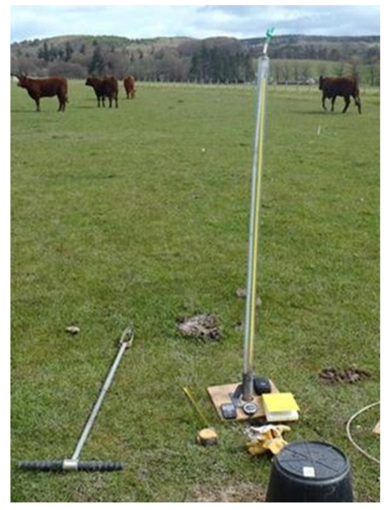
Grid Site	Description	No. of sampled points	Depth of augered holes
G1	Improved grassland >265 years	13	0.04-0.15m, 0.15-0.25m
DW1	Deciduous Woodland, mature Beech > 500 years	15	0.04-0.15m, 0.15-0.25m
G2	Improved grassland >265 years	16	0.04-0.15m
DW2	Deciduous mixed woodland <160 years	15	0.04-0.15m
G3	Improved grassland >265 years	16	0.04-0.15m
CW3	Conifer plantation 50 years	16	0.04-0.15m
G4	Improved grassland >265 years	16	0.04-0.15m, 0.15-0.25m
FW4	Deciduous Woodland, mature Willows < 180 years	12	0.04-0.15m

Descriptions of the each grid areas

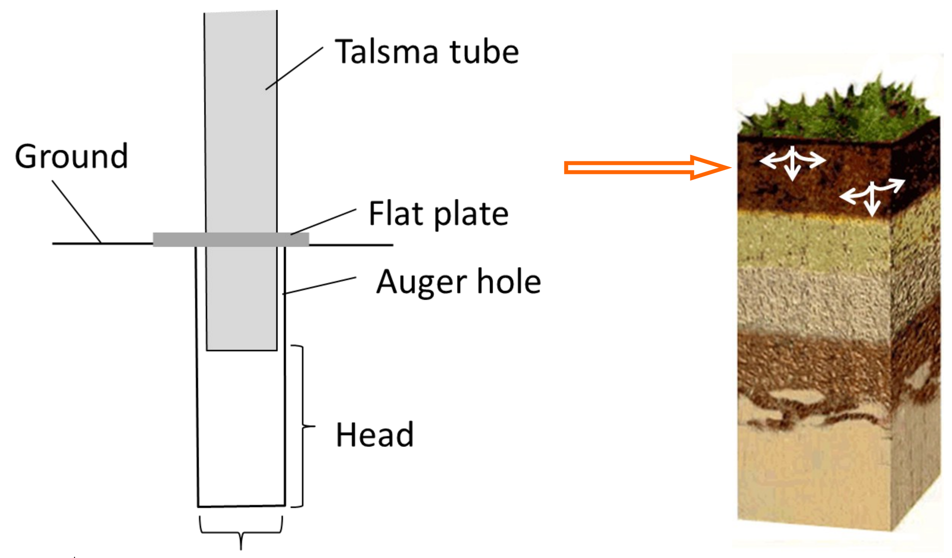
Methodology

Estimation of hydraulic conductivity (Kfs)

Subsoil Kfs for all grid areas was measured at 0.04 to 0.15 m using a Constant Head Well Permeameter as designed by Talsma and Hallam (1980). A stony layer below 0.15 m at sites 2 and 3 restricted augering below 0.15 m, whereas sites 1 and 4 were augered to 0.25m. Results are shown in fig. 1.



Constant Head Well permeameter



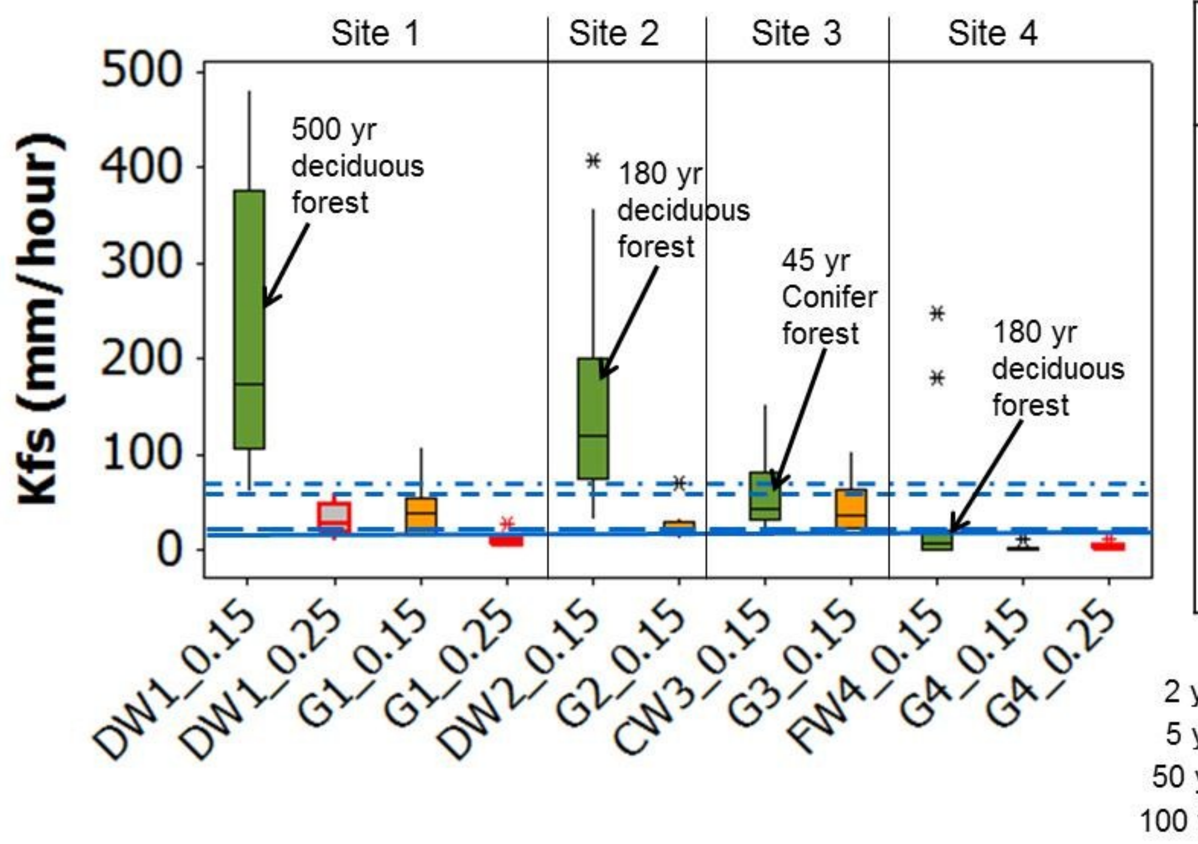
Soil profile with white arrows shows water flow from Kfs measurements

Estimation of storm events

Maximum rainfall intensities (I_{max})for different rainfall durations for the field site were derived using the Flood Estimation Handbook (FEH) depth-duration-frequency (DDF) model on a 1 km grid, as described by Faulkner (1999). Rainfall was aggregated over 15 to 360 minute rainfall durations for 2, 5, 10, 20 and 100 year return periods and superimposed on box plots (fig. 1).

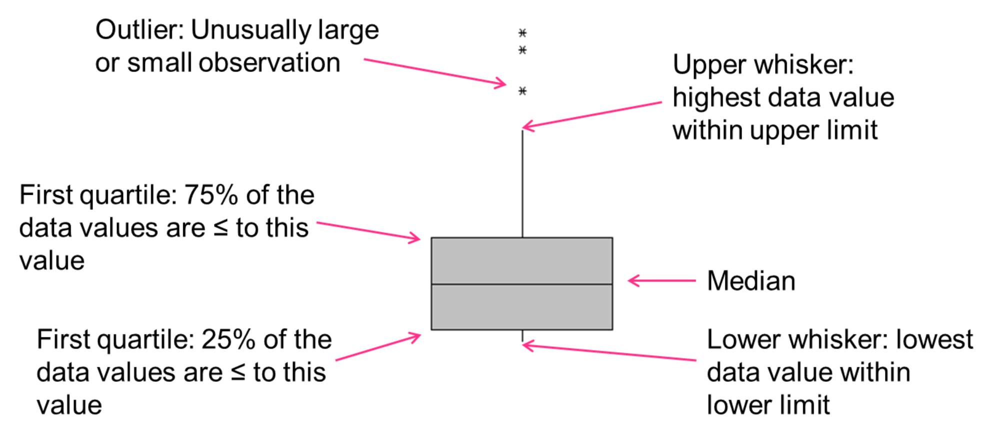
Results

Fig. 1) Box plots of hydraulic conductivity measured for all grid areas at 0.04 to 0.15 m and 0.15 to 0.25 m soil depth. Blue lines are superimposed $Imax_{15}$ rainfall for 4 storm return pe-



Site and soil depth	Kfs Median (mm hour^{-1})
DW1, 0.15m	174
DW1, 0.25m	27
G1, 0.15m	39
G1, 0.25m	7
DW2, 0.15m	119
G2, 0.15m	21
CW3, 0.15m	42
G3, 0.15 m	35
FW4, 0.15 m	8
G4, 0.15m	3
G4, 0.25m	6

Description of boxplot

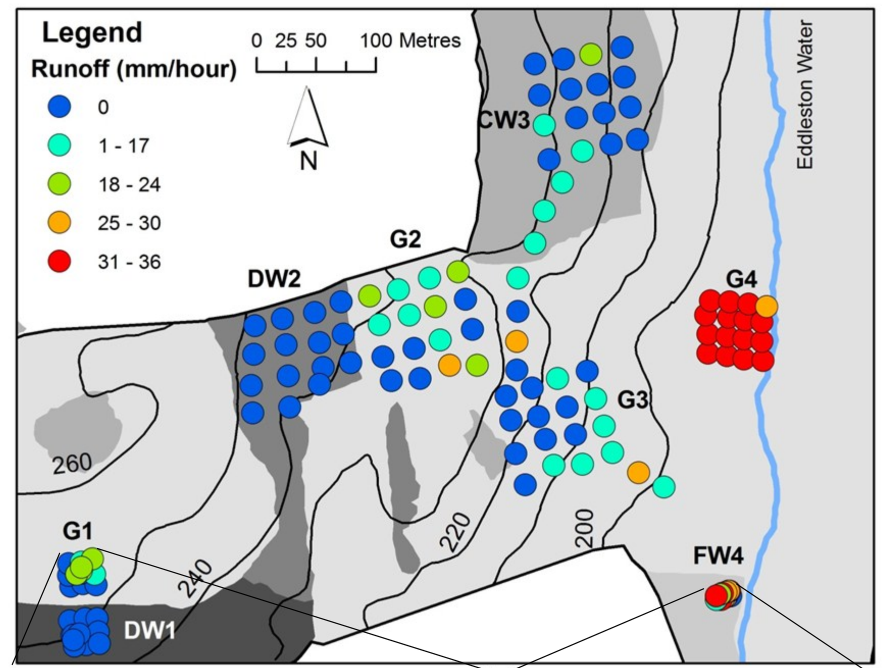


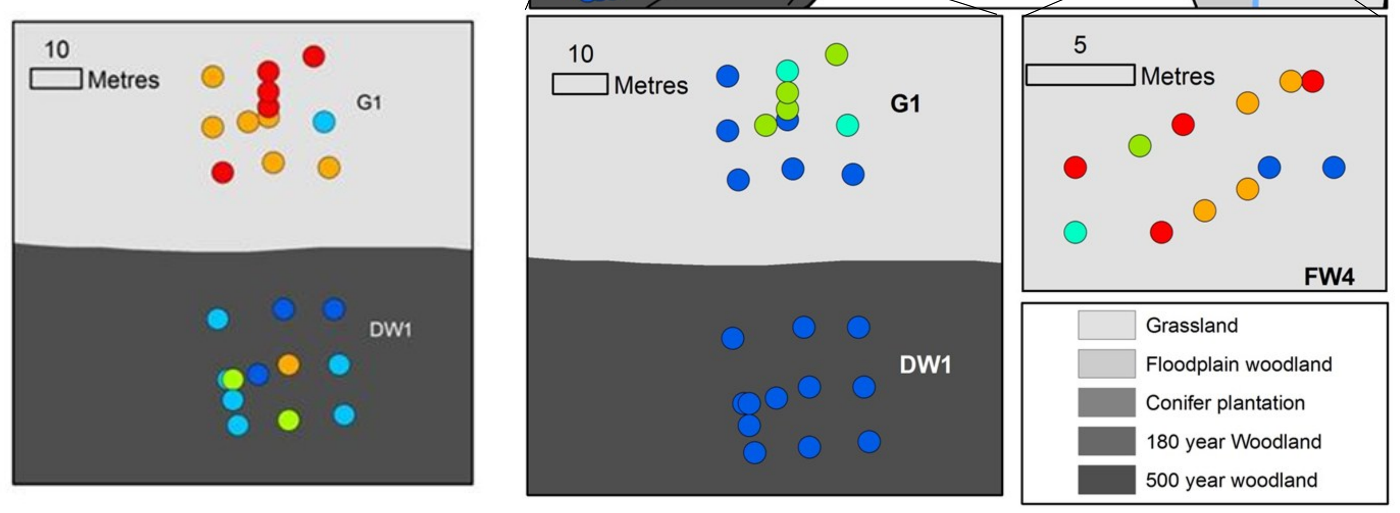
Results continued..

- Hydraulic conductivity is significantly higher under deciduous woodland (DW1 and DW2) on the hillslope than any other land cover. Conifer (CW3) or the wetland woodland (FW4) has less of an effect on hydraulic conductivity.
- Grassland areas (G1, G2, G3 and G4) have significantly lower hydraulic conductivity than adjacent woodland areas.
- A two year storm event will not infiltrate into floodplain woodland or grassland, which infers that infiltration excess overland flow could occur.
- Median *Kfs* under deciduous woodland (DW1) decreased by six times the amount of the *Kfs* measured in the upper soil layer. Such a decrease in *Kfs* at deeper topsoil depths is likely to cause subsurface storm flow, during high intensity rainfall events, particularly under woodland.

Development of conceptual diagram inferring areas of local hillslope runoff generation

Using the results from fig. 1 a conceptual diagram was developed to illustrate inferred runoff (infiltration excess overland flow) during I_{15max} 10 year rainfall event (36 mm hour^{-1}). When runoff is 0 mm hour^{-1}, the total rainfall will infiltrate because the *Kfs* measured at a point is greater than 36 mm hour^{-1}. If the *in-situ Kfs* is less than 36 mm hour^{-1}, a portion of the rainfall will become infiltration excess overland flow and generate runoff or subsurface storm flow.





Runoff generated at 0.15—0.25 m soil depth

Runoff generated at 0.4—0.15 m soil depth

Conclusion

- This study highlights the significant impact of deciduous woodland on the hillslope that increases *Kfs* in comparison to grassland areas. In particular, *Kfs* under 180 and 500 year old deciduous forest was found to be respectively 6 and 5 times higher than neighbouring grazed grassland areas on the same superficial geology.
- Older forests on pastoral hillslopes could mitigate local flooding because the significantly higher infiltration rates under forested areas which could act as sinks to high intensity rainfall, in comparison to significantly lower infiltration rates of adjacent grassland areas.

References

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