British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Natural Flood Management: Does the age of forest influence flood mitigation?

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Introduction

Forestry has the potential to alleviate flooding by delaying the downstream passage of flood flows, reducing the volume of runoff through interception (Calder et al. 2003) and promoting rainfall infiltration into the soil (Forest Research, 2010). However, it is difficult to predict how much a forest needs to grow, before there is any significant effect on soil properties to increase the capacity to 1) store water, 2) increase soil infiltration, 3) slow water and reduce water flow connectivity to rivers.

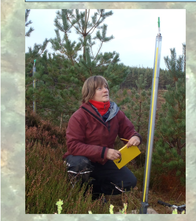
The structural coupling between plant roots and soil environment determines flow paths through the soil, where root growth and die-back influences soil hydraulic properties, increasing macropore distribution (Bengough, 2012) and soil permeability. We test the hypothesis: **Older forests will have greater density of macropores and higher permeability**

To test this we investigated forests of different ages.

Site area

Five areas were chosen in the Feshie headwaters, within the Cairngorm mountains, Scotland. These were: 6 year old, 48 year old plantations and remnant 350 year old individual Scots Pine (*Pinus sylvestris*), a two hundred year old grazed area located in the Glen Feshie Estate and a remnant 4000 year old Ancient Caledonian Forest within a Scottish Heritage conservation area.

Methodology



FIELD TECHNIQUES

In each field site, field-saturated hydraulic conductivity (K_{fs}) was estimated using a constant-head well permeameter (CHWP) as designed by Talsma and Hallam (1980).

Replicate soil cores were taken at 0.06 to 0.1 m, 0.16 to 0.20 m and 0.26 to 0.40 m from 3 soil pits within each site. Coarse roots (>1mm) were counted using Bohms's acetate technique (Bohm, 2012) and soil pits were described.

LAB TECHNIQUES

X-ray micro-computed tomography was used to obtain microscopic 3D images of the internal pore geometry of undisturbed soil samples.

To estimate water storage, water release curves were measured for all soil cores. Matric potentials ranging from -0.5, -1, -2.5, -5, -10, -25, -50 kPa were used to equilibrate the samples.

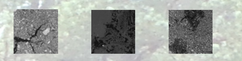
Macroporosity (> 30 µm) and **total porosity** were estimated from water release curves, **Macropore connectivity** was measured from 3 dimensional x-ray tomography, **root fractions** (>5 mm) were estimated from soil pits and **field saturated hydraulic conductivity (Kfs)** was measured using the CHWP.

Results

Site areas

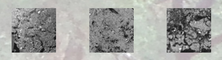
Soil/root profiles: 0 to 0.35m depth

X-ray tomography: 0.16 to 0.20m depth (512 x 512 voxels)



Significantly high macroporosity (>30µm), microporosity (between 30 µm to 0.2 µm) and pore connectivity. High organic matter at 0 to 0.10 m and 0.26 to 0.4 m

Ancient Caledonian Forest: 4000 years old (AF)

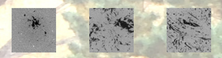


Significantly high macroporosity (>30µm) and pore connectivity. High organic matter at 0 to 0.20 m

Old Scots pine Trees: 350 years old (OT)

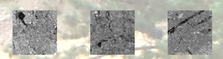
Significantly high macroporosity (>30µm) and pore connectivity. High organic matter at 0 to 0.20 m

Scots pine 48 year old plantation (48yr)



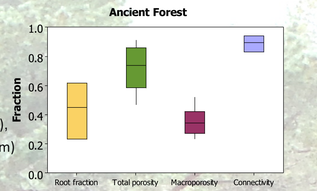
Significantly low macroporosity (>30µm) and pore connectivity. Highly organic matter at 0 to 0.40 m (mean 0.92 g/100 dry soil). Poorly structured throughout.

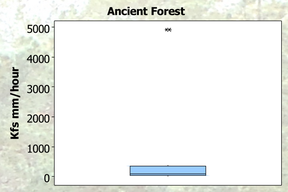
Scots pine 6 year old plantation (6yr)

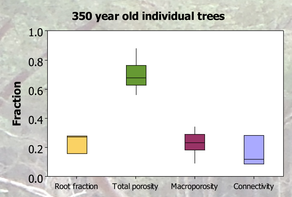


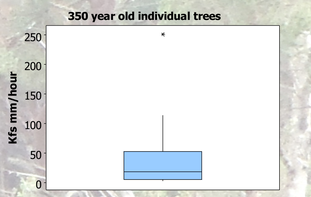
Significantly low macroporosity (>30µm) and pore connectivity. Low organic matter at 0 to 0.40 m (mean 0.13 g/100 dry soil). Well structured throughout.

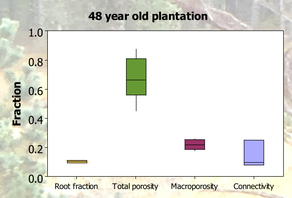
>200 year old rough grazing area (GL)

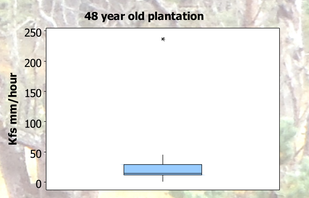


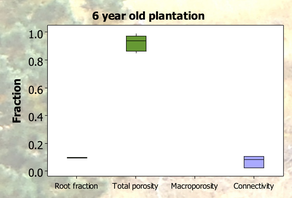


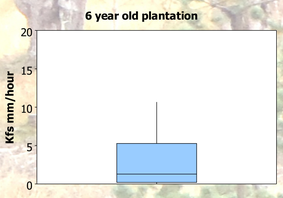


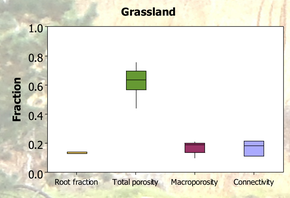


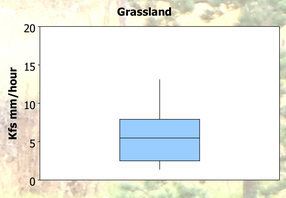












Soil structure characteristics

Field saturated hydraulic conductivity

Conclusions

- **The hypothesis is accepted. With increasing forest age macroporosity and soil permeability increases with forest age.**

The Ancient forest had 10 times higher Kfs than the 48 year old plantation and 350 year old individual trees and 1000 times more that the 6 year old plantation. Coarse root fraction (>5mm), macroporosity (>30µm) and macropore connectivity were significantly higher than all other sites.

350 year old individual trees and the 48 year old plantations have similar Kfs. This was because the 350 year trees had high Kfs rates near them and low Kfs in open areas. As an average, the site with individual 350 year old trees and open areas, provided similar average macroporosity and Kfs in comparison to the 48 year old plantation.

The 6 year old plantation had the lowest Kfs of all sites and the highest total porosity. Total porosity was high at this site, because the soils were highly organic, due to decaying wood from the previous plantation.

Further investigation is needed to understand forest plantation management and how this affects changes in macroporosity and Kfs. Natural forests also need to be investigated to understand the root dynamics and the structural coupling of soil in relationship to water movement.

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