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Runoff characteristics of different cultivations in Menstrie catchment, Scotland: From field observations to model development

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Natural Flood Management (NFM) practices include planting catchment woodland as a technique for potential interception and attenuation of runoff to mitigate downstream flooding and deliver multiple ecosystem services (e.g., habitat, amenity). According to The Scottish Forestry Strategy (2006), upland afforestation, as part of an NFM strategy can reduce flood runoff by increasing evapotranspiration, interception and soil infiltration. The Scottish Forestry Strategy (2006) therefore aims to increase woodland cover from 17.1% to 25% of Scotland's land area by the second half of this century. To realize this ambition, they Scotland plan the creation of ∼15,000 ha of new woodland per annum, and to develop novel approaches to assist in mitigating climate change, stimulate economic development and provide a range of other benefits, including sustainable flood management.

Menstrie village in Clackmannanshire, central Scotland, has a history of recurrent floods due to overbank flow from the Menstrie Burn (a hillslope tributary of the River Forth). In August 2004 approximately 30 properties were flooded (Clackmannanshire council, 2005). An even larger event occurred in 2012, demonstrating a continuing vulnerability of this village to flooding. In 2015 one of the largest modern-day woodland creation projects was implemented in Clackmannanshireupstream of Menstrie village. In total, 47% of the Menstrie Burn catchment (1200 ha) was subjected to the planting of, predominantly, productive conifer woodland (Sitka spruce). This scale of land use change was expected to provide elements of NFM in the medium to long-term, but concerns were raised about the potential for pre-planting cultivation to increase flood flows in the shorter-term.

In response to this research has been undertaken in Menstrie catchment since 2016 to analyze the different processes which affect flood generation namely: planting technique, overland flow sediment loading. This has been monitored at seven different locations (according to cultivation) and surface flow in the main watercourse and its tributaries.

Seven study plots (one unplanted plot, three plough cultivation plots, two excavation mounding technique plots, and one hand screefing cultivation plot) with secured repetition have been modeled over a two year period using GR4H rainfall runoff conceptual model. This model used an hourly time step of observed rainfall, flow, evapotranspiration, and temperature data time series to generate behavior of each monitored plot with similar preferences of observation.

The GR4H model optimizes four free parameters: maximum capacity of production store (mm), groundwater exchange coefficient (mm), the maximum capacity of routing store (mm) and time peak ordinate of hydrograph unit UH1 (day). This model has been built for two tributaries of Menstrie burn, the Menstrie burn and all seven study plots.

This approach has simplified output from field observation, assisted in a better understanding of the data gaps and elaborated on the observed trends of vegetation processes.

Moreover, the initial outputs from this model can be useful for future climate change mitigation via nature-based solutions.

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