Modelling the hydrological effects of woodland planting on infiltration and site discharge throughout the winter months using HEC-HMS

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Highlights

- 123 infiltration measurements were collected from a wooded study site in Warwickshire, UK.
- The collected infiltration data is modelled on a calibrated HEC-HMS model.
- Results show that discharge from grassland and woodland is similar during the winter months.

1. Introduction

Urbanisation and the replacement of permeable and vegetated surfaces to impermeable surfaces, such as asphalt and concrete, is reducing lag times and increasing peak flows in receiving watercourses, influencing the likelihood and severity of high-flow or flooding events (Ellis et al., 2021; Ferguson & Fenner, 2020). The global climate is predicted to change in ways unseen in recorded history (Lowe et al., 2019). In the UK, sea levels are expected to rise, the frequency of extreme weather events will increase, summers will become hotter and drier, winters will be warmer and wetter (Lowe et al., 2019; Murphy et al., 2021). Consequently, UK flood risk authorities are investing in more sustainable methods of mitigating flood risk, such as Natural Flood Management (NFM) techniques (Ferguson & Fenner, 2020).

One method of NFM that is assumed valuable, although under-investigated, is woodland planting (Dittrich et al., 2019; Murphy et al., 2021). Tree roots break up their surrounding soil - increasing the infiltration rate and water storage capacity, whilst simultaneously offering increased opportunity for interception and evapotranspiration (Chandler, Stevens, Binley & Keith, 2018; Wahren, Schwärzel, & Feger, 2012). However, there is a lack of evidence-based studies focussing solely on the impacts of changing infiltration due to woodland planting, proximity, and maturity.

In light of recent climate predictions projecting wetter winters, coupled with the lack of evidence-based studies investigating the feasibility of woodland planting as a method of NFM, this study aims to determine the extent to which woodland planting has influenced infiltration at a site in central England. A hydrological model is built using HEC-HMS, calibrated, and validated using the NSE method, and used to predict the ability of trees to increase infiltration, reduce runoff and subsequent flooding.

2. Methodology

2.1 Infiltration Data Collection

Infiltration data was collected bi-weekly throughout October to March 2019/20, and 2020/21, from specific areas of a 2.2 km^2 study site in Warwickshire, UK. Infiltration data was collected from woodland in the plots planted in 2006 (*Betula Pendula*), 2008 (*Populus Tremula*), 2010 (*Betula Pendula*) and 2012 (*Populus Tremula*), in addition to a plot of ancient woodland planted *cc.*1900 (*Quercus Petraea*) and a grassland control. See figure 1.

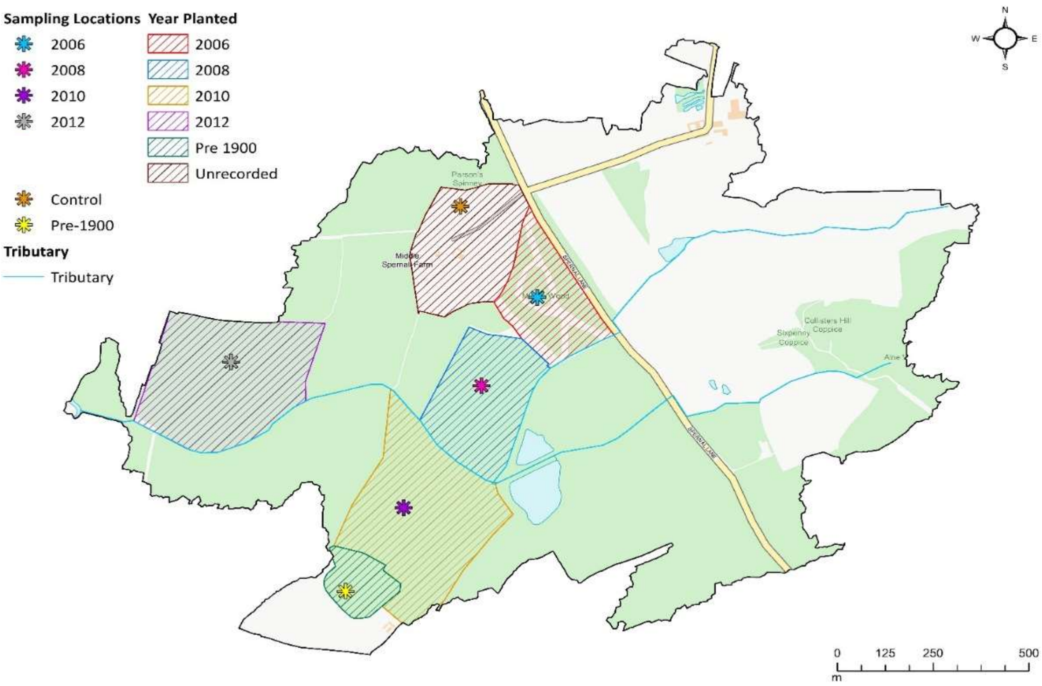

Figure 1. Study site area with sample plots, tributary, and infiltration sample locations annotated.

Infiltration measurements were collected 10 and 200 cm away from the tree using a Mini Disk Infiltrometer (MDI). The 10 cm proximity was chosen to represent the influence of the tree on infiltration directly adjacent to the trunk, and the 200 cm proximity was chosen to account for potential root spread due to tree growth (Hepner et al., 2020; Mauer & Palátová, 2003; Perry, 1982). A total of 123 infiltration measurements were collected for this study.

2.2 HEC-HMS Model Build and Simulations

Rainfall (in mm) was collected, and stage (in mm) and flow (in l/s) data was recorded via pressure transducers in the study site watercourse. A hydrological model was build using HEC-HMS, and calibrated and validated using the Nash and Sutcliffe Efficiency NSE indicator (Nash & Sutcliffe, 1970). NSE values were 0.65 and 0.87 for calibration and validation, respectively. The Flood Estimation Handbook (FEH) was used to generate 2-year, 10-year, 50-year and 100-year intensity design storms over 6, 24 and 96-hour durations. The study site was simulated as if the area was 100% impermeable, 100% grassland, and using the “present day” infiltration data collected throughout field data collection.

3. Results and discussion

Results of the HEC-HMS simulations are shown in table 1.

Table 1. Peak discharges of 6, 24- and 96-hour duration storms over 1 in 2, 10, 50- and 100-year return periods.

	Intensity	Impermeable (m^3/s)	Woodland (m^3/s)	Grassland (m^3/s)
6-hour	1 in 2	0.666	0.353	0.324
	1 in 10	0.889	0.567	0.546
	1 in 50	1.188	0.863	0.848
	1 in 100	1.356	1.030	1.016
24-hour	1 in 2	0.847	0.569	0.551
	1 in 10	1.118	0.845	0.833
	1 in 50	1.462	1.195	1.188
	1 in 100	1.684	1.382	1.377
96-hour	1 in 2	0.812	0.677	0.674
	1 in 10	1.016	0.897	0.896
	1 in 50	1.261	1.153	1.156
	1 in 100	1.387	1.284	1.288

Results from the simulations (table 1) show that over all durations and intensities, the “100% impermeable” infiltration scenarios show the highest runoff, quickest time to peak, and fastest return to base, as expected. Throughout the 6-hour duration simulations, “100% grassland” showed a lower (0.025 l/s) peak discharge than the “present day” simulations in the lower intensity storms (1:2,1:10), however this discrepancy reduced as the intensity increased. Throughout the longer duration storms, grassland and “present day” infiltration scenarios become more similar in lag time, hydrograph shape and discharge volume as the intensity increases. A t-test was undertaken to statistically compare the similarities of the “100% grassland” and “present day” simulations. The results from the t-test confirmed that there is no statistical variance between the modelled grassland and woodland outputs, with the significance of all tests resulting in a P-vale of >0.01.

Overall, the results of this study show that woodland planting has increased infiltration, increased lag times and reduced runoff significantly, compared to an entirely impermeable site. However, whilst woodland reduces peak discharge in comparison to the impermeable simulations, woodland and grassland are statistically indifferent in their runoff reduction capabilities in higher intensity, longer duration storms.

4. Conclusions and Future Work

This is a novel project that undertakes a comprehensive and continuous study into the impact that woodland planting can have on the surrounding soils infiltration characteristics. In addition to adding to the current level of understanding regarding the use of NFM, it proves how the use of woodland can be adopted to reduce peak flows and increase lag times considering increasing storm severity. Furthermore, the data collected and modelled throughout this study has provided insight into how to collect and extrapolate infiltration data and model such information in HEC-HMS. This will enable other authors in the field of hydrology to use this project as a framework when contributing to the knowledge base regarding infiltration, NFM, woodland planting and hydrology as a whole.

Future work will involve developing a method of projecting the collected infiltration data, with the intention of using the HEC-HMS model to project the ability of woodland planting to mitigate flow and overland runoff into the future, regarding precipitation and baseflow increases in light of climate change.

5. References

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