Trends in soil moisture and temperature dynamics in juvenile forests align to those of mature forest from the time of canopy closure

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Introduction

Afforestation besides the potential for increasing carbon sequestration impact hydrological process and the soil water balance in a complex way (Ellison et al., 2017). Water storage capacity and the buffering of runoff generations process are just some of the hydrological functions promoting by tree-planting (Landsberg et al., 2017).

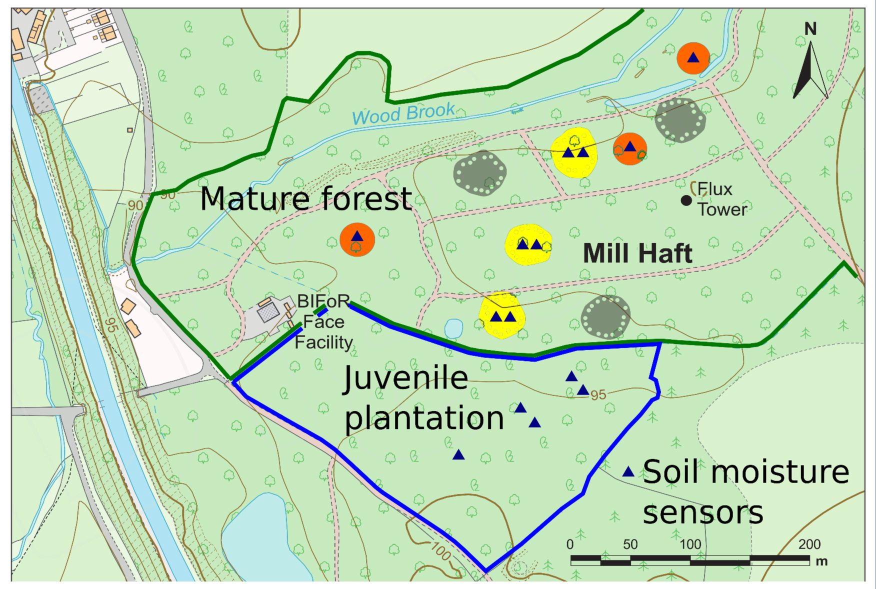
This study aims to improve the understanding of the time scale of when a juvenile forest starts to reach certain levels of hydrological functionality.

Through the analysis of a long-term dataset of soil moisture and soil temperature in a paired experimental plots of mature forest and juvenile plantation we analyse their trend in seasonal dynamics and event-based response to storm and dry period.

Field site description

1. a mature deciduous woodland planted around 1850 and composed mostly of English Oak. This forest hosts the Birmingham Institute of Forest Research Free-Air Carbon Dioxide Enrichment (BIFoR FACE) facility;
2. a juvenile deciduous forest plantation established in Spring 2014 on a previous farmland. It consists of saplings and young trees dominated by English Oak with samples of Silver Birch, common Hazel, Wild Cherry and other deciduous species

Mature forest that hosts the BIFoR FACE facility

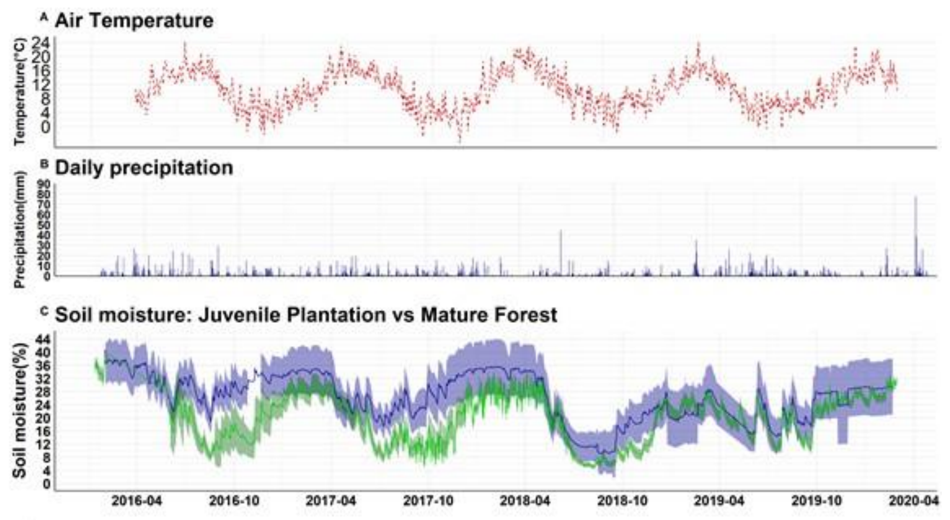


Juvenile deciduos forest adjacent to the Mature forest

The map shows the experimental setup with the soil moisture and temperature sensors located at BIFoR-FACE (undisturbed and control arrays only) and in the Juvenile plantation. Soil moisture was measured by two different sets of probes: in the mature forest CS655 probes by Campbell scientific were used while 5TM probes by Decagon Devices in the Juvenile plantation. Both probes were buried at 0.1 m. The Weather data was acquired until 2019 from the Gnosall weather station (3.5 km from the site) and then from the meteorological towers installed outside the boundary of the mature forest.

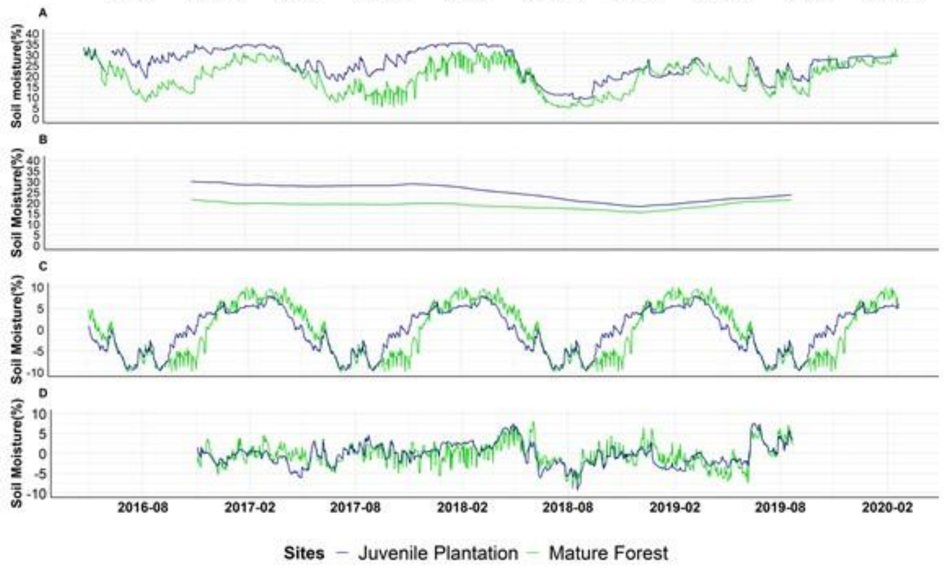
Preliminary results

Trend and time decomposition analysis



The data analysed in this study cover the period from 1st January 2016 until 1st March 2020.Daily temperature (A), precipitation (B), and soil moisture (C) observations for the juvenile plantation and mature forest that identifies higher water demand of mature forest compared to the juvenile.

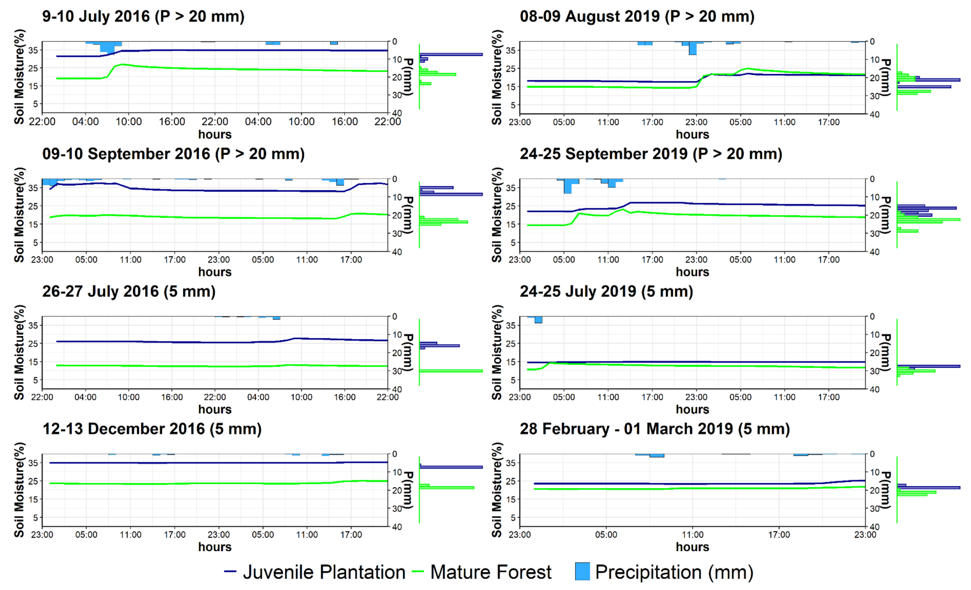
Long-trend of air temperature (A) and precipitation (B) for the period 2016-2020 as revealed by a times series decomposition highlighting substantial drought in 2018.

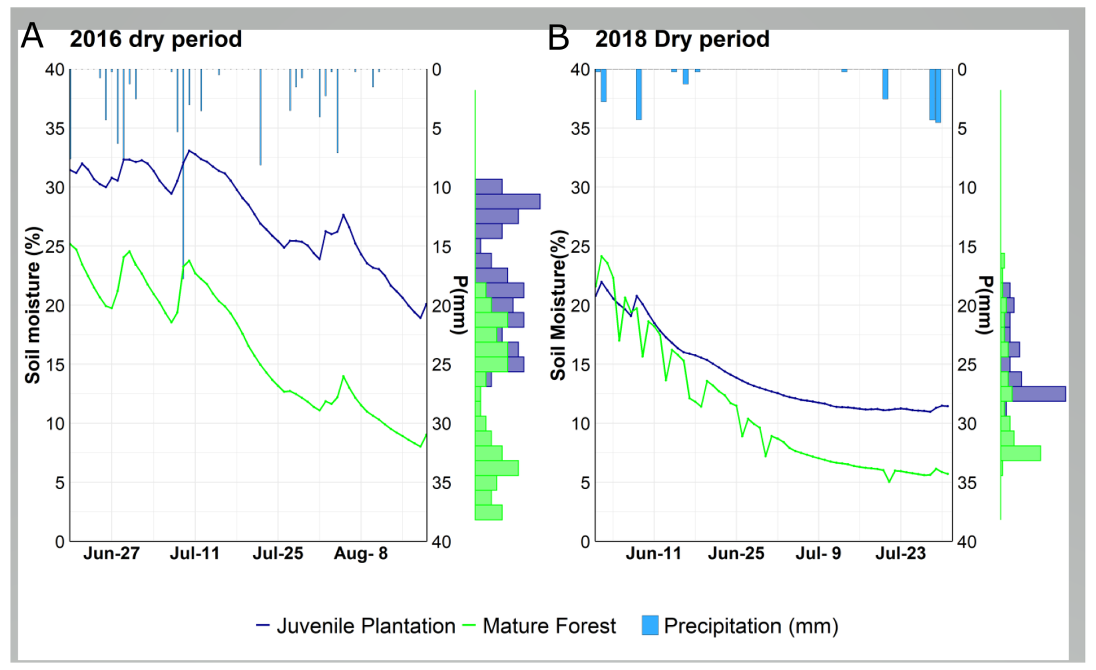


Decomposed soil moisture time series highlights several differences between the mature and juvenile plantation - decreasing trend in soil moisture in the juvenile plantation is more pronounced than mature forest. the mature forest responds faster after the drought period compared to the juvenile plantation (A). The third difference is the delayed seasonal response of the mature forest, in particular during the wetting periods where maxima were reached with a nearly two months delay.

Event based analysis of temporal differences in soil moisture responses

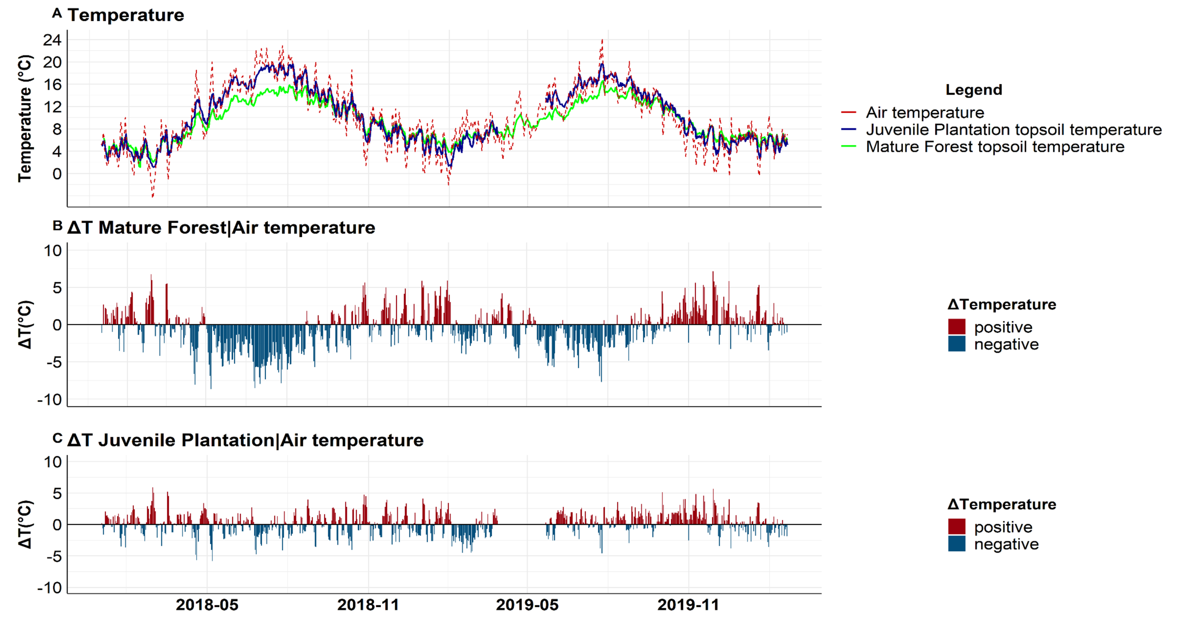
Soil moisture dynamics in the mature forest and in the juvenile plantation were analysed by selecting several storm events occurring in 2016 and 2019. For each year, four two-day periods with a total amount of 5 mm and greater than 20 mm were investigated – soil moisture in mature forest increase faster after every precipitation event and in one occasion exceeds the value of the juvenile plantation.





Additionally, a two-month dry period during the summer of 2016 and 2018, from mid-June to mid-August was selected and analysed

Impact of variable air temperature on topsoil temperature



Through the period from 2018 to 2020, mean daily air and soil temperature of the topsoil (0.1 m) were investigated to define the effect of temperature regulation mediated by the mature and juvenile forest. Soil temperature data were measured at BIFoR by 107 thermistors by Campbell Scientific while 5TM probes by Decagon Devices have been used at the juvenile plantation. Both sets of probes were buried at 0.1 m. The temperature difference was calculated as the absolute difference between the observed air temperature and topsoil temperature

Summary

- The ongoing long-term monitoring enable us to analyse the long-term trends, as well seasonal trends and the responses of the investigated treatment plots to hydrological events such as storms or dry periods;
- Preliminary investigation show how the soil moisture dynamic under the juvenile plantation start to match those of the mature forest coinciding with the development of a closed canopy during the vegetation period;
- These findings provide an understanding of the early evolution of some essential forest ecosystem functions that will be critical for supporting prediction of possible forest soil responses in the context of reforestation.
- On the other hand, the fact that soil thermal dynamics continue to differ between juvenile and mature forest highlights that some soil functions may be reached more rapidly than others.

Reference: Ellison, Morris, et al. "Trees, forest and water: Cool insights for a hot world." *Global Environmental Change (2017) : 51.61*
Landsberg, Waring, et al. "Water relations in tree physiology: where to from here?". *Tree physiology (2017): 18-32*

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