Modelling understory light availability in a heterogeneous landscape using drone-derived structural parameters and a 3D radiative transfer model

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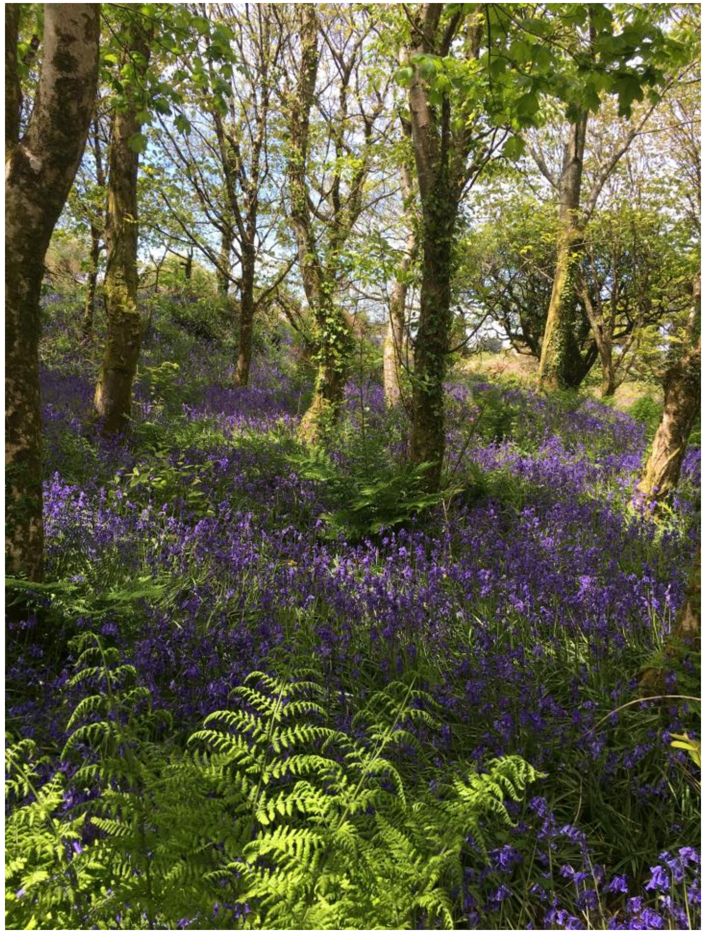
Background & Aims



The **light environment** within vegetated landscapes is a key driver of microclimate, creating varied habitats over small spatial extents and controls the distribution of understory plant species. Previously, simulations of understory light availability have relied primarily on geometric primitives and randomly distributed crowns (Ligot et al., 2014). But **modelling actual spatial variations of light in discontinuous systems requires finely resolved (< 1 m) information on topography and canopy properties.**

Datasets at these scales can now be efficiently acquired by drones. We demonstrate **an approach to parameterising the DART model** (discrete anisotropic radiative transfer, (Gastellu-Etchegorry et al., 2015)) with drone data across a period of spring green-up and use it to **simulate understorey PAR**. The model simulations of understory are assessed against field measurements to answer the following research questions:

1) **Can the model accurately simulate hourly understory PAR variations and daily light integrals?**

2) **How does the model informed by drone captured data compare to a simpler representation of the vegetated scene?** (work in progress)

Study design

Tree loggers

Woodland loggers

3DR Solo drone + Parrot Sequoia

Woodland PAR logger set-up

The study site located in west Cornwall (UK) is managed for the purpose of wildlife conservation and was selected due to its due to its **structural complexity and species richness**.

RGB and multispectral images were acquired at regular time-intervals throughout spring green-up using sensors mounted on a multirotor drone. These were **used to derive site 3D structure and plant area index (PAI)** respectively.

PAR was measured using quantum sensors throughout spring green-up under free-standing trees and locations in the woodland.

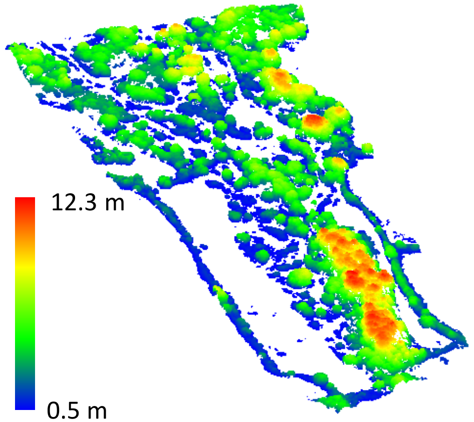
Using DART, **simulations of understorey PAR throughout single days were performed in one-hour time intervals** for three stages of the spring green-up transition period (pre-, mid- and end of green-up).

Crown geometry informed by SfM photogrammetry

Overlapping RGB images were processed using **structure-from-motion (SfM) photogrammetry** algorithms within the Agisoft Metashape software (St. Petersburg, Russia). The resulting dense 3D point cloud was normalised based on a LiDAR digital terrain model (DTM) of the site and points representing vegetation were **classified and segmented to represent individual plant crowns** using methods from the lidR package (Roussel & Auty, 2018).

Resulting crown heights were combined with a crown-ratio model based on field measurements to **represent vegetation as 3D voxels within the DART model** (resolution: 1 x 1 x 0.25 m).

Vegetation >0.5 m



Overstory segmented crowns

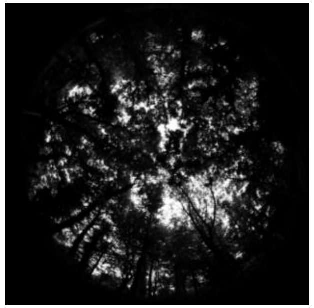
DART voxel representation

Plant area index informed by NDVI and hemispherical photography

Case 1) Closed canopy (woodland)

Image from transect pre green-up

Image from transect post green-up



Case 2) Individual crown

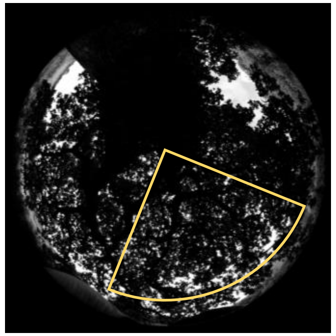
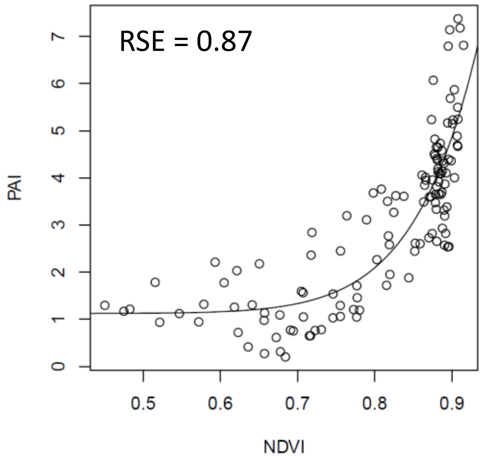


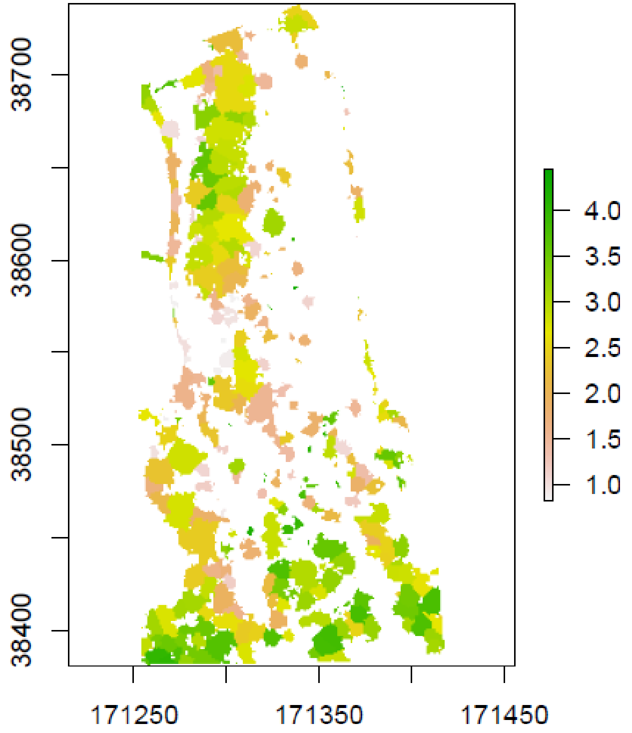
Image from single tree crown post green-up and illustration of used image sector

Hemispherical photography was acquired throughout spring green-up for 1) a transect through the woodland and 2) below individual crowns. **PAI was derived** from images using the Hemisfer software (WSL, Switzerland) following the LAI-2000 method (Li-Cor, US). To apply the method to single crowns, it was modified to make use of SfM derived crown geometry.

An **empirical relationship between PAI and NDVI from drone multispectral acquisitions** was used to determine a representative PAI per segmented crown.



Exponential model relating PAI to NDVI



Derived PAI map (post green-up)

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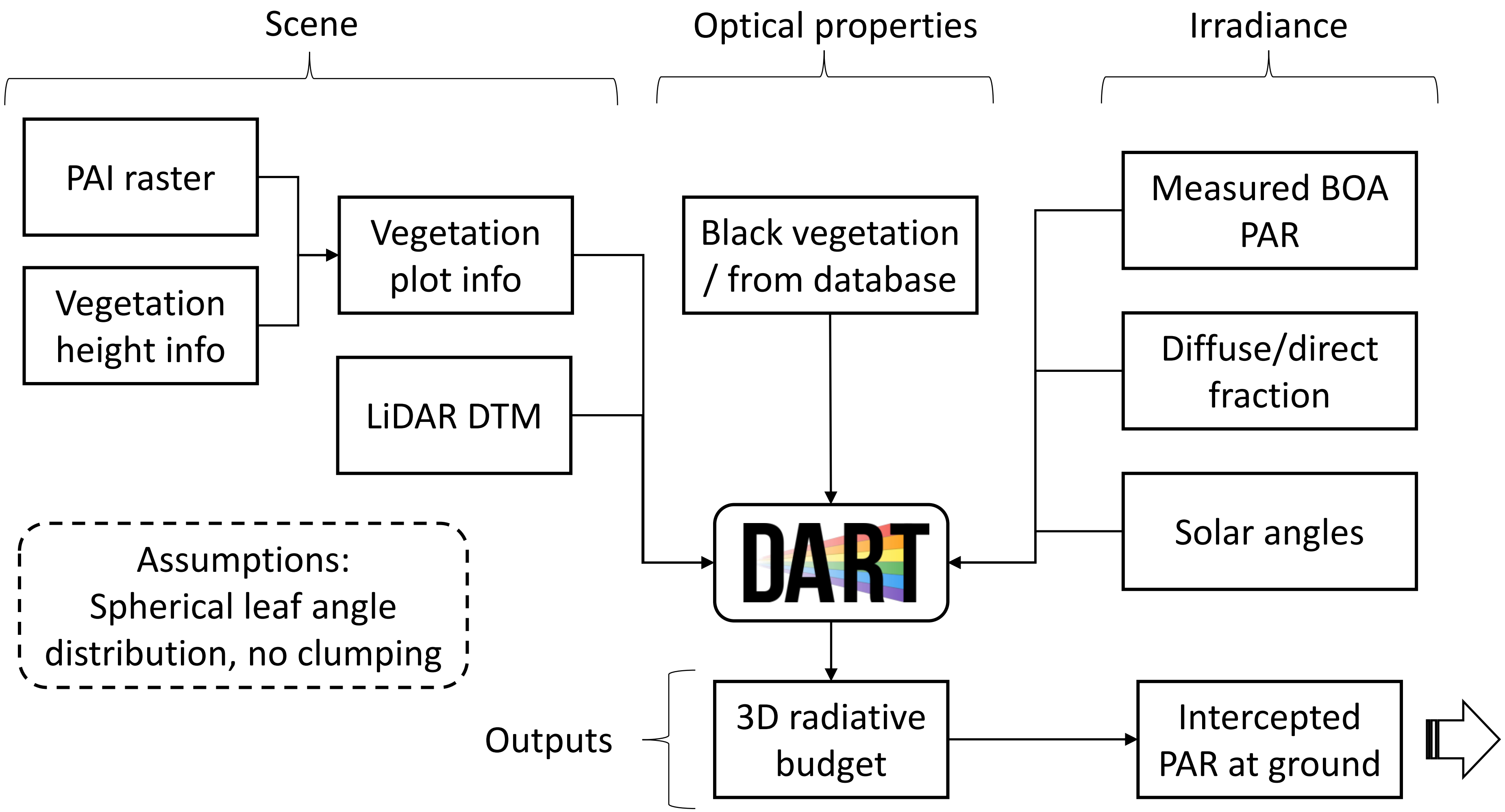
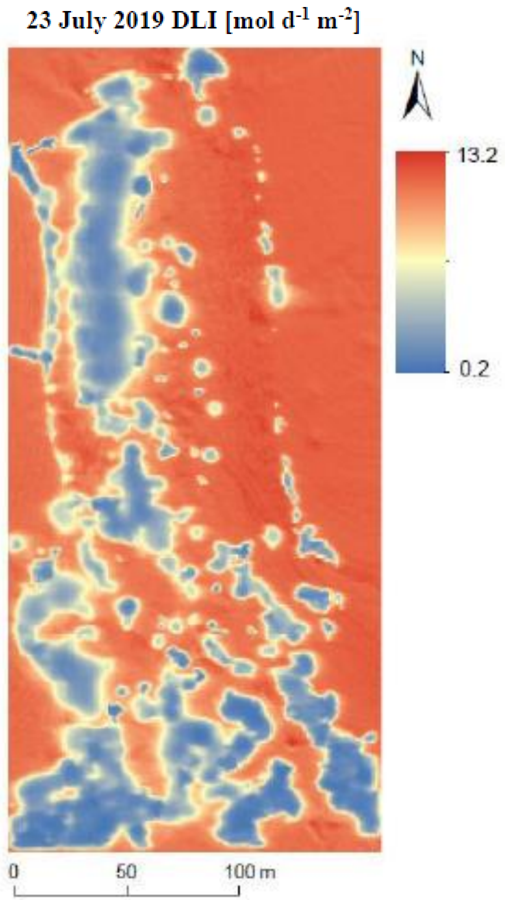
Parameterisation and outputs for the DART model



Daily light integral (DLI) map for 23rd July 2019 derived from DART outputs



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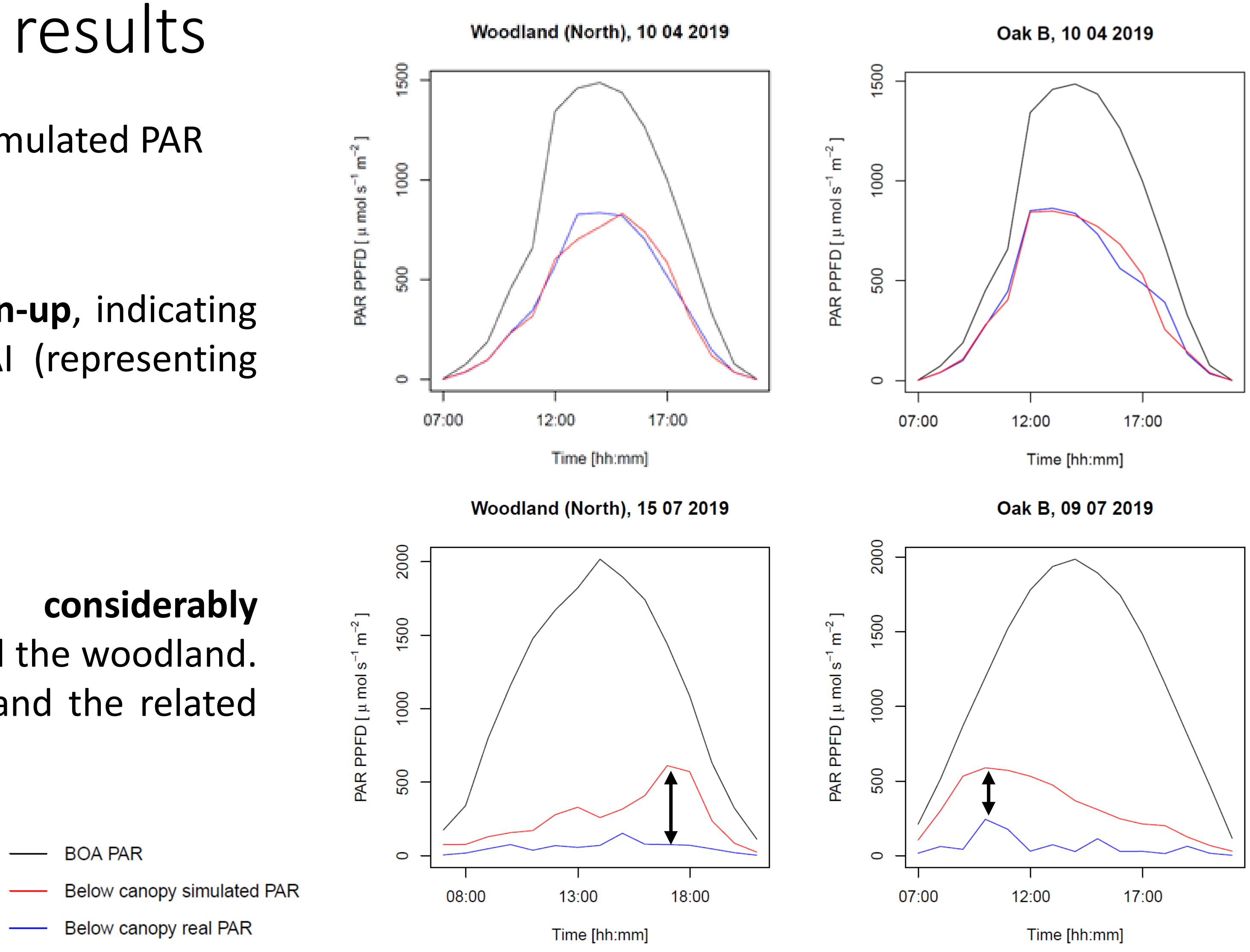
Assessing PAR simulation results

Preliminary results of daily progression of simulated PAR versus measured PAR in 1 hour time-steps.

Understory PAR is modelled well pre green-up, indicating adequate parameterisation of baseline PAI (representing wood area index).

Post green-up understory PAR is considerably overestimated for most measured trees and the woodland. This is likely an effect of NDVI saturation and the related uncertainty in deriving PAI.



Summary & Outlook

- Finely resolved drone structural and spectral data offer **new opportunities for parameterising** 3D radiative transfer models and can be used to **generate spatial maps of understory PAR** in discontinuous ecosystems which previously would have required very high point density airborne LiDAR data.
- The empirical approach to modelling PAI for the heterogeneous scene shows **limitations at high PAI values due to NDVI saturation** and leads to **overestimation of understory PAR**. Capability to model spatial variations within the woodland have yet to be assessed.
- DART simulations are **computationally intensive** (approx. 6 minutes). Comparisons with simpler, more efficient models for understory PAR modelling should be made to assess its added value (Ligot et al., 2014; Stadt et al., 2005). Developing a DART based **look-up-table approach** will be a focus towards operational implementation.
- Emerging technologies such as drone-borne LiDAR show promise for **better resolving vertical foliage distribution** at the required scales than empirical and indirect approaches (Zeng et al., 2019), however these systems remain costly with intensive processing required (Mlambo et al., 2017) and are thus **less suited to frequent acquisition for multi-temporal studies**.

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