UAV remote sensing for evapotranspiration extrapolation

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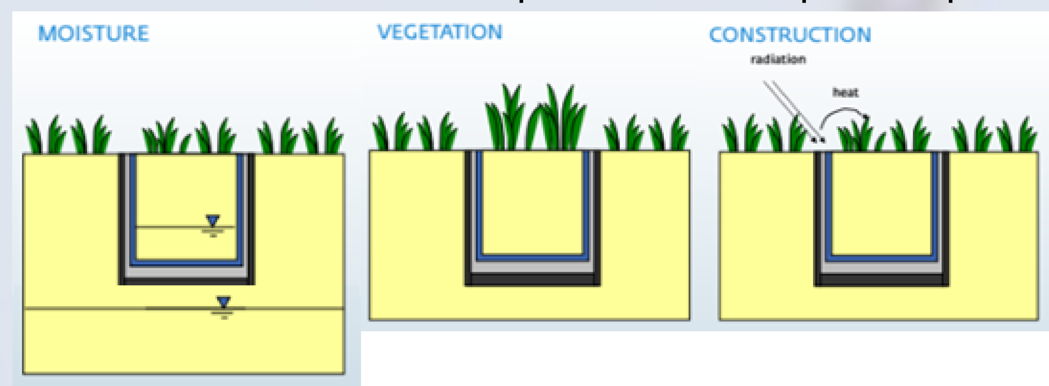
Introduction

Evapotranspiration (ET) is a major component of the water balance as it accounts for up to 80% of the total precipitation globally. Accurate large scale ET estimates are therefore essential for sustainable water extraction for agriculture and drinking water. **KWR** is a research institute that focusses on the hydrological cycle and aims to derive accurate ET estimates for drinking water companies. Lysimeters give the most accurate ET estimate by weighing the amount of water in a fixed volume of soil with vegetation on top. Installing many lysimeters in an area is economically and practically not feasible, therefore **extrapolation** of lysimeter measurements is necessary. The lysimeter is assumed to be representative for the surroundings in terms of **vegetation** and **soil moisture**. If this is not the case, it will cause errors in the extrapolation of evapotranspiration.



This study evaluates these possible errors for a KWR lysimeter station in National Park the Hoge Veluwe that consists of homogeneous heather vegetation. Unmanned Arial Vehicle (**UAV**) remote sensing was used to assess and map the study area on a high spatial resolution. The UAV contained RGB, thermal and hyperspectral sensors.

OBJECTIVES

- Evaluate vegetation related errors of the lysimeter
- Evaluate moisture related errors of the lysimeter

Vegetation related errors

Methods

To assess whether the vegetation on top of the lysimeter is representative for the surrounding area, the **vegetation height** and **LAI** is derived and compared. The vegetation height is derived as the differences between the Digital Surface Model (DSM) and Digital Elevation Model (DEM), which were made using stereo imagery on the RGB images. The LAI is derived from the NDVI using an empirical formula, where the NDVI was determined using the hyperspectral data. The lysimeter values are then compared with the values of the validation points to see if they are representative.

Results & Discussion

Vegetation height
Mean heather: 0.13m
Lysimeter height: 0.07m
Standard deviation: 0.05m

No significant difference (t-test, p=0.10, n= 67)

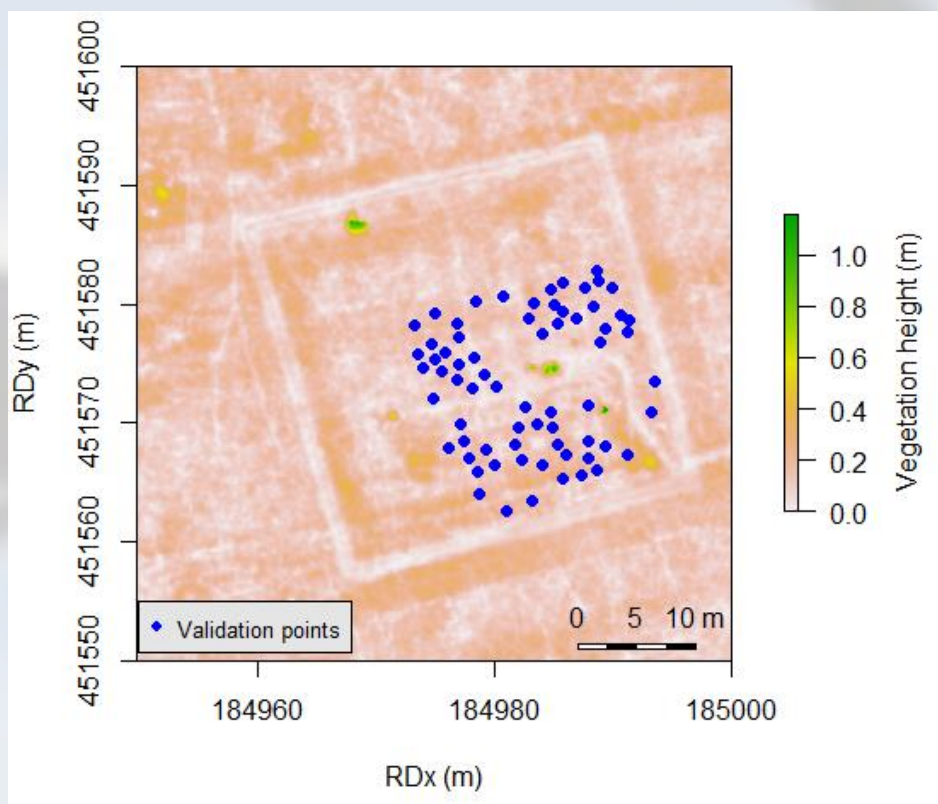


Figure 1. *Vegetation height map.*

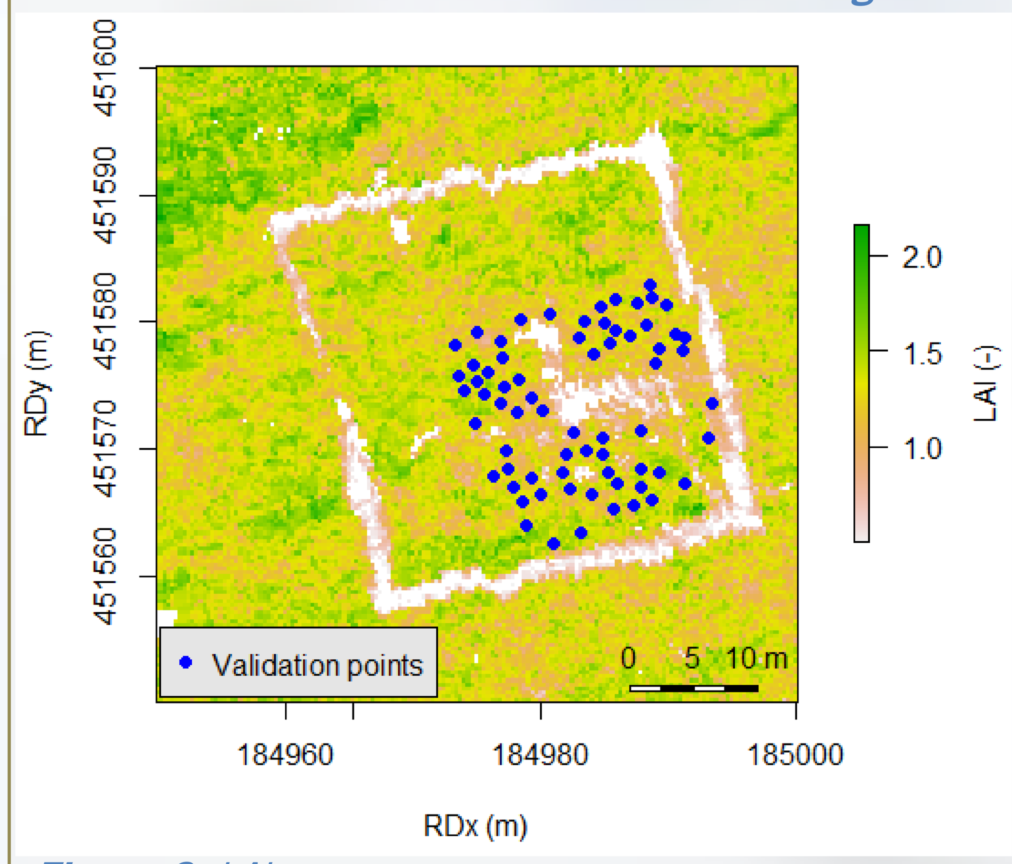


Figure 2. *LAI map.*

LAI
Mean heather LAI: 1.27
Lysimeter LAI: 1.09
Standard deviation: 0.16

No significant difference (t-test, p=0.13, n= 67)

- The vegetation height on top of the lysimeter appeared much higher than the given 0.07m from visual inspection and therefore more similar to the surroundings. Further research indicated that probably the DSM was biased.
- The found LAI values are well in line with literature.

Moisture related errors

Methods

To assess the representativity of the soil moisture in the lysimeter, a model will be used to estimate the evapotranspiration (ET) in the study area. As the amount of ET by a plant is related to the soil moisture, a difference in ET between the lysimeter and the surroundings would suggest that it is not representative. The three temperatures model (**3T model**) compares the energy balance of a reference surface (subscript r) with a surface under study (subscript i):

$$LE_i = R_{ni} - G_i - (R_{nr} - G_r - LE_r)\frac{T_{si}-T_a}{T_{sr}-T_a}$$

Where LE = latent heat flux; R_n = net radiation; G = Ground heat flux; T_s and T_a = surface and air temperature, respectively.

With the thermal images from the UAV, a map was produced to investigate the spatial heterogeneity, which was then corrected for albedo and emissivity differences between vegetation types.

Results & Discussion

Due to the experimental setup only three useable images were obtained from the thermal camera and not possible to stitch these images together. Therefore the analysis was conducted on the three images separately.

Figure 3 shows the outcome of the 3T model. The values found at the lysimeter are in line with the weather station measurements, but the surroundings appear to have a higher latent heat flux.

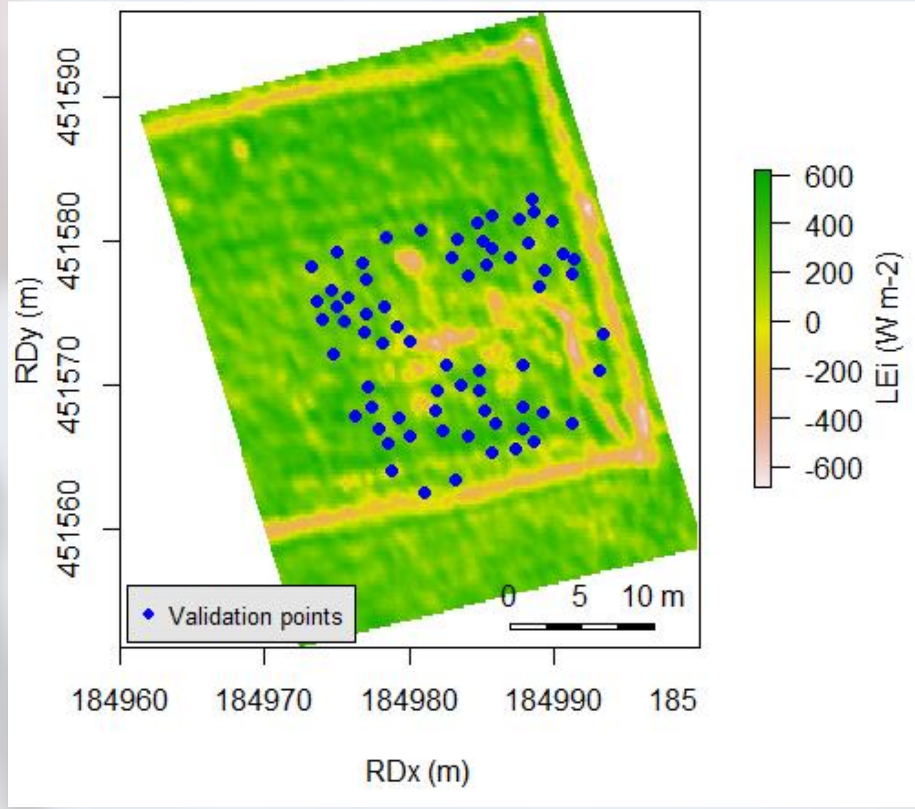


Figure 3. *Latent heat flux output from the 3T-model.*

Table 1. *Output of t-tests comparing lysimeter with validation points*

	Mean (W m-2)	SD (W m-2)	Lysimeter (W m-2)	P-value
Image 1	257.5	113.9	138.2	0.15
Image 2	268.5	77.9	150.5	0.06
Image 3	304.2	122.8	162.0	0.12

Table 1 shows that the LE values in the lysimeter are not significantly different from the surroundings for all three images. However, the lysimeter values are all at least one standard deviation different from the mean, which does raise suspicion. A possible explanation is that the lysimeter pixels can contain mixed signals from also the areas outside and the borders of the lysimeter.

Conclusions

- The vegetation on top of the lysimeter is representative for the surrounding heather vegetation.
- The soil moisture at the lysimeter is representative for the surrounding soil.
- UAV remote sensing is suitable for extrapolating to field scale estimates of LE.

Recommendations

Although the outcome of the research indicated that there is no significant difference between the lysimeter and the surroundings, p-values of the t-tests are that low that a follow-up study is advised. Collecting the data under more stable weather conditions is recommended so there is an equilibrium in the radiation balance. A higher spatial resolution is preferred to prevent mixing of the lysimeter pixels with the borders.

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