UAV-based vegetation mapping in a Namibian savanna: do remotely-sensed structural parameters contain indications of the prevailing disturbance regime?

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1. Motivation

Disturbances such as fire and grazing herbivores are one major feature that drive the coexistence of grass and woody species in savanna ecosystems (*Scholes & Archer (1997), Wagenseil & Samimi (2007)* - among many others). In Namibia's Northern Otjozondjupa Region, land use and tenure (commerical and communal rangelands, state-protected forest) cause diverse disturbance regimes, while other environmental factors affecting plant communities (e.g. rainfall) remain relatively homogeneous.

Unmanned Aerial Vehicles (UAV) equipped with consumer-grade cameras are nowadays regarded as serious remote-sensing systems. We hypothesize that such a system can reliably assess structural vegetation parameters (height and cover), which we investigate for their disturbance impacts.

2. Data

- Flight campaign:

19 flights with a Soleon Coanda x12 (cf. Fig.1) were carried out at the end of the dry season 2015. The UAV was equipped with two Nikon 1 V3 cameras (VIS and NIR) mounted on a two-axis gimbal-stabilized platform. The flights were preferentially undertaken around mid-day and flown in autonomous waypoint-mode with a 50 % sideward and forward overlap (two consecutive images via IR-triggering). A flight altitude of approximately 70m yielded a ground sampling distance < 2cm.

Fig. 1: *The Soleon Coanda x12 on duty (Image: C. Samimi).*

- Structural vegetation parameters:

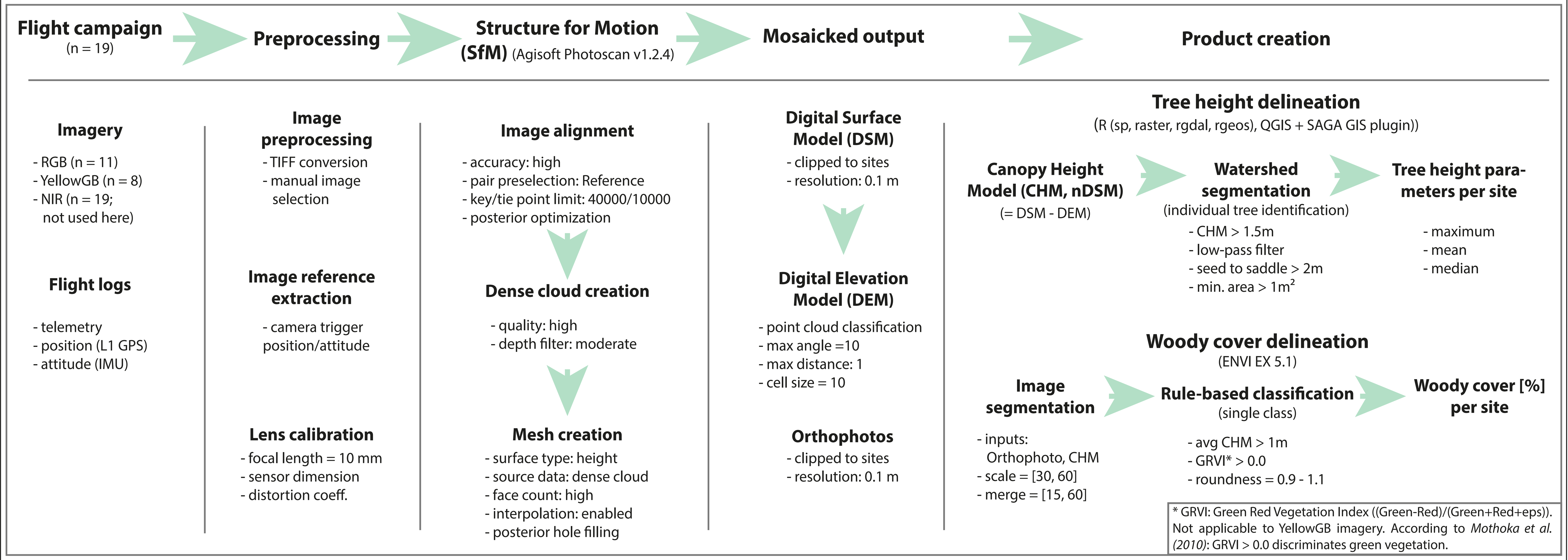
Tree and shrub heights (> 1.5m) were measured using a laser distance meter (Leica DISTO D510) along a regular point pattern (30m grid). Height measurements (n = 322) were conducted for all woody individuals covered by an upward-facing full-frame fisheye photograph (taken at 1m height). Furthermore, we estimated vegetation type, cover fractions and strata contribution for each of the 19 sites (size range: 0.65 - 1.85ha).

- Disturbance regime:

Based on expert interviews with landowners, residents and forestry staff, in-field recognition and NASA's FIRMS (Fire Information for Resource Management System) database, the prevailing fire and grazing regimes were assessed.

3. Methods

We used a Structure for Motion (SfM) approach to generate mosaicked orthophotos, DSMs as well as DEMs derived from point cloud classification. Direct georeferencing relied on the on-board single-frequency GPS and barometric sensor. Canopy Height Models (CHM), from DSMs and DEMs, were further processed using watershed segmentation to yield per-site tree heights. To assess woody covers, we applied a rule-based feature extraction approach.



4. Results

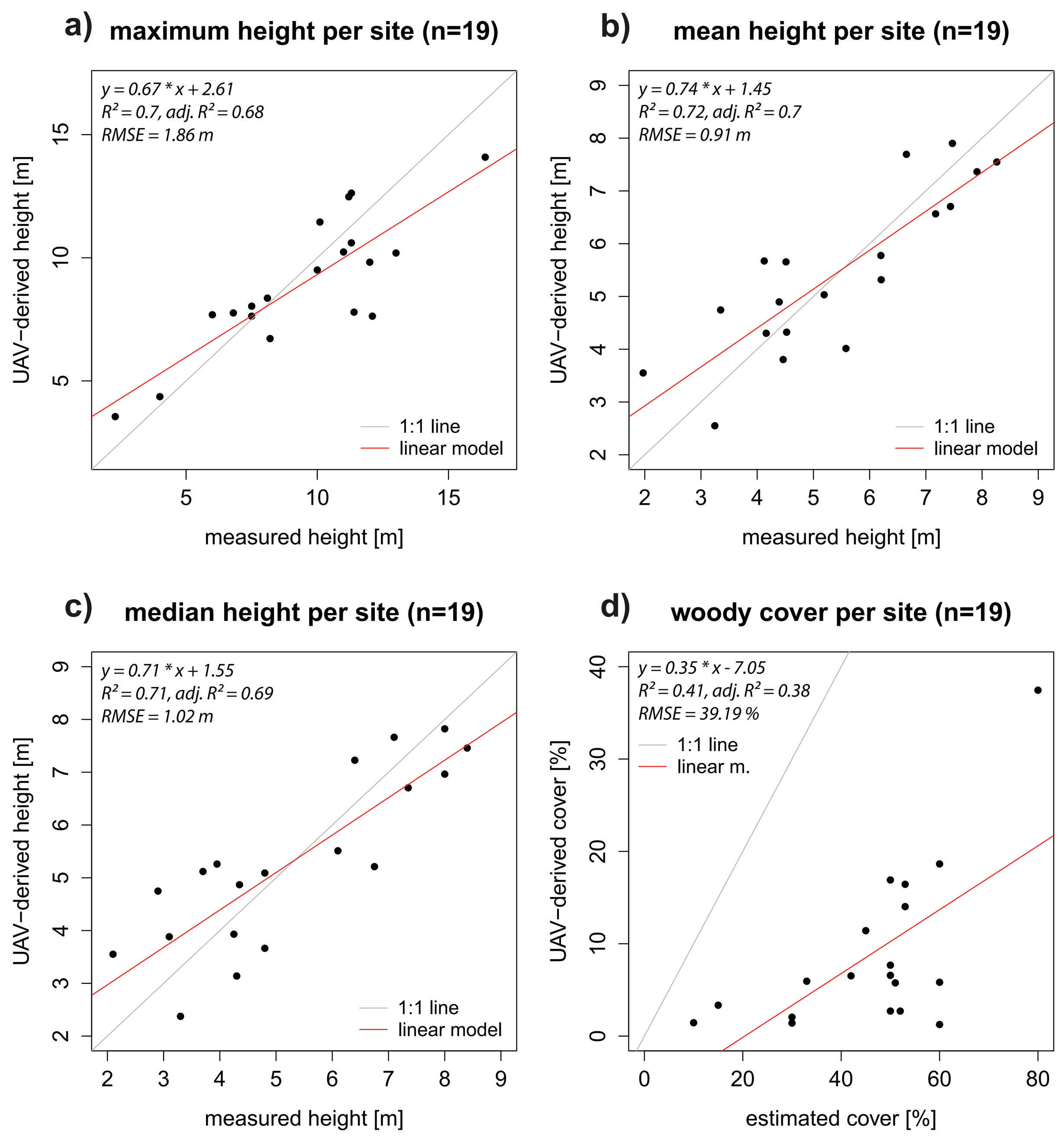
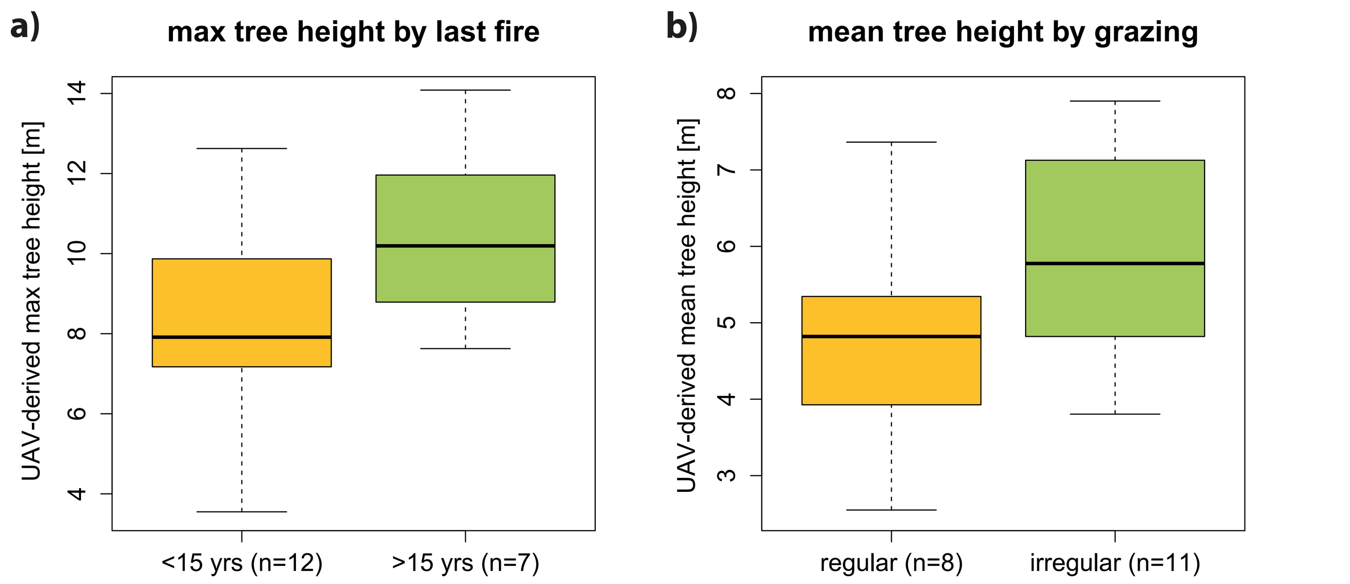


Fig. 2: *Linear models and Root-Mean-Square-Errors (RMSE) of UAV-derived vs. in situ parameters per site. Whereas height parameters (a-c)) show sophisticated agreement with in situ parameters, woody cover (d)) is strongly underestimated with the imagery used and the classification procedure applied.*

UAV-derived tree height parameters (cf. Fig. 3 a-c)) showed good agreement with *in situ* measured heights and could thus be used as a surrogate for those in assessing the influence of disturbances on per-site tree heights. In contrast to heights, woody covers (cf. Fig. 4 d)) were severly underestimated in the UAV-derived approach. Maximum tree heights were significantly lower on sites that were burned within the last 15 yrs and decreased as a function of an intensified disturbance regime (cf. Fig. 3 a+c)). Frequently grazed sites had sigificantly lower mean tree heights (cf. Fig. 4 b)).



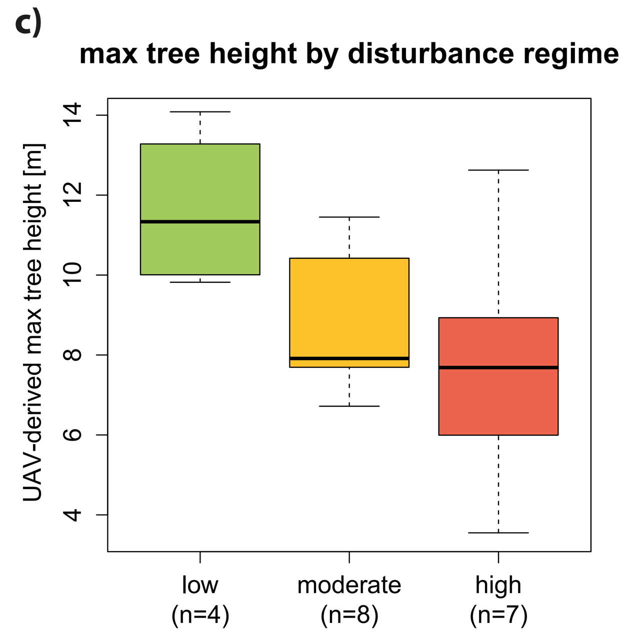


Fig. 3: *Boxplots illustrating the significant effects of disturbances on site-scale tree height parameters derived from UAV-imagery.* ***a)*** *Maximum tree height and last fire occurrence. Group differences (mean) were significant at the 0.1 level from a Welch Two Sample t-test.* ***b)*** *Mean tree height and grazing. Group differences were significant at the 0.1 level from a Welch Two Sample t-test.* ***c)*** *Maximum tree height and the combined disturbance regime. A group difference (mean) was significant at the 0.05 level from an one-way ANOVA. Disturbance classes correspond to ‚low' (no fires within 15 yrs AND irregular grazing), ‚moderate' (fire within 15 yrs AND/OR regular grazing) and ‚high' (several fires within 15 yrs AND regular grazing).*

5. Discussion

Despite the absence of high-accuracy reference data (Ground Control Points/dGPS, high-resolution survey-grade DEM), the approach applied here was able to produce data of sufficient geographic accuracy for the aims of this study. The derived site-scale tree heights were fairly consistent with *in situ* measurements. A comparison on individual tree scale was not possible here, but is hypothesized to yield lower accuracies. This is due to the point clouds relying on few matches at the end of the dry season (many species not yet or only partly with leaf-on canopies), which might partly explain the retrieved underestimation of tree heights. Hence, the accuracies can be expected to increase under fully leaf-on conditions. This also holds true for the derivation of woody covers, which definitely need further refinement.

Our study assumes an exclusive direct feedback of the disturbances fire and grazing on tree/shrub structural parameters. Clearly, a such is a simplification of the real world. Soils and nutrient availability, species differences, but also other factors of the disturbance regime (browsing, drought, frost, pests) determine site-scale structural tree parameters. These need to be better accounted for, where possible, in future studies.

6. Conclusions

Dry-season remote sensing of vegetation with optical sensors is generally a challenging task. However, the approach and results presented here are promising. We found a high agreement (R^2 ~ 0.7) but also slight underestimation (RMSE < 1.8m) for each of the site-scale UAV-derived tree height parameters with their *in situ* correspondents. The results for woody cover are not sufficient in their current state (strong underestimation; RMSE = 39.19 %; R^2 = 0.41). However, it needs to be mentioned that also reliable in-field estimations of woody cover during dry season are difficult.

Although all sites under investigation were considered quasi-homogeneous regarding their environmental framework (flat terrain, rainfall, sandy soils), small-scale variability of environmental factors cannot be neglected. Furthermore, species differences an further disturbance factors were not considered here. This clearly hampers the generality of our study and the results retrieved.

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