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Assessment of Rangeland Condition in a Dryland System Using UAV-Based Multispectral Imagery

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Assessment of rangeland condition in a dryland system using UAV-based multispectral imagery

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Key words: arid savannah; degradation gradient; drone; ground-truthing; supervised classification

Abstract

Dry savannahs are water-limited and under increasing anthropogenic pressure. Thus, considering climate change and the unprecedented pace and scale of rangeland deterioration, we need methods for assessing the status of such rangelands that are easy to apply, yield reliable and repeatable results that can be applied over large spatial scales. Global and local scale monitoring of rangelands through satellite data and labour-intensive field measurements respectively, are limited in accurately assessing the spatiotemporal heterogeneity of vegetation dynamics to provide crucial information that detects degradation in its early stages. Fortunately, newly emerging techniques such as unmanned aerial vehicles (UAVs), associated miniaturized sensors and improving digital photogrammetric software allow us to transcend these limitations. Yet, they have not been extensively calibrated with rangeland functional attributes. In our study, we fill this gap by testing the relationship between UAV-acquired multispectral imagery and field data collected in discrete sample plots in a Namibian dryland savannah along a degradation gradient. The first results are based on a supervised classifier performed on the very high resolution multispectral imagery to distinguish between rangeland functional attributes, with a relatively good match to the field observations. Integrating UAV-based observations to improve rangeland monitoring could greatly assist in climate-adapted rangeland management.

Introduction

Land degradation in drylands remains one of the most serious environmental problems to these systems (Mansour et al. 2012), especially because productivity is already constrained by limited moisture availability (Millennium Ecosystem Assessment 2005; Middleton 2018). Despite their low productivity, their structurally and functionally diverse ecosystems serve as habitats for wildlife, are suitable for livestock rearing, play a dominant role in carbon sequestration, and support over two billion people (Millennium Ecosystem Assessment 2005; Smith et al. 2019). With such a high dependence it is no surprise that close to 30 % of drylands are estimated to be severely degraded (Millennium Ecosystem Assessment 2005). Thus, considering climate change and the unprecedented pace and scale of land degradation, it is crucial that methods assessing the status of such rangelands are rapid, easy to apply, yield reliable and repeatable results and can be applied over multiple spatial and temporal scales. The monitoring of rangelands at global and local scales through satellite-based information and field observations respectively, are limited in providing crucial information to detect degradation in its early stages. For example, while satellite-based remote sensing provide large scale automated and repeatable data products, imagery can be costly, their quality is affected by climatic conditions such as cloud cover and their resolution can be inadequate for detecting subtle changes especially in heterogeneous landscapes such as savannahs. On the other hand, although field-based observations provide fine-scale information, they are labour-intensive, intrusive, require field specialists and interpolations are based on a limited set of samples with inter-sample information lacking. Fortunately, extensive progress has been made over the last two decades to integrate multiscale information that accurately map and monitor indicators of vegetation condition to provide answers to ecological questions (Lawley et al. 2016; Karl et al. 2017; Díaz-Delgado et al. 2019; Gillan et al. 2020). Unmanned aerial vehicles (UAVs), better known as drones, with associated sensors are receiving increasing attention from the ecological research community for monitoring vegetation and other ecosystem components (Assmann et al. 2019; Gillan et al. 2019; Alvarez-Vanhard et al. 2020). Yet, the relevant data processing and analysis methods are still largely ad-hoc and their application still requires standardization and extensive calibration (Gallacher 2019). These methods need to encompass the complexities of the systems in which they are used, especially if they are to be integrated for long-term monitoring. Our study uses field observations to evaluate the applicability of UAV-based multispectral imagery in assessing rangeland status in a dry savannah along a degradation gradient in Namibia.

Methods and Study Site

To assess rangeland condition, the research was conducted in a semi-arid savannah found in central Namibia a typical representative of dryland systems. A MicaSense RedEdge MX sensor (www.micasense.com) mounted on a DJI Phantom 3 Advanced (www.dji.com) drone was used to acquire imagery along a 1500 m degradation gradient with increasing distance away from a water point. The multispectral sensor captures images in 5 spectral bands (Blue – 475@20nm, Green – 560@20nm, Red – 668@10nm, Red edge – 717@10nm and Near infrared – 840@40nm), with radiometric calibration achieved through the use of a reflectance calibration panel and irradiance sensor (www.micasense.com). The imagery was acquired in January and March 2020 (early and mid-growing season respectively) using the Pix4DCapture (www.pix4d.com) flight planning application. Flight height was 80 m above ground level, resulting in a 5.8 cm/ pixel resolution. This very high spatial resolution imagery was pre-processed in Pix4DMapper Pro (Pix4D, Switzerland, V3.3) to generate mosaicked, orthorectified reflectance images. Using the maximum likelihood classifier in ENVI, visual training data (Figure 1) were used to classify the images into rangeland functional attributes (RFAs) (bare, non-woody plants, and woody plants). To validate the drone-based estimates, field assessments using an adapted version of the line-point intercept method (Herrick et al. 2017) to estimate the RFAs cover by only recording the topmost canopy layer (bird's eye perspective) were done in 9 x 100 m^2 plots along the degradation gradient. The proportional cover of the three main rangeland functional attributes (RFAs) were estimated from the high resolution imagery and compared with field-based estimates in the early growing season (January) and mid-growing season (March) along a degradation gradient.

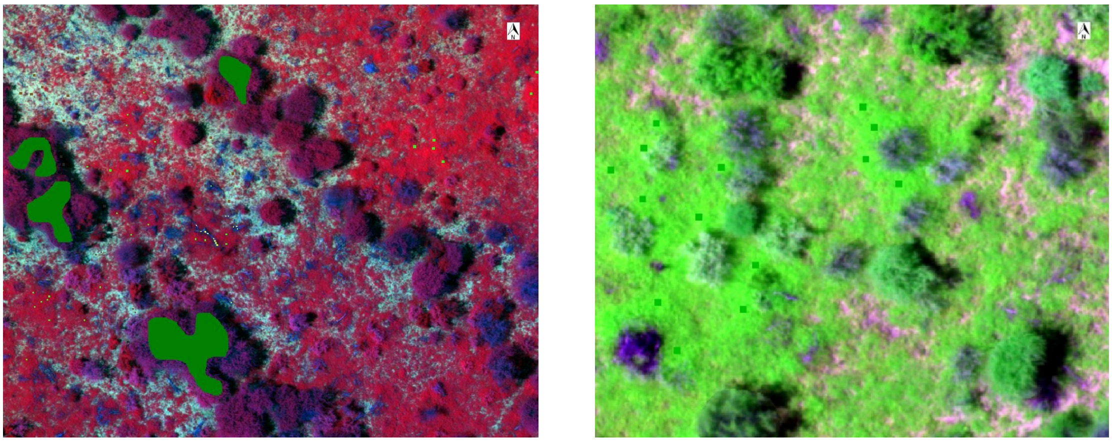

Figure 1. Visual training data collection in ENVI using the region of interest tool and different band combinations to highlight different rangeland features (left composite: NIR-G-B for woody plants; right composite: G-NIR-B for non-woody plants)

Results

The general trend of the RFAs cover along the degradation gradient is similar between the UAV-estimates and the *in situ* estimates, with the largest difference found during the mid-growing season for bare ground and non-woody cover estimations, while the least difference (except for January at 0 m) was found for the woody RFA across the gradient and throughout the season (Figure 2). Both methods indicate that bare ground was higher in the early growing season, especially at the beginning of the gradient where the highest livestock impacts occur and the non-woody (herbaceous) cover increased along the gradient and as the season progressed. Although the UAV-estimates captured bare ground in all the plots in the mid-growing season, the *in situ* observations did not record any in the plots at 390 m and 1500 m along the degradation gradient (Figure 2).

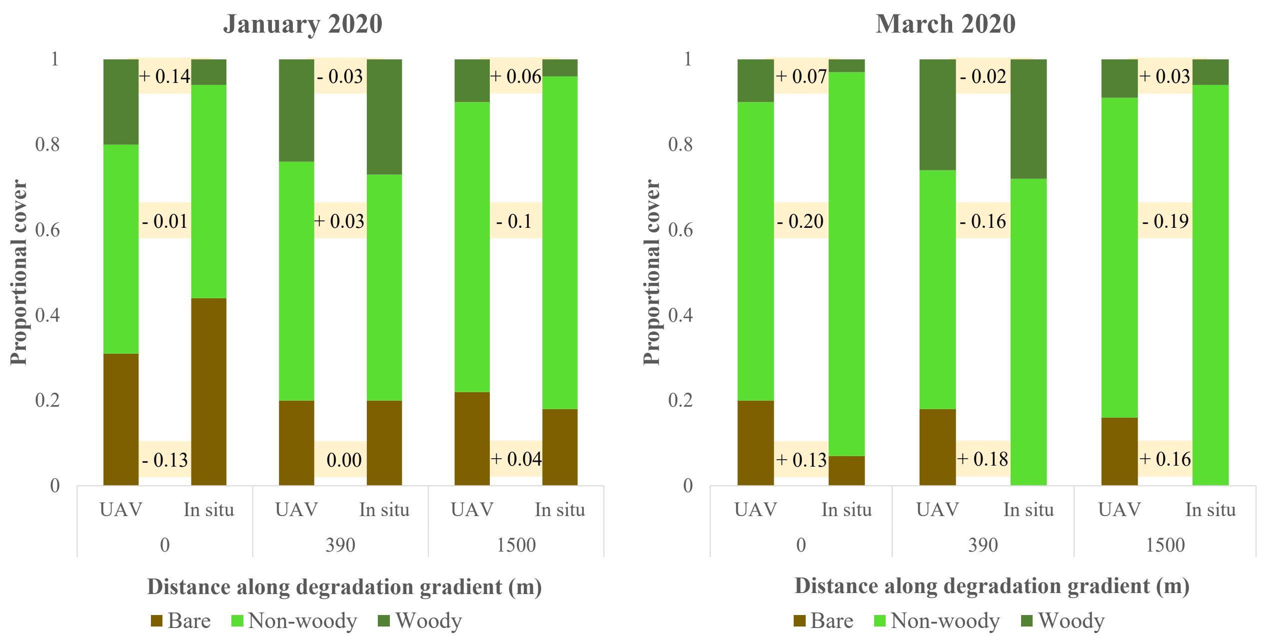

Figure 2. UAV and in situ estimated proportional cover of rangeland functional attributes (RFAs) for early and mid-growing season along a degradation gradient with distance away from a water point. The values in the yellow boxes indicate the difference of the UAV estimated proportional cover from the *in situ* observations.

Discussion [Conclusions/Implications]

There is a relatively good match between the UAV estimated RFAs and the field-based observations, highlighting the applicability of this technology to assess the condition of rangelands. For example, in January at 390 m away from the water point, both methods closely estimated the cover of the three RFAs, while woody cover was most closely estimated by the two methods along the gradient and across the season. As expected, higher bare ground was found closest to the water point, which declined with decreasing livestock impacts along the gradient and as the season progressed (Figure 2). During the mid-growing season, the field estimates did not record bare ground for the plots further away from the water point, largely because *in situ* observations are bound to sampling points, from which extrapolations are made, a limitation that may mislead the management of rangelands. This underlines the need to calibrate and integrate the rapidly advancing UAV technology, which offers a complete overview of the area of interest with greater flexibility, efficacy and sufficient accuracy for rangeland monitoring (Laliberte et al. 2010), as evident in Figure 2. The first results from this research showcase how UAVs may be a better option for rapidly assessing heterogeneous systems to address a range of ecological phenomenon (Rango et al. 2009; Barnas et al. 2019) such as climate change impacts and land degradation.

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References

Alvarez-Vanhard, E., Houet, T., Mony, C., Lecoq, L., & Corpetti, T. (2020). Can UAVs fill the gap between in situ surveys and satellites for habitat mapping? Remote Sensing of Environment, 243, 111780.

Assmann J. J., Kerby J.T. and Myers-Smith I.H. (2019) Vegetation monitoring using multispectral sensors — best practices and lessons learned from high latitudes. *Journal of Unmanned Vehicle Systems.* 7(1): 54–75. doi: 10.1139/juvs-2018-0018.

Barnas A.F., Darby B.J., Vandeberg G.S., Rockwell R.F. and Ellis-Felege S.N. (2019) A comparison of drone imagery and ground-based methods for estimating the extent of habitat destruction by lesser snow geese. *PLoS ONE* 14(8): 1 – 19.

Díaz-Delgado R., Onodi G., Kröel-Dulay G. and Kertesz M. (2019) Enhancement of Ecological Field Experimental Research by Means of UAV Multispectral Sensing. *Drones*. 3(1): 1 – 15. doi: 10.3390/drones3010007.

DJI: Phantom 3 Advanced. Available at https://www.dji.com (Accessed: 15 March 2020).

Gallacher D. (2019) Drone-based vegetation assessment in arid ecosystems. *Springer Nature.* Available at: https://doi.org/10.1007/978-3-030-04417-6_7 (Accessed: 24 October 2020).

Gillan J.K., McClaran M., Swetnam T.L. and Heilman P. (2019) Estimating forage utilization with drone-based photogrammetric point clouds. *Rangeland Ecology and Management*. 72(4): 575–585. doi: 10.1016/j.rama.2019.02.009.

Gillan J. K., Karl J. W. and van Leeuwen, W. J. D. (2020) Integrating drone imagery with existing rangeland monitoring programs. *Environmental Monitoring and Assessment.* 192(5). doi: 10.1007/s10661-020-8216-3.

Herrick J.E., Van Zee J.W., McCord S.E., Courtright E.M., Karl J.W. and Burkett L.M. (2017) Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. Volume II. Available at: www.uapress.arizona.edu (Accessed: 18 June 2020).

Laliberte A.S., Herrick J.E., Rango A. and Winters C. (2010) Acquisition, orthorectification, and object-based classification of unmanned aerial vehicle (UAV) imagery for rangeland monitoring. *Photogrammetric Engineering and Remote Sensing.* 76(6): 661–672. doi: 10.14358/PERS.76.6.661.

Lawley V., Lewis M., Clarke K. and Ostendorf B. (2016) Site-based and remote sensing methods for monitoring indicators of vegetation condition: An Australian review. *Ecological Indicators*. 60: 1273–1283. doi: 10.1016/j.ecolind.2015.03.021.

Manssour K., Mutanga O. and Everson T. (2012) Remote sensing based indicators of vegetation species for assessing rangeland degradation: Opportunities and challenges. 7(22): 3261–3270. doi: 10.5897/AJAR11.2316.

MicaSense: RedEdge MX – The sensor that doesn't compromise. Available at: https://micasense.com (Accessed: 14 November 2019).

Middleton N. (2018) Rangeland management and climate hazards in drylands: dust storms, desertification and the overgrazing debate. *Natural Hazards*. 92: 57 – 70.

Millennium Ecosystem Assessment (2005) Ecosystems and human well-being. *Island Press*, Washington, DC. Available at: www.islandpress.org (Accessed: 2 November 2020).

Pix4D: A unique photogrammetry software suite for drone mapping. Available at: https://www.pix4d.com (Accessed: 15 November 2020).

Rango A., Laliberte A. and Herrick J. E. (2009) Unmanned aerial vehicle-based remote sensing for rangeland assessment, monitoring, and management. 3: 1–15. doi: 10.1117/1.3216822.

Smith W.K., Dannenberg M.P., Yan D., Herrmann S., Barnes M.L., Barron-Gafford G.A., … Yang J. (2019) Remote Sensing of Environment Remote sensing of dryland ecosystem structure and function: Progress, challenges, and opportunities. *Remote Sensing of Environment*. 233: 1 – 23. doi: 10.1016/j.rse.2019.111401.