Drone and Digital Camera Imagery Estimate C3 and C4 Grass Ratios in Pastures

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Abstract
The following study investigates the accuracy and practicality of exploiting the color dichotomy present between C3 and C4 grass species to estimate their respective proportions from drone or camera captured imagery. Understanding the proportions of C3 and C4 grasses in pastures is vital to sound decision making for livestock production. The ability to monitor these proportions remotely will also allow for large scale monitoring as well as detection of changes in botanical composition over time and in response to weather events, management, or climate change. A free green canopy cover (GCC) analyzing software, Canopeo, was used to quantify green plants in captured images, providing an estimation of C3 grasses that retain green color in colder seasons while C4 grasses do not. The GCC estimates from Canopeo were compared to what was measured using occupancy grids. We found that green canopy cover software could estimate the proportion of C3 grasses in images captured by a drone and a Nikon camera.

Introduction
Climate change projections for Kentucky have predicted more severe droughts, increased rainfall, and increased frequency of flooding (United States Environmental Protection Agency, 2016). Models for years 2030 and 2080 have also predicted consistent warming significant enough to cause changes in land cover (Dale et al., 2009). These findings from climate change experts may be connected to anecdotal evidence from Kentucky farmers who have noticed increased amounts of C4 grasses encroaching into their cool-season pastures.

Kentucky farmers generally rely on C3 forages such as tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort., nom. cons.), orchardgrass (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.), and Kentucky bluegrass (*Poa pratensis* L.) (Lacefield, 2014). Some C4 grasses are used in Kentucky forage systems however they cannot be the sole source of forage due to their short period of productivity that is limited to the warmest parts of the year, June-August (Ball et al., 2007).

Land managers tend to visually notice the presence of C4 grasses in their C3 pastures, however there is not currently a fast, accurate technique available for quantifying various species of grasses within pastures. Monitoring change in grasslands in response to environmental or management factors is commonly done via repeated sampling (Whalley and Hardy, 2000). Pasture and grassland characteristics have been successfully analyzed in the past using various types of remote sensing. Unmanned Aerial Vehicle (UAV)-captured normalized difference vegetation index (NDVI) data have been used to estimate sustainable stocking rates in large scale areas but required combination with field-collected biomass and botanical composition data (Primia et al., 2016), thus not eliminating the need for hands-on sampling

In the present study we are focusing on red, green, and blue (RGB) imagery for detecting and monitoring changes in pasture composition. Variances in productivity periods between C4 and C3 grasses are visible due to green color loss during dormancy. C3 grasses however retain much of their green color in these parts of the year. These color differences are even visible in photographs which may allow us to use Green Canopy Cover (GCC) software to quantify the C3 species by using their retained green color. These images can then be paired with free, user-friendly GCC software.

The objective of this study was to evaluate the accuracy of drone and digital camera imagery compared to occupancy grid sampling to quantify percentages of C3 and C4 grasses in pastures. We will also compare the accuracy of these methods in the fall versus the spring.

Methods
This study was conducted on seven farms across western Kentucky and one farm in northwestern Tennessee. Farms were in Caldwell (3), Trigg (1), Fulton (1), Marshall (1), and Daviess (1) counties in Kentucky and

Weakley County (1) in Tennessee. Two fields per farm were sampled. Median field size was 10 ac with a range of 3-15 acres.

Digital images were captured using a Nikon ® D750 Digital Single-Lens Reflex (DSLR) camera with an AF-S NIKKOR 20mm f/1.8G ED Wide-Angle Lens and a ProMaster ® 77 mm UV Haze Ultraviolet Filter (4857). A DocaDone DocaPole, 6 – 24 Foot Extension Pole with a ClickSnap Camera Swivel Adapter, was used to suspend the camera perpendicular to the ground approximately 3 m (10 ft) high. Photos were captured remotely using the Nikon ® Wireless Mobile Utility application for iOS. Thirty images per field were captured and samplings were done in the fall of 2020 and spring of 2021. Images were captured every twenty steps while walking in a random zig-zag pattern.

Aerial images were captured using a DJI Phantom 4 Pro V2.0 quadcopter with a 1-inch CMOS sensor (20MP). FieldAgent ® by Sentera (Saint Paul, Minnesota) was used for flight planning and execution. Images were uploaded to ©DroneDeploy (San Francisco, California) for orthomosaic stitching. Drone flights were done 50-100' altitude, 6-8mph, and 40% overlap to maximize resolution and optimize battery life. Drone flights were executed over each field in the fall of 2020 and the spring of 2021. The goal was to capture drone imagery in multiple seasons for comparison.

Occupancy grids were used to capture ground measurements for percentages of warm season grass, cool season grass, legumes, soil, or weeds. A grid was constructed from a steel fence panel with 6 x 6" squares by cutting a 5 x 5 square piece and spray painting it orange for visibility in tall grass. The grid was thrown every twenty steps and the dominant species was recorded within each square. Species were identified by trained observers. Abbreviations were used to record the dominant species within each square across the grid and then percentages were later calculated by entering the species data into Microsoft Excel.

The ©Canopeo application within MATLAB by MathWorks® was used for Green Canopy Cover (GCC) Analysis. Settings used were as follows: Red/Green = 1.1; Blue/Green = 0.9; Noise reduction = 1. Batches of photos were run by date with results exported to Microsoft Excel. Noise reduction of 1 was chosen due to the high resolution necessary for detecting individual bunches of grass. A higher noise resolution would exclude "small clusters of undesired green pixels, such as weeds" which is not ideal in this scenario (OSU Plant and Soil Sciences Department).

Results of Nikon photos were averaged within each plot using Microsoft Excel. Drone images had already been combined by orthomosaic stitching so did not require this step. Occupancy grid samples were grouped into representative categories: warm season, cool season, and soil. The cool season species percentage from the occupancy grids was subtracted from the green canopy cover value from the same field's imagery to produce a residual value (i.e., the difference in green species measured by occupancy grids and digital imagery). The absolute value was taken of these residuals to obtain a net difference value. GCC and occupancy grid data were imported into RStudio for further analysis.

A linear mixed effects model was used to investigate interactions within the dataset due to the nested nature of the field within farm variable. An ANOVA was then performed within each season to determine differences between methods.

Results and Discussion

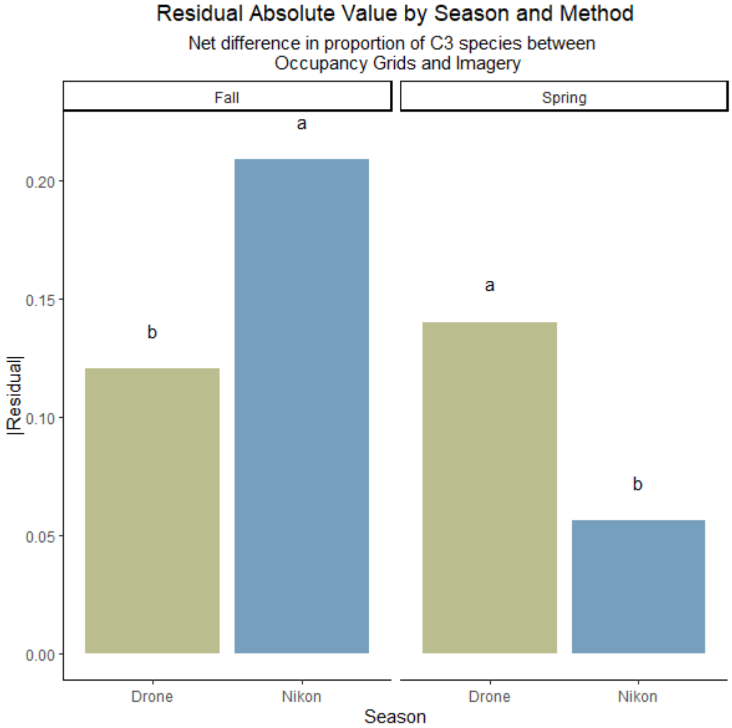

Figure 1. Net difference in proportion of C3 species between occupancy grids and Canopeo-analyzed imagery. Bars with same letter within same season are not different according to ANOVA test.

An interaction was found between sampling season and sampling method for residual absolute values (AV), so data were analyzed by season (Figure 1). Because of the existing interaction, we cannot make comparisons across seasons. If a field is to be sampled in the fall, this study would suggest that more accurate results would be obtained if a drone were used to measure GCC. The opposite is true should a field be sampled in the spring; a Nikon camera would provide more accurate GCC results.

The overarching goal of this study was to compare three methods for measuring cool season grasses in pastures. Because of the interaction between method and season in our study, we were not able compare the accuracy of each method across the sampling seasons, only within each season. While we cannot conclusively say from this study whether the drone or Nikon are similar enough to occupancy grids to replace them completely, we did see that we could reasonably estimate cool season grasses percentages in pastures. The drone and the Nikon also had different means within each season, but additional repetitions of each season would be required to determine the underlying cause of these differences.

There are several possibilities for what may have caused the differences between the proportion of C3 grasses measured by the Nikon and the drone. The first is coverage. The drone was able to take photos of the entire sampled area, which were then stitched into one composite photo. Theoretically, every area in the pasture was covered and analyzed. With the Nikon and the occupancy grid, only 30 random spots were sampled, making up a relatively small composite area that becomes representative of the pasture. This also makes it difficult to compare the three. We have no way of knowing from this study if the drone is truly more accurate because it has more complete coverage of the sampled area, or if the value of larger coverage is diminished by the reduction in sampling quality. Discussing sampling quality leads into the second possible cause for differences between the methods: resolution. Because the Nikon camera is closer to the ground (10’), the resolution is much higher than the drone that is 50-100’ away. This higher resolution may lead to more precise readings and thus quantification of C3 grasses, but this would need to be investigated further in the future by having accurate geotagging of Nikon photos to compare with drone photos of the exact same area.

Another potential cause of differences between methods was the areas sampled for the occupancy grids and Nikon camera. We chose different ground sampling areas for the occupancy grids and the Nikon camera, meaning it is likely that the areas sampled by the occupancy grid were never sampled by the Nikon. Conversely, every area sampled by the occupancy grids was sampled by the drone since it covered the entire field.

An important consideration in evaluating these methods is practicality. For any of these to be useful, they need to be affordable and doable within time and labor constraints.

Conclusions and/or Implications

Both the Nikon and the drone show promise in their abilities to quantify cool season grasses in pastures but require further research to refine their methodologies and to provide accurate results to farmers. If this strategy is to be used for long-term documentation of botanical shifts over large areas, a drone will be much more practical. This could also be scaled up to satellite imagery in the future should high-quality images with high spatial and temporal resolution become more affordable and accessible.

If these methods are to be used at the individual farm level, more research is required to determine what level of error is acceptable in these sampling methods. It will be important to know how the measurements to the actual biomass of various species with different nutritional value and yield, and how that may affect decision making within an operation and ultimately the performance of the animals or forage products coming from that land.

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