QUANTIFYING VOLE DAMAGE WITH AERIAL IMAGERY

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Introduction

The gray-tailed vole (*Microtus canicaudus*) can cause substantial yield losses in Willamette Valley grass seed crops (Verhoeven and Anderson, 2021). Historically, high vole population numbers occurred every 4–8 years, followed by population crashes (Gervais, 2007). Recently, populations have remained elevated, with reports of severely damaged fields every year since 2019. Beyond the Willamette Valley, other species of voles are known to damage many crops.

Few control options are available for vole control in grass seed fields. Chemical control is limited to zinc phosphide baits. Above-ground application of zinc phosphide baits is limited to the period between early May and September 15 to protect migratory geese. Between September 15 and when migrating geese have left the valley in the spring, bait applications may only be made below ground by placing bait in the entrances of vole burrows. In one survey, only 26% of growers reported that zinc phosphide baits provided satisfactory control (Verhoeven and Anderson, 2021). Tillage can reduce vole populations, but it is used only as a last resort because it requires removing an established crop, which is a significant financial loss. Birds of prey and other predators feed on voles, but owl boxes and raptor poles have not provided detectable reductions in vole damage.

There is a clear need for improved vole control options, but evaluating new control practices is difficult and costly. The most rigorous method of measuring vole populations is to tag and release individuals, but this method requires labor-intensive live trapping programs. Gervais (2010) studied whether indicators of vole activity such as burrows and fresh droppings could be used to estimate populations, but none of these signs of vole activity was a good predictor of vole populations. An alternative approach is to measure crop damage, but this method has not been evaluated.

Voles live in colonies with extensive networks of burrows and runways. During the vegetative growth period of grass seed crops, grazing damage is concentrated in the area immediately surrounding the colony. These patches of damage range from 1 to more than 10 feet across, and they are irregular in shape. The severity of damage can differ among patches within a field, among fields, and over the course of the growing season. Variability in the size, shape, and severity of damage patches can complicate damage assessments. Nearby patches of damage are easy to see when walking in a field, but it is difficult to see damage at a distance because it is blocked from view by taller, undamaged plants.

Aerial imagery collected with unmanned aerial systems (UAS or drones) has been increasingly used in agricultural settings to evaluate crop health and nutrient and water status (Hassler and Baysal-Gurel, 2019). A drone can capture data on every square inch of a field in a relatively short time, something that would not be feasible on foot. This study tested whether aerial imagery captured with a drone can be used to quantify vole damage in grass seed fields.

Materials and Methods

Field sites

This study was conducted in two established tall fescue fields with severe vole infestations: a turf-type field, variety 'Renegade DT', approaching its third harvest, and a forage type, variety 'Goliath', approaching its eighth harvest. The turf type had distinct crop rows, while rows were not visible in the forage-type field. Tall fescue fields can differ in appearance, depending on variety and stand age, and these two fields were selected to represent the range of visual characteristics that tall fescue fields might exhibit.

UAS

The aerial imaging system used in this study consisted of a DJI Matrice 210 v2 quadcopter drone outfitted with two cameras. A Micasense RedEdge MX camera captured five-band multispectral imagery (blue, green, red, red-edge, and near infrared), and a MicaSense downwelling light sensor (DLS2) recorded ambient light levels. A Sony a6000 camera captured high-resolution natural color (RGB; red, green, and blue) imagery. Both cameras were set up to capture one image per second.

Georeferencing

Accurate location information for all data collected ensured that data collected on the ground could be matched to the corresponding location in the aerial imagery. Global navigation satellite system receivers capable of real-time kinematic positioning (RTK GPS, the technology used for tractor positioning) were used to collect accurate location information. A base station (Emlid Reach RS+) was set up prior to data collection and was set to record satellite observations throughout data collection. A rover module (Emlid Reach M+) was installed on the drone to record its location when photos were taken, and a second module was installed on a survey pole and was used to record locations on the ground. Ground control points (markers that are visible in drone imagery) were placed in the field prior to each flight, and their locations were recorded with the ground rover. Log files from the GPS modules were processed using Emlid Studio software. The location of the base station was determined using data from the closest continuously operating reference station (CORS).

Data collection

Two UAS flights were conducted in each field. The turf-type field was flown on March 22 and April 27, 2022, and the forage-type field was flown on March 23 and April 22, 2022. The UAS was flown at 164 feet above ground level, resulting in a ground sample distance of 1.38 and 0.49 inches per pixel for the multispectral and RGB cameras, respectively. A multispectral photo was taken of a MicaSense calibrated reflectance panel (CRP) before and after each flight.

Ground-truth data were collected after each flight for 20 patches of vole damage and 20 undamaged areas distributed throughout the study area. Ground-truth points were identified as damaged if there were clear signs of vole activity such as droppings, runways, fresh signs of digging, or freshly clipped leaves and stems. Burrows alone were not considered sufficient evidence of vole damage because burrows can persist for several months without vole activity. Undamaged areas had vigorous crop growth with no evidence of vole activity. Observations, photographs, and RTK GPS location information were recorded for each ground-truth point. Evidence of other causes of poor crop growth was looked for but not observed.

Data analysis

Drone pictures were processed using Pix4D Mapper software, which stitched the images collected during each flight into large images covering the entire flight area. The locations of ground control points were entered during this processing step to ensure the images were accurately georeferenced. To correct for any differences in lighting conditions between flights, a radiometric calibration was performed, which converted raw multispectral image data to reflectance values. Reflectance is the fraction of ambient light (measured using the CRP photos and the DLS2) that was reflected by the surface in the photo and captured by the camera sensor. Data outputs also included digital surface models (DSM), which showed the elevation of the crop canopy, and a normalized differential vegetation index (NDVI) map.

ArcGIS Pro software was used for further analysis. Using elevation data from the DSM, relative canopy height was calculated as the difference in elevation between each pixel in DSM and the average elevation of the surrounding area (40.8-foot radius). Next, data were extracted from the aerial imagery at the locations of ground-truth points. At each ground-truth point, a circular area with a radius of 5.9 inches was defined, and summary statistics (average and standard deviation) were calculated for pixels in that area for the NDVI and relative canopy height images. ANOVA and Wilcoxon rank sum tests (when assumptions of normality were not met) were used to compare the NDVI and relative canopy height values of damaged versus undamaged ground-truth points.

Image classification was performed for each flight using a combination of all multispectral image bands, plus DSM and NDVI, via the image classification wizard in ArcGIS Pro. Training data for the classification model were created by manually marking areas of damaged plants, undamaged plants, and soil, based on appearance in the imagery. Prior to classification, the image was divided into objects, or groups of adjacent pixels with similar spectral characteristics (object-based classification). The model assigned objects to one of the three classification categories (soil, damaged plant, or undamaged plant). A previous attempt at image classification did not include a soil category and did not produce an accurate classification result.

The accuracy of the image classification model was evaluated by assessing whether the computer classification produced by the model was consistent with the human classification made for each ground-truth point. This was done by determining the percentage of the area within a radius of 5.9 inches of each ground-truth point that was assigned to each classification category.

Results and Discussion

Both fields had extensive vole damage that was distributed throughout the study area. Areas with vole damage were easily distinguishable from undamaged areas in imagery from all four flights. Small plants and large areas of visible soil characterized damaged areas, while undamaged areas had larger plants with little to no visible soil.

There was notable crop growth between the March and April flights in both fields. In the March imagery, the turf-type field had narrow strips of visible soil between the crop rows in undamaged areas, but no soil was visible in the April imagery. While the forage-type field had little visible soil in undamaged areas in the March imagery, vigorous crop growth was evident in the April imagery as many damaged areas decreased in size.

Figure 1 shows relative canopy height and NDVI standard deviation measured for both damaged and undamaged ground-truth points. Plants in damaged areas were significantly shorter ($P < 0.05$) than plants in undamaged areas, based on relative canopy height. Average NDVI values were lower ($P < 0.05$), and NDVI standard deviations were higher ($P < 0.05$), in damaged areas compared to undamaged areas, likely due to the presence of visible soil. Damaged points are clustered in the bottom or bottom right of the graphs,

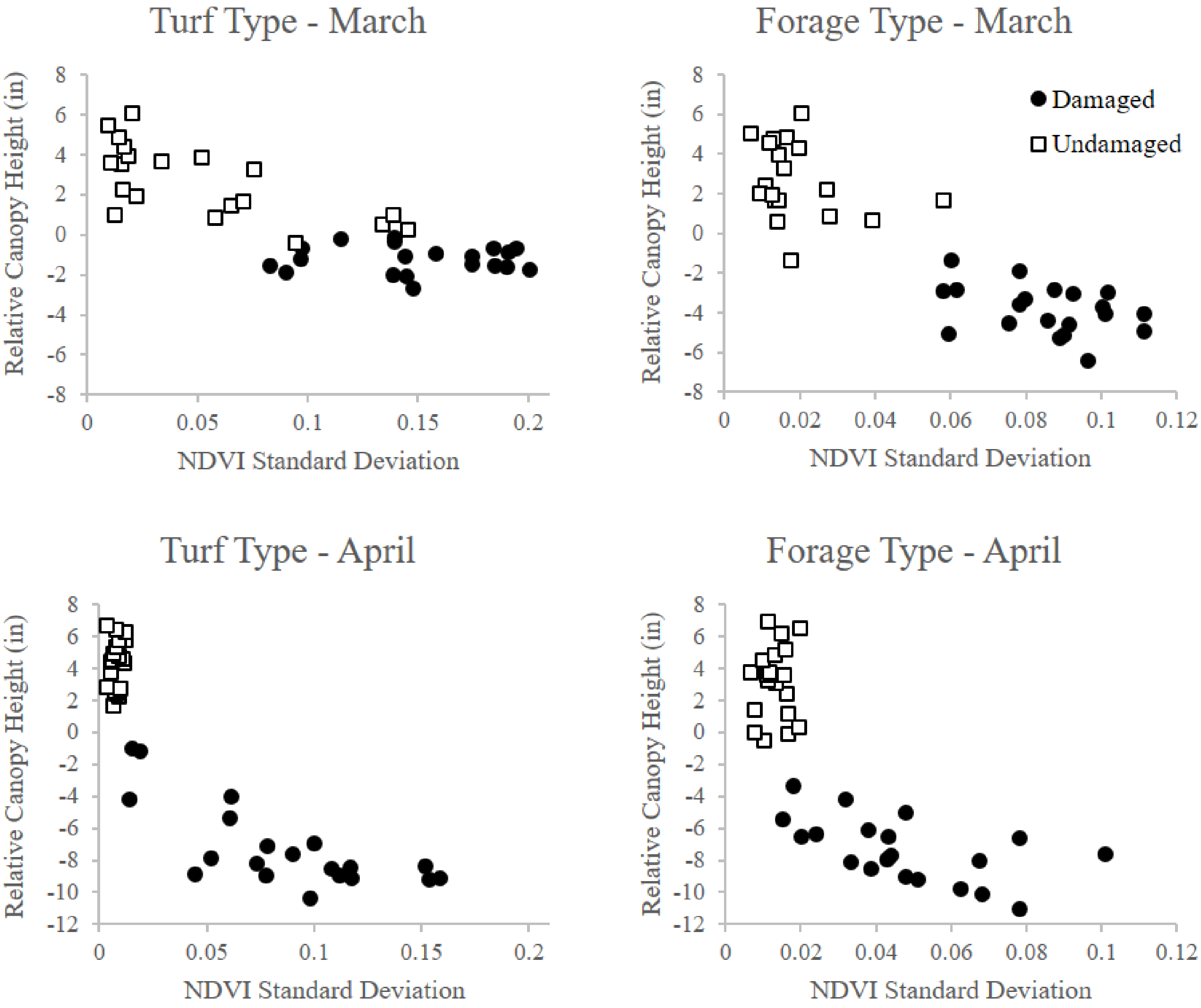

Figure 1. Aerial imagery values for locations that were observed from the ground. Relative canopy height is derived from the digital surface model and is shown on the y-axis. NDVI standard deviation is shown on the x-axis. Each point represents one ground-truth that was determined to be damaged (black circles) or undamaged (empty squares). Each panel shows data from one field and flight date.

and undamaged points are clustered in the top left. The clear separation between damaged and undamaged points suggests that vole damage can be detected using automated methods.

Image classification results are shown in Figure 2. Most of the area surrounding undamaged ground-truth points was classified as undamaged plants by the computer. The majority of the area surrounding damaged ground-truth points was classified as either damaged plants or soil.

The aim of this study was to differentiate between damaged and undamaged areas, so accuracy assessments focused on the damaged plant and undamaged plant classification categories. Soil was clearly visible in damaged areas in the aerial imagery, so areas surrounding a damaged ground-truth point that were classified as soil were considered to be correctly classified. Three undamaged ground-truth points had some area classified as soil, and a visual inspection of the aerial imagery showed that this classification was an accurate representation of that location. Therefore, an undamaged ground-truth point was considered correctly classified if the surrounding area was assigned to the undamaged plant or soil categories. A damaged ground-truth point was considered correctly classified if the surrounding area was assigned to the damaged plant or soil categories.

Out of 160 ground-truth points, the area surrounding 123 points was 100% correctly classified. Ten points showed major classification errors, meaning that more than 50% of the surrounding area was classified

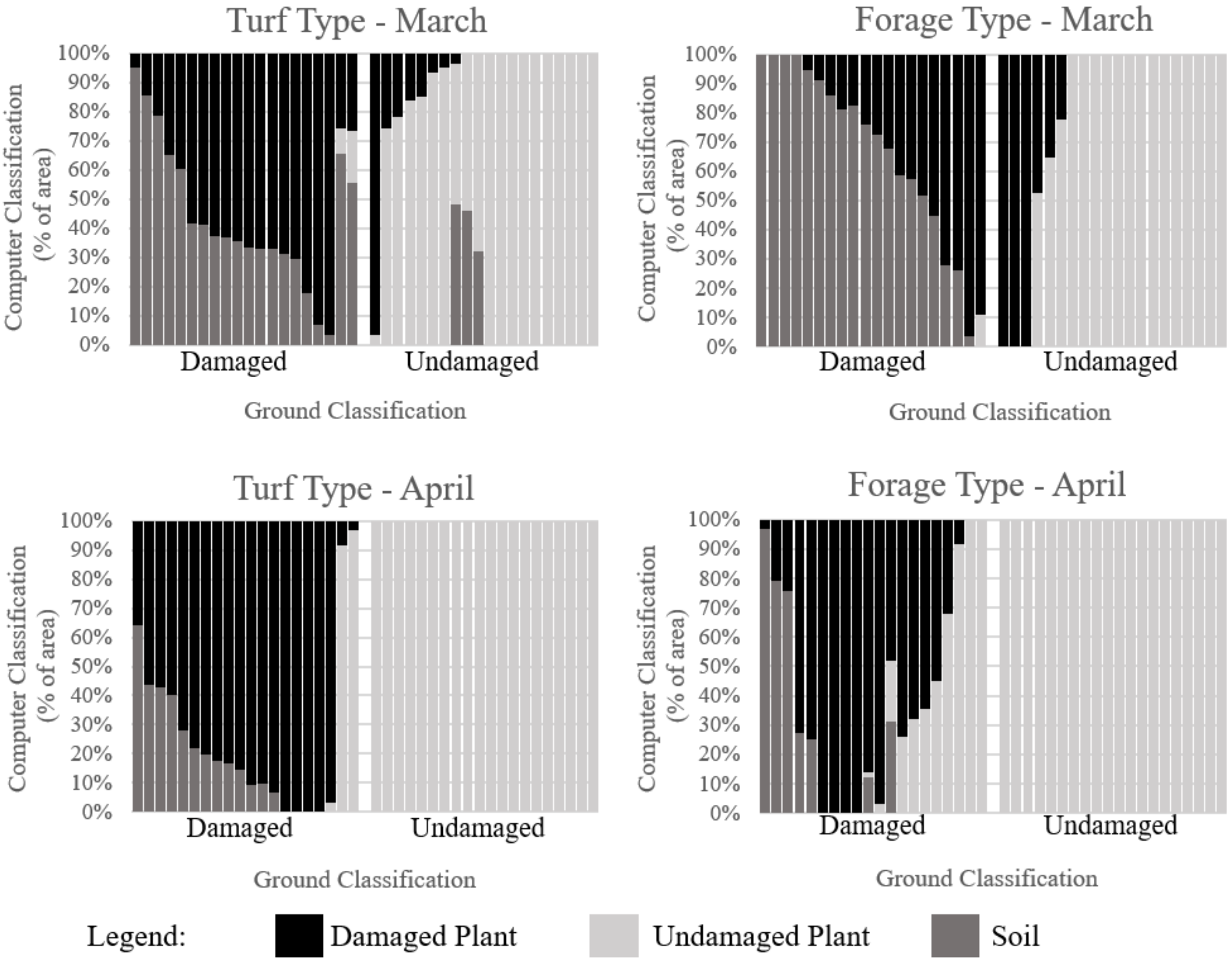

Figure 2. Classification results for the area surrounding each ground-truth point. Each bar represents the area immediately surrounding (within a radius of 5.9 inches) one ground-truth point. The shading of the bar shows what percentage of that area was assigned to each category by the image classification algorithm. Damaged points are grouped on the left side of each panel, and undamaged points are on the right. Each panel shows data from one field and flight date.

incorrectly. An additional 27 points had less than 50% of the surrounding area classified incorrectly.

The direction of classification errors differed between flights. In March, the most common error was undamaged ground-truth points classified as damaged plants. In April, undamaged ground-truth points were 100% correctly classified, while the area around damaged ground-truth points was sometimes classified as undamaged plants. Overall, more than 90% of the combined area surrounding ground-truth points was correctly classified (Table 1).

This study demonstrated that vole-damaged areas in tall fescue fields can be differentiated from undamaged areas by drone aerial imagery collected in March and April. This approach can be used to test vole control practices in the future and may also be adapted as a scouting tool prior to canopy closure.

References

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Table 1. Classification accuracy summary. Percentage of the area surrounding damaged and undamaged ground-truth points that was assigned to each classification category by the image classification algorithm.

Ground-truth classification	-------- Computer classification --------		
	Undamaged plant	Damaged plant	Soil
	-------------------- (%) --------------------		
Undamaged	91.0	7.5	1.6
Damaged	9.4	54.0	36.0