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Estimating Shrub Forage Yield and Utilization Using a Photographic Technique

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Abstract

We assessed a photographic technique to estimate shrub yield and utilization of common snowberry, snowbrush, and heart-leafed willow found in mixed-conifer rangelands. We determined the correlation between green leaf area size (LA) and forage yield (Y) and compared plant utilization estimated by photographic technique (ULA) to actual utilization (UY) values. Shrub forage yield and utilization were determined by hand plucking in five to eight increments. Before the first plucking, and after each subsequent plucking, we took two photos that were perpendicular to each other at the intersection of the shrub. Each photo was evaluated using image-processing software to produce red (R), green (G), and blue (B) color band images. Green leaf area was determined as follows: pixel = ([G-R] + [G-B])/ (G+R+G+B); Green leaf area, cm^2 = (Calibration [C], $cm^2 \cdot pixel^{-1}$) × (LA, pixel). Green leaf area calculated from the photographic technique was strongly correlated (r^2 = 0.83-0.94, P < 0.001) with forage yield for all three shrubs. A strong correlation (r^2 = 0.95, n = 142) was detected between utilization values estimated through green leaf area size and actual values. Utilization estimated by LA did not differ (P = 0.60, n = 142) from actual utilization values. In summary, our results indicate the photographic technique could be used once calibration curves are developed, to measure available browse yield and utilization of shrubs in a nondestructive approach.

Introduction

Shrubs comprise a significant amount of total forage resources in rangelands; however, estimating browse yield and use is one of the most difficult vegetation characteristics to determine (Bonham 1989). The twig length measurement method (Nelson 1930) is used to determine yield after completion of annual growth in particular shrubs. This technique gives good estimates of utilization but is only effective on shrubs that have a definitive growth period.

The extensive browse technique (BLM 1996) is designed to provide data on age and form classes, utilization, species composition, availability, and hedging of the browse component. This technique is more rapid than techniques requiring measurements but is less accurate because of subjective, visual estimates. Basile and Hutchings (1966) and Lyon (1968) concluded that using length-diameter relationships was a promising technique of estimating utilization from post browsing diameter measurements. However, twig diameter measurement required a definitive period of growth and was not effective on shrubs that had indeterminate or opportunistic growth (Reynolds 1999).

This study was designed to determine the potential of a photographic technique in assessing shrub forage yield and its utilization. If practical, digital sampling of vegetation could prove to be efficient, accurate, precise, less subjective, and nondestructive.

Materials and Methods

Study Area

Research was conducted on the USDA, Forest Service, Starkey Experimental Forest and Range (Starkey) in the Blue Mountains (45°15’N, 118°25’W), of northeast Oregon, which is approximately 35 km southwest of La Grande, Oregon. Vegetation characteristics of this area are described by Skovlin et al. (1976), Holechek et al. (1982) and Damiran (2006). Cattle (*Bos taurus*) graze seasonally, and mule deer (*Odocoileus hemionus hemionus*) and elk (*Cervus elaphus*) are sympatric with cattle at Starkey (Coe et al. 2001).

Shrub Selection

We selected three shrubs that represented variation in leaf area density, leaf orientation, and leaf shape, abundance on the landscape, and nutritive value for wild and domestic ungulates. We sampled common snowberry (*Symphoricarpos albus* [L.] Blake), snowbrush (*Ceanothus* *velutinus* Douglas ex Hook.) and firmleaf willow (*Salix rigida* Muhl.) found in mixed-conifer rangelands at Starkey. We sampled ten randomly chosen plants from each species on clear days on 27-29 June 2000 between 1000 and 1500 hours, using techniques generally similar to those as described by Reynolds (1999) and Hyder et al. (2003). Size of shrubs ranged from 35 to 96 cm tall and 15 to 180 cm wide. Shrubs were accessible to wildlife year round, but were not accessible to cattle for this growing season. Additionally, shrubs selected showed no sign of heavy utilization but evidence of light browsing was present on some individual plants of all three species selected.

Preparation of Plants for Photographing

Before taking photographs, shrubs were isolated from excess herbaceous vegetation to eliminate potential interference from leaf material on stems and background vegetation during later analysis. A backdrop was made of a white bed sheet supported on a plastic pipe frame measuring 1 × 1 m or 1.5 × 2.0 m, which was large enough to provide a background for the entire shrub. White sheets were also spread on the ground separating shrubs from ground vegetation. A meter board painted yellow and marked with 1-cm wide bands at 10-cm intervals was placed perpendicular to each photo point at the center of each shrub without interfering with the shrub image. A wooden stake was placed behind the meter board to allow for relocation of the board placement in successive photos. The shrub identification, sample number, side of approach, and increment number of leaf removal was written on a dry-erase notepad and attached to the backdrop so it would appear in each photograph.

Photographing and Browsing

Shrubs were photographed using an Olympus D-500L, digital single-lens reflex camera. The camera was mounted on a tripod 50 cm above the ground and photos were taken at a distance of

1.5 or 3.0 m from the shrub depending on shrub size. We simulated browsing each shrub through hand plucking (Cook and Stubbendieck 1986) in five to eight increments until the shrubs were completely defoliated. Before the first plucking, and after each plucking, photos were taken from two horizontal directions perpendicular to each other.

The harvested plant material for each shrub and plucking event was placed in separate paper bags dried in a forced air dryer at 50°C for 2 days, and weighed to obtain forage yield for each shrub and plucking event. Total forage yield (Y, g) of each shrub was determined by summing all dry weights from each plucking event for the shrub. Utilization (UY, %) for each plucking event was then calculated based on the total plant material removed from the shrub up to and including the current plucking event.

Image Processing

The images were downloaded to a computer and saved as JPEG files. Then images were imported into Corel Photo-Paint 8 (SYNEX Inc, Brooklyn, NY) software, cropped to show just the shrubs and meter board, and saved in a Windows Bitmap (BMP) file format for computer processing. The BMPs were imported into a software package VegMeasure (Johnson et al. 2003) to produce red (R), green (G), and blue (B) color band images or spectral components (wavelengths are as follows: red = 620-700, green = 500-578, and blue = 446-500 nanometers). Each of these images was recombined using the image calculator function. Green leaf area size was determined as follows: pixel = ([G-R] + [G-B])/ (G+R+G+B). For each image, we then analyzed the meter board to determine the ratio between the metric height and pixel height to calculate a scaling factor for the size of each pixel (C $cm \cdot pixel^{-1}$) to convert image’s pixel length to “metric” length. For each image, we then summed the number of green pixels to calculate green leaf area. We averaged the green leaf area from the two images made at perpendicular directions after each plucking event. Utilization estimated by green leaf area (ULA) size was calculated, % = ([Before browsing leaf area size, cm^2 – After browsing leaf area, cm^2]/ [Before browsing leaf area size, cm^2] × 100).

Statistical Analysis

Shrub green leaf area size was regressed against the corresponding forage yield using the REG procedure of SAS (SAS 1997). Utilization values were analyzed as a split-plot design with 3 (shrub species) × 2 (technique for estimate utilization) factorial arrangements of treatments using the DIFF option in the SAS/GLM LSmeans statement of SAS. In addition, we also compared required shrub number to detect a difference of 20% of the mean forage yield with a probability of 80% using a 5% significance level (Kuehl 2000) for both techniques to determine if these techniques differed in precision.

Results and Discussion

Using the photographic technique the correlation (r^2) between green leaf area and forage yield was 0.81 ($n = 169$, $P < 0.001$) when data were pooled from all three shrubs. Both the slope and Y-intercept of the regression model differed significantly ($P < 0.05$) among shrubs (Figure 1, 2).

Utilization values using green leaf area size were strongly correlated with actual utilization values (Table 1). A shrub species × research technique interaction on utilization estimates was not detected ($P > 0.05$). Utilization values estimated through green leaf area were not different ($P = 0.603$, $n = 142$) from actual utilization values.

To detect a difference of 20% of the mean forage yield with a probability of 80% and using a 5% significance level (Kuehl 2000), at least 25, 18, and 79 snowberry, snowbrush, and firmleaf willow plants, respectively would be required. Likewise, to detect above-mentioned differences using a traditional technique (hand plucking) at least 21, 22, and 79 snowberry, snowbrush, and firmleaf willow plants would be required, respectively.

Our results suggest that digital images and an algorithm based on color theory can provide good estimates of shrub forage yield in mixed-conifer rangelands with plants that have discrete canopies. The technique requires a proper calibration based on double sampling, harvesting forage yield, and taking photos of shrub species at a particular stage of growth. However, shrub utilization can be assessed through direct comparison of green leaf area size estimated from images taken before and after browsing.

Care should be taken to minimize shadows that fall on shrubs photographed. Shadows make it more difficult, but not impossible, to separate leaves from woody material and background in photographs. Shadows from tall vegetation confound many types of image analysis either by hiding areas of interest or by altering color in shaded areas (Booth et al. 2004). Consequently, cloudy days may reduce shadows and be better than bright sunny days for this technique. If the shrubs' twigs and stems contain high chlorophyll pigment, the available forage yield and utilization value may be overestimated. This technique will be difficult to use on large shrubs due to the limitations of harvesting the entire plant which is necessary for creating regression equations. Removing obstructing vegetation or isolating the shrubs surrounding vegetation is the main task required to increase accuracy. Raindrops, or early morning dew, and windy days also may affect green leaf area size. If during browsing, natural /climatic events occurred (i.e., frost, insect damage, or disease), utilization values may also be biased. To avoid bias caused by utilization during the growing season, some shrubs should be protected with wire cages which would be inaccessible to browsing animals. Protected shrubs would serve as a control to adjust growth or senescing rate and loss caused by reasons other than browsing. To determine proper calibration, photographs of protected shrubs should be taken before and after utilization photos. The use of readily available computer technology and photographic equipment will decrease the subjectivity and increase the accuracy of field measurement of plant geometry and associated losses due to herbivory or other factors (Hyder et al. 2003). As image analysis technology improves, the applicability, accuracy, and precision of techniques such as the photographic technique will improve. Also, digital images have proven to be a quick and accurate means for vegetation classification (Louhaichi et al. 2001; Johnson et al. 2003). Therefore, we speculate that, in the future, this technique probably can be used for plants with continuous canopies.

Conclusions

This study demonstrated that the photographic technique has a very high probability of improving shrub yield and utilization estimates/monitoring in range conditions in terms of a research accuracy stand point. Unlike many traditional utilization techniques, this technique is non-destructive and more practical. However, the application of this technique is currently limited to the use of shrubs that are small and shrubs that can be individually isolated from the vegetation community for photography.

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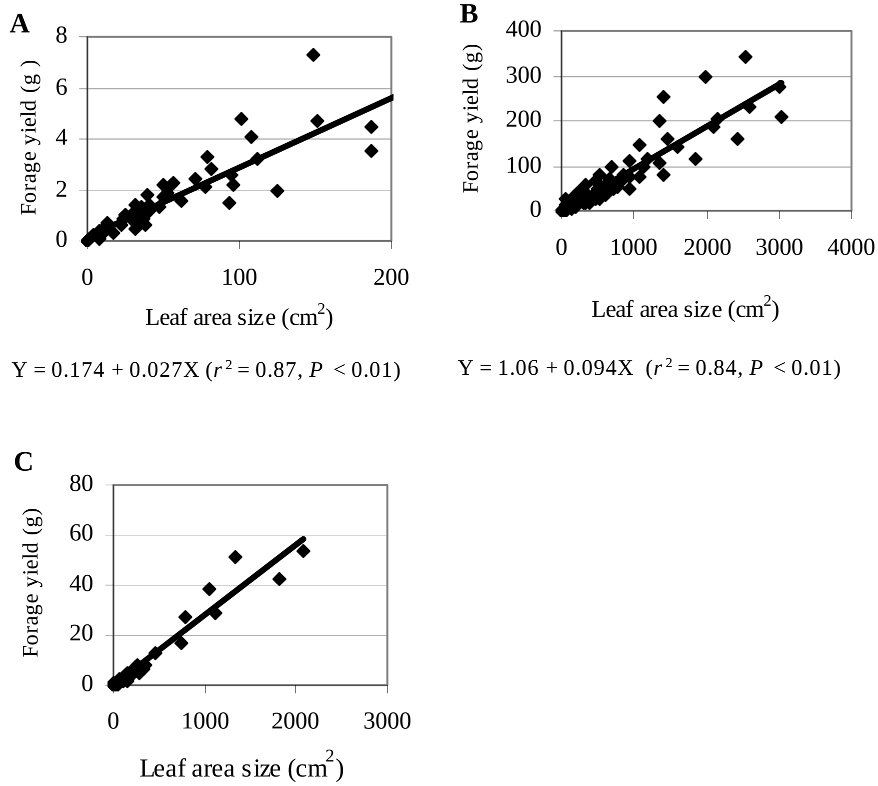
TABLE 1. Correlation coefficients (r^2), slope, Y-intercepts, *F*-value and number of observations (*n*) for the linear model fit to utilization (%) estimated by green leaf area size (X) and predicted actual (Y) values.

Shrubs	Y-intercept	Slope	r^2	*F*	*n*[1]	*P*-value
Common snowberry	3.943	0.955	0.934	694	50	<0.001
Snowbrush	2.042	0.976	0.963	1454	57	<0.001
Firmleaf willow	8.913	0.932	0.962	869	35	<0.001

[1]*n* = number of data pairs used to develop a prediction equation.



A: Y = 0.174 + 0.027X (r^2 = 0.87, P < 0.01)

B: Y = 1.06 + 0.094X (r^2 = 0.84, P < 0.01)

C: Y = -0.212 + 0.028X (r^2 = 0.94, P < 0.01)

Figure 1. Regression equations for the linear model fit to the green leaf area size (X, cm^2), and predicted forage yield (Y, g DM basis) of common snowberry (A), snowbrush (B), and firmleaf willow (C).

Leaf area, cm^2					
140.9	99.3	71.1	46.6	18.7	3.2
Defoliation (Utilization, %)					
0	34.2	54.8	68.5	87.7	100.0

Figure 2. This common snowberry shrub simulated browsing in five increments until the shrub was completely defoliated. Before the first plucking, and after each subsequent plucking, photos were taken from two horizontal directions perpendicular to each other and averaged for estimation of leaf area sizes.