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J D. Rotz
Va. Tech

A O. Abaye
Va Tech

E B. Rayburn
WVU

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Technical Note

Classification of Digital Photography for Measuring Productive Ground Cover

J. D. Rotz,[1] A. O. Abaye,[2] R. H. Wynne,[3] E. B. Rayburn,[4] G. Scaglia,[5] and R. D. Phillips[6]

Authors are [1]graduate student and [2]Associate Professor, Department of Crop and Soil Environmental Science, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, USA; [3]Associate Professor, Department of Forestry, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, USA; [4]Professor, Department of Agronomy, West Virginia University, Morgantown, WV 26506, USA; [5]Assistant Professor, Department of Animal and Poultry Science, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, USA; and [6]Research Associate, Department of Computer Science, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, USA.

Abstract

Productive ground cover (PGC) is often used as a measure of sward health and persistence. To measure PGC, a camera stand was constructed to provide diffuse lighting of grass swards for color digital photography; the photographs were classified into productive and nonproductive cover using Mahalanobis distance. The PGC measurement techniques were tested on a grazing experiment that used four forage types: Lakota prairie grass (*Bromus catharticus* Vahl.), Kentucky 31 endophyte (*Neotyphodium coenophialum*)-free tall fescue (*Lolium arundinaceum* [Schreb.] S. J. Darbyshire), Kentucky 31 endophyte-infected tall fescue, and Quantum (novel-endophyte) tall fescue. The accuracy of the PGC maps was assessed using a stratified subsample of 48 images, 12 from each of four productive cover classes (0%–39%, 40%–59%, 60%–79%, and 80%–100%). On each of these 48 images 100 random points were labeled by a single skilled interpreter. The PGC percentages thus derived had an 83.7% agreement with the PGC maps. However, the percentages derived from the PGC maps were not well correlated with the PGC percentages derived from either ocular estimation ($r = 0.22$) or a simple digital point quadrat method ($r = 0.47$). This experiment highlights the potential for semiautomated classification of ground-based digital photographs for estimating PGC, though further research (including more direct comparison with established field techniques) is warranted.

Resumen

La cobertura basal (productiva PGC) a menudo es usada para medir la persistencia y salud de la pradera. Para medir la PGC se construyó un soporte para cámara para proveer una iluminación difusa de praderas de zacates para fotografías digitales a color. Las fotografías se clasificaron en cobertura productiva y no productiva usando la distancia de Mahalanobis. Las técnicas de cobertura basal productiva fueron probadas en un experimento de apacentamiento que uso cuatro tipos de forrajes: "Lakota prairie grass" (*Bromus catharticus* Vahl.), "Tall fescue Kentucky 31" (*Lolium arundinaceum* [Schreb.] S. J. Darbyshire) no endofito (*Neotyphodium coenophialum*), "Tall fescue Kentucky 31" endofito y "Tall fescue" Quantum (novel-endofito). La precisión de los mapas de PGC fue evaluada usando una submuestra estratificada de 48 imágenes, 12 de cada una de las cuatro clases de cobertura productiva clases (0%–39%, 40%–59%, 60%–79%, y 80%–100%). En cada una de las 48 imágenes un interpretador entrenado etiqueto aleatoriamente 100 puntos. Los porcentajes de PGC derivados de las imágenes tuvieron una concordancia de 83.7% con los mapas, sin embargo, los porcentajes derivados de los mapas de PGC no estuvieron bien correlacionados con los porcentajes de PGC derivados por estimación ocular ($r = 0.22$) o por el método de cuadrante simple de puntos digitales ($r = 0.47$). Este experimento resalta el potencial de la clasificación semi-automatizada de las fotografías digitales terrestres para estimar la PGC, aunque se requiere mas investigación (incluyendo una comparación más directa con las técnicas de campo establecidas).

Key Words: camera stand, digital aerial photography, image classification, grazing, pasture, prairie grass, tall fescue

INTRODUCTION

Productive ground cover (PGC) is often used to assess forage persistence and vigor. Visual (ocular) evaluation techniques often are used to estimate percentage of ground cover as well as to evaluate plant dominance, succession, and total cover (Hatton et al. 1986). However, these techniques are subjective and can result in inconsistency among evaluators. Hatton et al. (1986) tested the accuracy of individuals in assessing total ground cover. They concluded that evaluators were relatively good at estimating coverage at or near 60% ground cover, but as cover increased or decreased from 60%, the ability of evaluator to accurately assess ground cover decreased. Other methods, such as the point methods (e.g., line intercept, point quadrat etc.) are available, but are not usually utilized due to the cost of time associated with these techniques (Richardson et al. 2001).

More recently, ground-based remote sensing has been viewed as a possible means of measuring PGC (excluding standing dead material) and total ground cover (including standing dead material and thatch). Schut et al. (2003) evaluated traditional

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Correspondence: Ozzie Abaye, Dept of Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24060, USA. Email: cotton@vt.edu

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multispectral remote sensing to assess percentage of ground cover (using traditional multispectral platforms near ground levels). The method assessed ground cover at a high accuracy level; however, the cost associated with data collection and manipulation may limit its use. Recently, digital photography has been shown to be a cost-effective alternative to multispectral data for various uses (Adamsen et al. 1999; Purcell 2000; Richardson et al. 2001). Richardson et al. (2001) used digital photography combined with image classification to assess ground cover under turf grass and row crop conditions. Although ground cover assessment using such techniques has gained credibility, little is known about how this technology can be applied in pastures. One of the issues to be addressed before using digital photography in pastures is the need to minimize the effects of shadowing from the tall dense sward. In an attempt to minimize this shadowing, Bennett et al. (2000) and Booth et al. (2004) constructed stands that create more consistent lighting environments.

Favorable results have been obtained (Murphy and Lodge 2002; Booth et al. 2005) when digital photography and semiautomated image classification were compared with other methods to assess PGC. The overall objective of this study was to assess the ability of digital photography coupled with image classification to estimate productive and nonproductive ground cover in pasture settings.

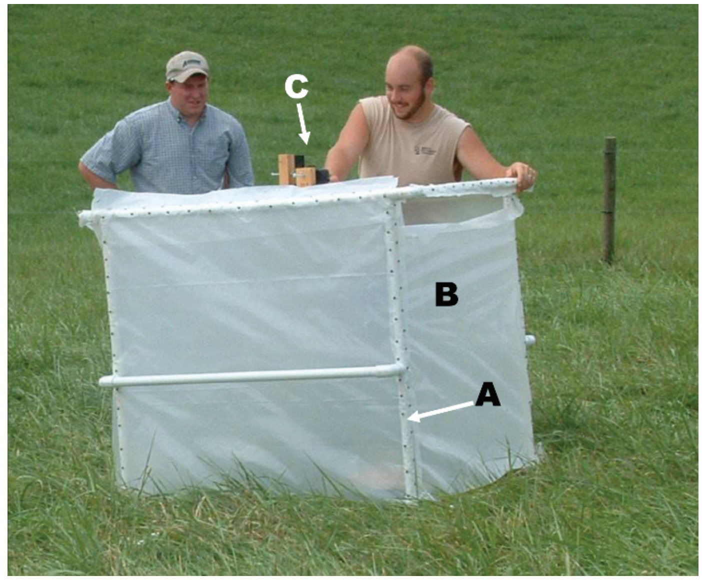

Figure 1. Image of camera stand used to attain images in the field for assessment of productive cover. The stand was made of a 1-m^3 polyvinyl chloride (PVC) frame (**A**, 3.81-cm PVC pipe) and covered with 6-mm clear plastic (**B**). **C**, A 5-megapixel digital camera was affixed to stand with a focal declination of 90° from the base. The camera height was 1 m above the ground.

METHODS

A grazing experiment was initiated in September 2002 at the Kentland Research Farm near Blacksburg, Virginia. Four replicates of Lakota prairie grass (*Bromus catharticus* Vahl.), Kentucky 31 endophyte (*Neotyphodium coenophialum*)-free tall fescue (*Lolium arundinaceum* [Schreb.] S. J. Darbyshire), Kentucky 31 endophyte-infected tall fescue, and Quantum (novel-endophyte) tall fescue ($n = 16$) were established in a randomized complete block design on 17.8 ha. Seeding rates were 39 kg $\cdot$ ha^{-1} for Lakota and 25 kg $\cdot$ ha^{-1} for the fescues. Animal movement from paddock to paddock was ultimately determined by available forage. In 2003, grazing began in July; for the 2004 and 2005 grazing seasons, grazing began in May.

A portable camera stand was built that was approximately 1 m wide by 1 m long and 1 m high. The stand was covered on all sides and the top with 6-mm clear plastic to create a diffuse lighting environment, thus mimicking conditions found on an overcast or cloudy day. The camera was affixed in the center of the top of the stand to allow a distance of 1 m to the ground (Fig. 1). The pixels most distant from the center of the photograph were displaced from their true position because of relief displacement. Given the inverse relationship between object distance and relief displacement, this issue could be partially obviated by using a higher camera mount.

During the 2005 grazing season, three 0.25-m^2 quadrats per treatment replication were visually assessed for PGC on every paddock prior to cattle grazing. After visual assessment was completed, images were taken using a Nikon Coolpix 5700 digital camera (Nikon Corporation, Tokyo, Japan) from the same three 0.25-m^2 areas. For the initial 13 of 27 sampling dates (2 May 2005 to June 2005) images were acquired without any filter applied; however, for the final 14 of the 27 sampling dates (6 July 2005 to 20 September 2005) a polarized filter was added to the camera to investigate the effect of glare on image quality and classification. Images were saved as uncompressed JPEGs. Once acquired, images were then cropped to contain only the area inside the quadrat. Once all images had been collected over the 2005 grazing season (May–October) 145 images (20%) were randomly selected to be assessed by the digital point-quadrat method. For this method all images were overlaid by an 11 $\times$ 11 (one-fourth-m^2) grid in Adobe Photoshop (Adobe Systems Incorporated, San Jose, CA) to identify 100 points to be classified in each image. Each observed point in the image consisted of a 10 $\times$ 10 pixel area. This technique is more limited than advanced procedures for point-sampling digital images (e.g., Booth et al. 2006). However, it did simplify analyst training. Evaluators classified each point of crossing as green or nongreen. Five evaluators with no prior experience were used for this portion of the experiment. Although minimal, evaluators did receive instruction on how to use the digital point quadrat. More specifically, they were taught where in the quadrat to look and how to identify a 10 $\times$ 10 pixel area as green or not green. All evaluators were also given a quick background on how the resulting data were to be used. Each evaluator received 33 images, of which 10 images were common among observers. Once all images had been completed the 10 common images were used to analyze if differences existed among evaluator's classification of PGC.

Images were also classified using the Mahalanobis distance decision rule in Erdas Imagine® (version 8.7, Leica Geosystems Geospatial Imaging, LLC, St. Gallen, Switzerland) into two classes: productive cover (class 1) and nonproductive cover (class 2). The same special signatures were used for all 695 images. The classifications were then recorded to form the PGC maps, with two categories, productive and nonproductive

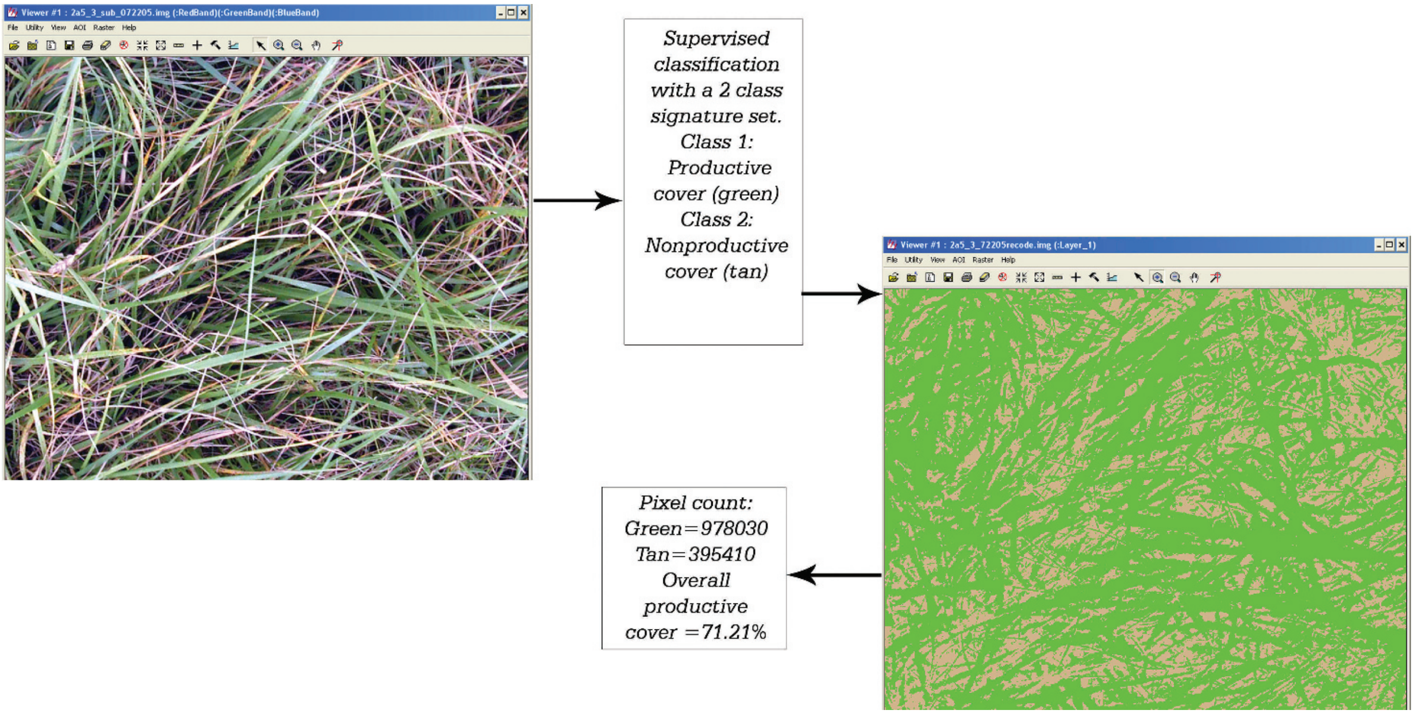

Figure 2. Example of image classification process.

(Fig. 2). Productive cover percentages were obtained from the PGC maps by dividing the number of pixels in class 1 by the total number of pixels.

For the accuracy assessment 48 images were randomly selected from the entire population (697). Images were stratified by ground cover groupings and filter as described in Figure 3. For each image, 100 random points were created and labeled as either class 1 (productive cover) or class 2 (nonproductive cover) by a single interpreter. The resulting percentages were compared with those obtained from the PGC maps. All data were analyzed in SAS (version 9.1, 2002–2003, SAS Institute, Incorporated, Cary, NC).

RESULTS AND DISCUSSION

Image Classification Accuracy by Productive Cover

The results of the accuracy assessment are shown in Table 1. The average accuracy of the image classification was 83.7%. There was a significant difference in classification accuracy for images with PGC between 0% and 39% and images with PGC between 40% and 100% (Table 1). However, no difference was noted in PGC maps when the PGC was over 40% (Table 1). Classification accuracy was above 80% for all the images above 40% PGC. In this experiment, fewer than 0.5% ($n = 3$) of all the images were under 10% cover. When accuracies were examined further, it was found that low accuracies were only observed in images below 10% PGC. For images ranging from 10% to 39% PGC, map accuracy was 80.8%.

Similar conclusions were made by Booth et al. (2005) when comparing digital photography analysis by VegMeasure (Johnson et al. 2003) to other methods of analysis. Furthermore it can be assumed that these accuracies would have been lower had direct illumination been used because shadowing can confound many types of image analysis (Booth et al. 2004).

Image Classification Accuracy by Polarized Filter

In examining image quality, one major concern noted in our study was the effect of high reflectance (glare) from leaf blades, and the effect this may have had on classification accuracy. To address this concern, a polarized lens was added to the camera to decrease the level of glare from leaf blade surfaces. Due to extraneous circumstances our filter was not available for use until the study had already begun. We decided to add the filter, then test for a significant difference in order to decide if all of

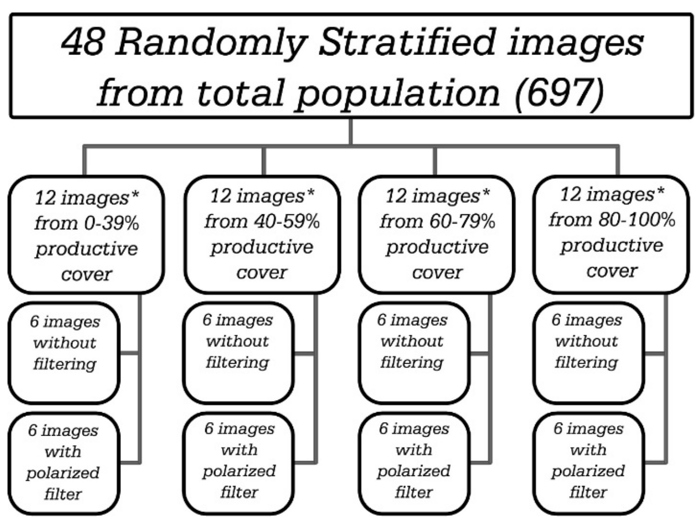

Figure 3. Stratification of images for accuracy assessment. (*All images were classified using 100 random points stratified by class [50 points, class 1; 50 points, class 2].)

Table 1. Classification accuracy of subsample by stratified groups. Class 1 is productive cover; class 2, nonproductive cover. Mean classes (as determined using Fisher's LSD test) are shown as lowercase letters in the "Accuracy" column.

Grouping (%)	Sample size	Accuracy (%)
By productive cover		
0–39	12 images	78.1 b
40–59	12 images	85.3 a
60–79	12 images	85.5 a
80–100	12 images	85.9 a
By filter		
Filter 0–39	6 images	80.0 a
No filter 0–39	6 images	76.2 a
Filter 40–59	6 images	83.6 a
No filter 40–59	6 images	86.8 a
Filter 60–79	6 images	84.7 a
No filter 60–79	6 images	86.3 a
Filter 80–100	6 images	85.5 a
No filter 80–100	6 images	86.3 a
Overall		
0–100	48 images	83.7
Filter	24 images	83.5 a
No filter	24 images	83.9 a

our data could be pooled or not. No significant difference was observed in classification accuracy between images obtained with the camera equipped with polarized lens vs. those obtained with no polarized lens (Table 1). This led us to conclude that the addition of a polarized filter to the digital camera did not significantly affect the ability to accurately classify PGC at any ground cover level; thus, all images could be pooled for analysis.

Source of Image Classification Error

Once all images had been tested for accuracy, eight images were randomly selected and stratified by cover group. For each of these images all misclassified pixels were observed to better understand the source of errors. It became apparent that many of the misclassified pixels came from areas of shadow and edges or transition zones. It can be assumed that with a more diffuse light, shadowing will be less; however, we did not compare our diffuse lighting condition with direct light in this experiment.

Comparison of Techniques

Image classification was compared with ocular estimation and the digital point quadrat to find the most accurate method of PGC estimation. Similar to results obtained by other investigators (Hatton et al. 1986; Booth et al. 2005), the means of all the methods were not statistically different. However, there was little correlation between the classifications and either ocular ($r = 0.217$) or digital point quadrat ($r = 0.469$) estimates of PGC. The low correlation can be expected due to the minimal training received by the evaluators, and the subjective nature of both visual evaluation (Hatton et al. 1986) and digital point-quadrat methods. Nonetheless, given the accuracy of the image classifications, we can conclude that semiautomated classification of ground-based digital photography has potential as a means of assessing PGC.

IMPLICATIONS

Currently, there are only a few ways to assess PGC. Visual evaluation and point quadrats are often used as ground cover estimation techniques. The estimates often are based on total ground cover from dead and live materials. Due to its subjective nature, visual evaluation often gives highly varied results. Although digital photography coupled with remote sensing has been used to collect data for turf and field crop research, its applicability in pasture conditions has not been fully explored. The current study showed that digital photography can be used to accurately classify PGC in pasture settings.

Further research on this method should be validated by point-frame estimates of productive cover that correspond to image area. In addition, we recommend testing the effect of diffuse vs. direct light on classifications. Based on our results, if remote sensing coupled with digital photography is to be used to classify productive cover, some considerations need to be taken to assure maximum image quality. Maximum image quality can be obtained by reducing shadow and glare and by the use of even, diffuse lighting.

LITERATURE CITED

Adamsen, F. J., P. J. Pinter, E. M. Banes, R. L. LaMorte, G. W. Wall, S. W. Leavitt, and B. A. Kimball. 1999. Measuring wheat senescence with a digital camera. *Crop Science* 39:719–724.

Bennett, L. T., T. S. Judd, and M. A. Adams. 2000. Close-range vertical photography for measuring cover changes in perennial grasslands. *Journal of Range Management* 53:634–641.

Booth, D. T., S. E. Cox, and R. D. Berryman. 2006. Point sampling digital imagery with 'sample point.' *Environmental Monitoring and Assessment* 123:97–108.

Booth, D. T., S. E. Cox, C. Fifield, M. Phillips, and N. Williamson. 2005. Image analysis compared with other methods for measuring ground cover. *Arid Land Research and Management* 19:91–100.

Booth, D. T., S. E. Cox, M. Louhaichi, and D. E. Johnson. 2004. Technical note: lightweight camera stand for close-to-earth remote sensing. *Journal of Range Management* 57:675–678.

Hatton, T. J., N. E. West, and P. S. Johnson. 1986. Relationships of the error associated with ocular estimation and actual total cover. *Journal of Range Management* 39:91–92.

Johnson, D. E., M. Vulfson, M. Louhaichi, and N. R. Harris. 2003. VegMeasure version 1.6 user's manual. Corvallis, OR, USA: Department of Rangeland Resources, Oregon State University. 51 p.

Murphy, S. R., and G. R. Lodge. 2002. Ground cover in temperate native perennial grass pastures. 1. A comparison of four estimation methods. *Rangeland Journal* 24:288–300.

Purcell, L. C. 2000. Soybean canopy coverage and light interception measurements using digital photography. *Crop Science* 40:843–837.

Richardson, M. D., D. E. Karcher, and L. C. Purcell. 2001. Quantifying turfgrass cover using digital image analysis. *Crop Science* 41:1884–1888.

Schut, A. G. T., J. J. M. H. Ketelaars, and C. Lokhorst. 2003. Image spectroscopy for grassland management. *In:* S. Cox [ed.]. Precision livestock farming. Wageningen, Netherlands: Wageningen Academic Publishers. p. 155–160.