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QUANTIFYING SURFACE GROUND COVER FROM DIGITAL IMAGES*

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ABSTRACT

Surface ground cover plays a critical role in protecting soil from erosion. Qualitatively, landscapes susceptible to erosion can be identified by exposed soil. Simulation models that predict and quantify erosion rely on input values to indicate exposed soil. Traditionally, ground cover is measured using point intercept transect methods, which are laborious and can have a high degree of variability. Alternatively, an algorithm-based method applied to digital images provides a less labor-intensive quantification of percent ground cover that is both repeatable and yields consistent results. A method was developed to sample pixels within an image and determining their class. Cover type was identified as rock, bare soil, or vegetation by examining and interpreting the geometric and color properties of surrounding pixels. A flood fill technique was used to determine the extent of the region surrounding a sampled pixel. A total of 316 points representing rock, bare soil, or vegetation were sampled. The method was used to correctly classify 76% of sampled rock, 75% of sampled bare soil, and 100% of sampled vegetation.

1.0 INTRODUCTION

Vegetation and surface ground cover play a critical role in protecting soil from accelerated erosion. Cover parameters are a primary input to simulation models such as the Universal Soil Loss Equation (Wischmeier and Smith 1978) as well as more complex process-based models such as the Water Erosion Prediction Project (Laflen et al. 1991). Accounting for the spatial distribution of cover is important for accurately modeling runoff and sediment (Lane et al. 1995). The use of lumped values representing large-scale aerial averages of vegetation and surface ground cover limits modeling of distributed runoff and erosion processes. However, collecting distributed ground surface cover and vegetative cover data is time consuming and inherently variable depending on the data collection methodology and the data collector.

Cover information is also critical for rangeland management. Cover has traditionally been monitored as a component in developing conservation plans. Knowledge of cover condition is useful for quantifying trends on rangelands over space and time. Traditional measurement methods to quantify surface cover serve as monitoring strategies for assessing trends in species composition and abundance. Traditionally, sampling consists of laying out a tape and recording occurrences of cover along the length; alternatively, a quadrat (or plot) is used as a sample unit. The line intercept method (Bonham 1989) yields an overall estimate of coverage, the variance of the coverage, and a confidence interval for the coverage. As a complement to quantitative methods, photographs provide a mechanism for documenting conditions (Bennett et al. 2000, Howery and Sundt 1998) and a relatively quick means for visually assessing landscape changes. Photographic records complement frequency measurements taken along transects to quantify plant community dynamics. Two to three transects per day can be read using traditional methods (Robinette 1989).

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An opportunity exists to extend traditional rangeland monitoring methods and adapt them to collect data for parameterizing hydrologic and erosion models. Field data collection procedures can be improved by developing algorithms for interpreting cover from digital images. An algorithm to quantify surface characteristics offers the advantages of repeatability and efficiency while producing unbiased and consistent results.

Digital images contain information in the form of red, green, and blue color components for the pixels that make up the image. These data can be used to classify elements within an image based strictly on color. Research was undertaken to evaluate geometrically based statistics generated from digital images to provide additional information for quantifying percent vegetation, rock, and bare soil.

This project was undertaken with a self-imposed restriction on the type of digital image that would be used. The procedure was developed for images taken with a commonly available digital camera or for images produced by scanning paper photographs to produce images made up of red, green, and blue color bands. Infrared and other spectral data may be used in future research to improve the algorithms, but are beyond the scope of this project.

Ultimately, the goal of developing an algorithm based method for assessing cover is to efficiently compute percent cover by type for larger areas. This paper describes a method for classifying cover type based on sampled points within an image.

2.0 ESTIMATING COVER

2.1 DIGITAL IMAGES

Initial algorithm and testing is based on digital images covering approximately 0.6m by 0.5m taken perpendicular to the ground at a resolution of 1800 pixels by 1350 pixels. Pictures were taken with a 35mm camera and converted to digital form by scanning at a resolution of 600 dots per inch. The color range of each image was normalized using the autoequalize function of a graphics package.

2.2 IMAGE SAMPLING

Estimating percent cover is based on sampling. Sampling pixel locations within an image and assessing the cover class to which the pixel belongs can quantify the percentage of rock, bare soil, and vegetation within a digital image. The percent of cover attributed to rock, soil, or vegetation within an image is taken to be the relative frequency of the identified cover class from among the sampled points. Cover class membership is assessed by evaluating several factors. The first factor involves determining a set of pixels surrounding the sampled pixel that are similar in color to the sampled pixel and assessing geometric statistics of this set. The second factor involves computing a green/red ratio for the pixels in the surrounding region.

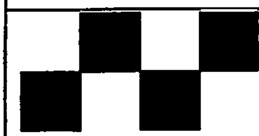
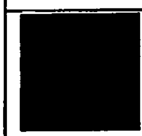
The set of pixels surrounding the sampled pixel is determined using a flood fill technique. It should be noted that the goal of this procedure is not to identify the actual cover item, but rather to determine a set of pixels whose characteristics can be used to assign a cover classification. Quantifying the percent cover by type within an image does not rely on picking out and counting objects that can be identified by eye as rock, vegetation, or soil. Rather, the image is sampled and sampled points are interpreted as having an area/edge relationship characteristic of rock, vegetation, or soil. The entire image is sampled and results are aggregated to quantify the cover percent of the image represented by rock, vegetation, and bare soil.

2.3 ALGORITHM DEVELOPMENT

Color bands are commonly used to separate features within digital images. In fact, the green color band is an obvious separator for vegetation. However, color is of limited use for classifying rock vs. bare soil, which can potentially be similar in color because soil and rock may derive from common parent material.

The geometric characteristics of shapes within an image provide a basis for generating statistics that can be used to separate cover classes. Area and edge length are basic properties of 2-dimensional objects (Table 1). It is anticipated that the relationship between area and edge can be used to separate cover classes.

Table 1. Geometric Characteristics Of Shapes

Shape	Area	Edge Length	Area/edge ratio
	1	4	1/4
	4	16	1/4
	4	8	1/2

The first step is to identify representative regions. A flood fill is initiated by a mouse click on a pixel. The flood filled area is a pixel set that is selected using an algorithm to assign individual pixels to the set based on similarity in color to the sampled pixel. The resulting pixel set is a continuous region that can be characterized by its shape. For example, the flood filled area on rock (Figure 1) has a higher area to edge ratio than the flood filled area on bare soil (Figure 2).

For this analysis a simple hard limit flood fill algorithm was used to determine pixel sets. A breadth-first search of surrounding pixels was performed and pixels for which the red, green, blue values were within a fixed increment from the selected pixel were determined as being in the set.

Figure 1. Black Flood Filled Regions Characterizing Rock

Figure 2. Black Flood Filled Region Characterizing Bare Soil

The next step is to generate statistics of pixel sets based on the resulting shape. The goal of this project is to evaluate shape characteristics and to select those that show promise for use in classifying vegetation, rock, or bare soil. These characteristics can then be aggregated to estimate percent cover for each type.

2.4 APPLICATION OF THE ALGORITHM

The previously described algorithm was applied to three images. From each image, 41 points known to be rock were sampled and an area/edge statistic and green/red statistic for the flood filled region were computed. This procedure was followed to sample 41 bare soil points and 17-28 vegetation points, depending on the image. Lack of vegetation in the images limited initial sampling. The relationship between the area/edge statistic and the green/red statistic was used to define thresholds for classification (Figure 2). The green/red statistic can be used to separate vegetation from rock and bare soil. The area/edge statistic showed a good, but not absolute, separation of rock from bare soil. The determination of a threshold value to separate rock from bare soil currently has no definition from principle. However, based on a threshold at 4.5, 75% of rock was correctly classified, 76% of bare soil was correctly classified, and 100% of vegetation was correctly classified (Table 2). These initial results show promise in using the statistics of geometric regions to separate rock from bare soil.

Table 2. Summary of classification results for rock, bare soil, and vegetation.

Real		Classification: Rock	Classification: Bare Soil	Classification: Vegetation
Real	Rock	93 (76%)	24 (20%)	5 (4%)
Real	Bare Soil	29 (24%)	92 (75%)	2 (1%)
Real	Vegetation	0	0	71 (100%)

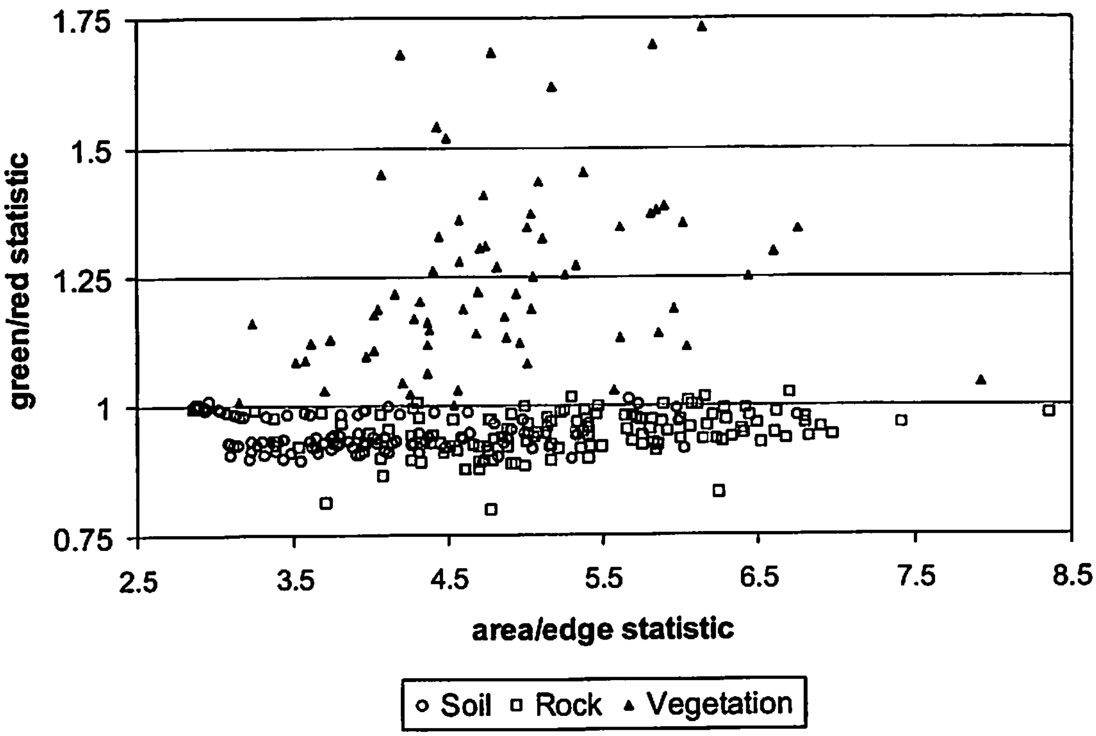


Figure 2. Relationship Between Area/Edge Statistic And Green/Red Statistic For Three Sampled Images

3.0 CONCLUSIONS

A method for quantifying cover classes using statistics of geometric regions within digital images has been developed. The method shows promise for expanding interpretations based on color bands by including geometric properties of regions. Cover classes that are not readily quantifiable based on color, such as rock and bare soil, can be quantified using geometric characteristics of representative regions. The algorithm-based method offers the advantages of repeatability and efficiency while reducing the amount of labor needed to collect field data.

Additional testing is necessary to refine the flood fill algorithm used to select pixel sets. A refined algorithm may accommodate shadows, which offer a particular challenge to interpreting objects within an image, and were not addressed as part of this project. Surface litter may also be identifiable using the methodology presented in this paper with improvement to the flood fill routine. Finally, further research is required to quantify characteristic area to edge ratio of rangeland vegetation forms and ultimately individual species. The practical application of this method as a field tool will require development of a procedure and specifications for taking the images. The algorithm-based method for assessing cover should be compared with traditional rangeland monitoring methods.

4.0 REFERENCES

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