Distinguishing shrub and grass vegetation using a combined panchromatic / multispectral approach

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INTRODUCTION

Land use change is an important area of study for assessing ecosystem health. Land use change over decadal time scales is an area of current research that suffers from a lack of important historical data. Old black and white aerial photographs are often the only record of the condition of an area under study. Methods for extracting information from black and white photographs to ascertain ecosystem change would be very valuable. For example, in the arid Western United States, a common dynamic in rangelands is the change in the amount of shrubs existing in an area. Black and white aerial photographs are often used to determine proportion and type of vegetation based on human judgment, which can be effective, but is extremely time consuming. Computerized vegetation classification of black and white aerial photographs has been met with limited success (Carmel and Kadmon, 1998). Several satellite sensors that specialize in Earth observation have a wide panchromatic band similar to a traditional black and white photograph in addition to narrower multispectral bands. We propose to combine the information from multispectral bands and the panchromatic band to assist in distinguishing shrubs from grasses which would greatly aid in quantifying shrub encroachment.

METHODS

Most remote sensing satellites designed for Earth observation have bands in the visible and the near-infrared (NIR) spectrum. The red and the NIR bands have been used extensively for developing vegetation indices. These indices have proven to be very effective in quantifying green biomass but are not good at distinguishing different vegetation types with the same amount of green biomass. We will show that when a semi-arid rangeland is at its peak biomass, grasslands and shrubs can be distinguished from each other in a panchromatic image due to shadowing effects. The shrubs in this study are consistently darker in the panchromatic image than the green grass because their height and clumped distribution cause greater shadowing. Under certain conditions, historic black and white photographs could be used to derive a classification map that distinguishes shrubland and grassland without the time consuming process of visual analysis. This approach can be implemented with panchromatic images currently being acquired. Ten meter SPOT panchromatic images have been available since 1986. Landsat 7, which was launched in 1999 includes a 15 meter panchromatic band. In 1999 Space Imaging launched a commercial satellite, IKONOS, with a 1 meter panchromatic band. To date, few researchers have used the panchromatic band for distinguishing vegetation types. Jofre and Lacaze (1993) used SPOT panchromatic data to estimate tree density in an oak savannah using a threshold approach.

Site

The USDA Walnut Gulch Experimental Watershed (WGEW) is representative of approximately 60 million hectares of brush and grass covered rangeland found throughout the semi-arid southwestern United States. Cattle grazing is the predominant land use, with mining, limited urbanization, and recreation making up the remaining areas. The site is semi-arid, with a hot summer and a dry winter. Precipitation at the site is highly variable, with intense and localized convective thunderstorms provided two thirds of the annual rainfall.

Though historically covered by grassland, shrubs now dominate two thirds of the Walnut Gulch watershed. A small portion of this site, approximately 2 x 3 kilometers, was used to assess grassland / shrubland distribution from satellite data

Data

The image used for this analysis was acquired from the IKONOS satellite on July 12 2000. IKONOS was launched in September 1999 by Space Imaging, a private company based in Thorton, Colorado. The imaging sensors are panchromatic and multispectral (Table 1). The satellite has a polar, circular, sun-synchronous 681-km orbit and both sensors have a swath width of 11 km.

Table 1. Band description of IKONOS platform

Band	Wavelength Region (μm)	Resolution (m)
1	0.45-0.52 (blue)	4
2	0.52-0.60 (green)	4
3	0.63-0.69 (red)	4
4	0.76-0.90 (near-IR)	4
PAN	0.45-0.90 (PAN)	1

Procedure

In WGEW, vegetation generally consists of grass and shrubs/small trees. At the scale of this study, 4km and 1km, the shrubs can be distinguished by their location (i.e. near washes) shape and/or 'color'.

The IKONOS image captured the eastern portion of the Walnut Gulch watershed (Figure 1). In order to make the data more manageable, a subset of the IKONOS image was used that included both grassland and shrubland (Figure 1). The subset used for this analysis was 1800 by 3200 pixels creating a maximum data set of 5,760,000 values. The IKONOS multispectral data was rescaled to 1 meter so a direct comparison could be made to the panchromatic band. A normalized difference vegetation index (NDVI) (Eq. 1) was calculated for the image,

$$NDVI = (NIR - RED)/(NIR + RED) \qquad \text{Equation (1)}$$

Where

NIR = near infrared (band 4 in Table 1)
RED = red (band 3 in Table 1)

and a histogram of the data was generated (Figure 2). From the histogram, a high NDVI for this image was determined to be 0.25 and above. Hannan et el. (1993) measured the NDVI of single west African savannah trees which ranged from 0.24 to 0.37, suggesting this threshold would encompass tree/shrub vegetation classes of even very small spatial extent. The image was then masked using this threshold to include only that shrub vegetation and live grass biomass. Although such a map would not indicate an absolute amount of grasslands and shrubs, it would be a good spatial indicator of the extent of green biomass.

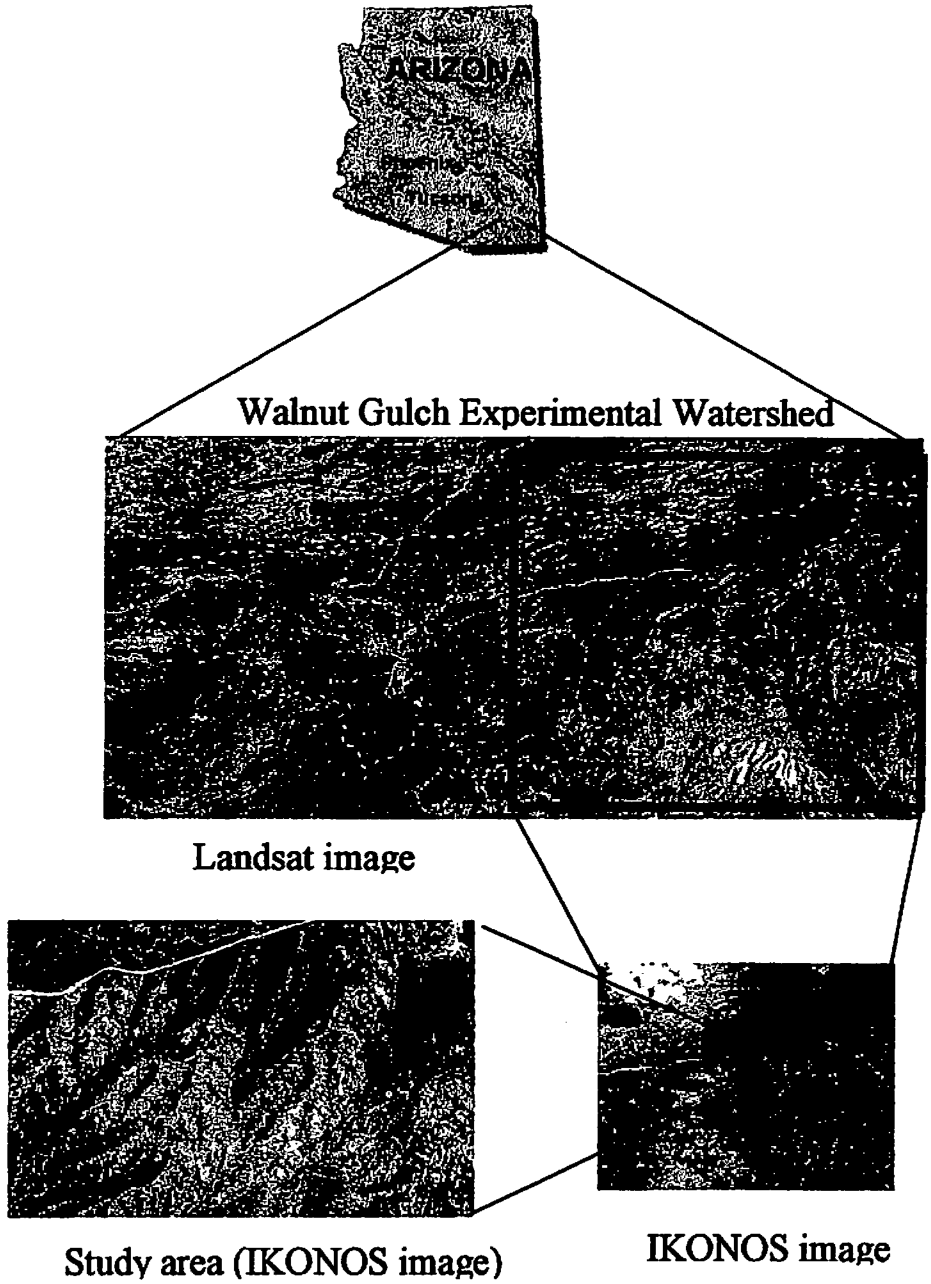

Figure 1. Location of study site illustrated with a Landsat 28 meter multispectral image and an IKONOS 1 meter panchromatic image.

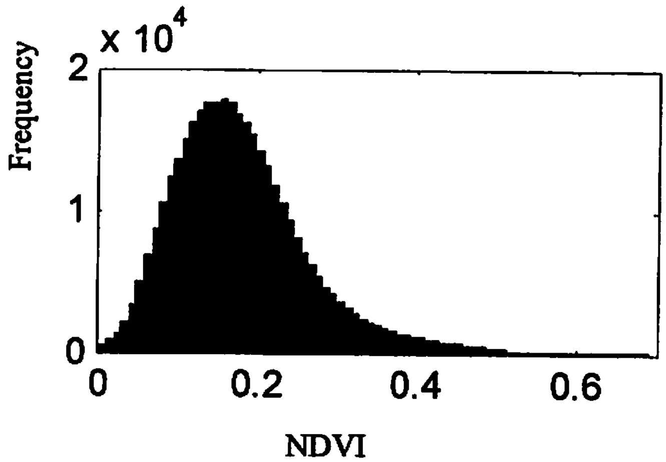

Figure 2. Histogram of NDVI of study site.

Four different areas were extracted from the green biomass image by visually inspecting the 1 meter panchromatic image: one area of mostly shrubs/trees, one area of a mixture of shrubs and grasses, one area of mostly grasslands with no slope and one area of grasslands with a slope 18° away from the sun. Histograms of the panchromatic band of each area were created to see if there was a bimodal distribution of the grass biomass and shrub biomass.

As of this writing, four meter resolution satellite images are not readily available. In fact, IKONOS is the only satellite platform with this resolution that is publicly available. More commonly, satellite resolutions are around 30 meters, such as the Landsat platform which has been transmitting images to Earth since 1972. To test the importance of resolution on distinguishing shrub vegetation, we degraded the IKONOS images to 28 meters in the red and NIR bands and to 15 meters in the panchromatic band to match the resolution of a Landsat image and regenerated the histogram of mixed grassland and shrubland to check for a bimodal distribution. In order achieve enough pixels for a representative histogram, we had to enlarge the mixed grassland shrubland area. The areas of pure grassland and pure shrubland were too small to enlarge to get enough pixels for a representative histogram so the other histograms were not duplicated at the 28 meter resolution.

RESULTS

The histogram of the panchromatic band of 2,319 m^2 of a mixed shrub grassland scene had a bimodal distribution as predicted. The bimodal peaks occurred at *dn* (digital number) of 412 and 505 (Figure 3a). The median value of the scene of mostly shrubs (Figure 3b) was 402, very close to the low bimodal value of the mixed scene. The grassland with the no slope (Figure 3c) had a median value of 526, higher than the bimodal value of the mixed scene. The second grassland scene was darker because of a lower sun angle due its slope away from the sun and had a median value of 436 (Figure 3d), which is 90 *dn* values less that the high bimodal value and 34 *dn* values greater than the low bimodal *dn* value. Thus, sun/slope geometry due to topography has a significant influence over the panchromatic *dn* value of a grassland.

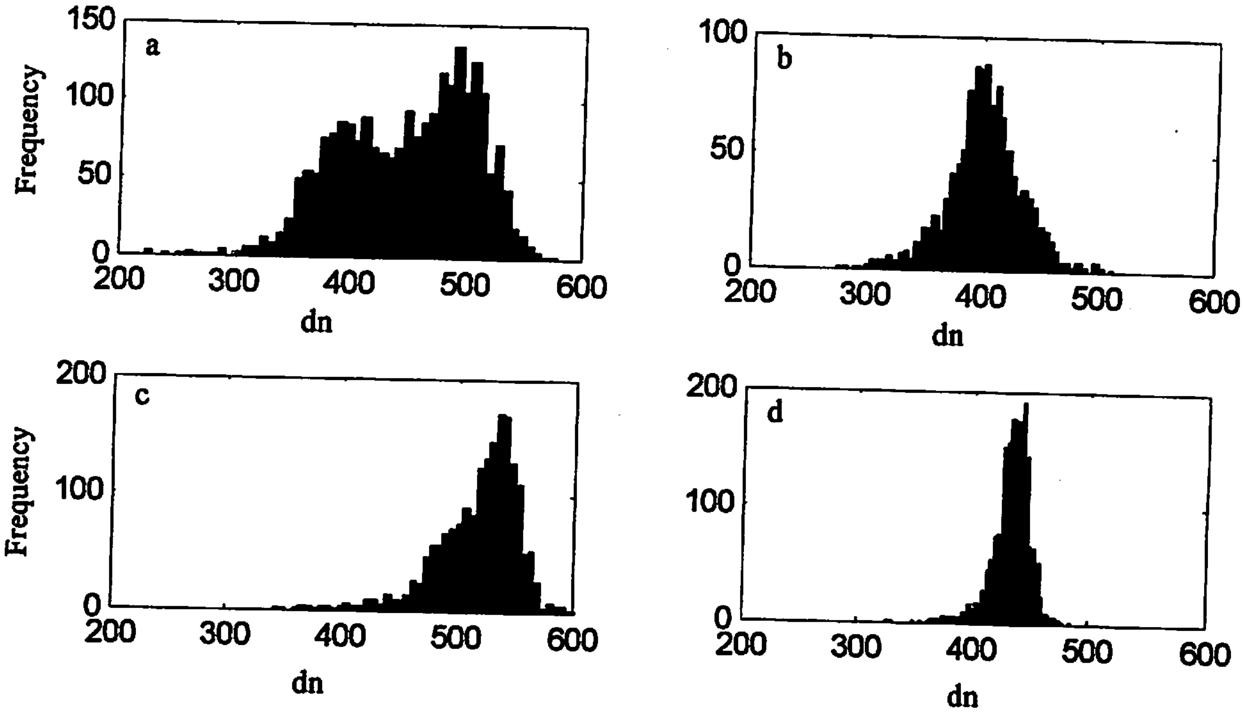

Figure 3. Histograms of 1 meter panchromatic band for selected sites, a) mixed shrubland / grassland, b) shrubs, c) grassland with no slope, d) grassland sloping away from sun

The histogram of the mixed grassland/shrubland area (25,228 m^2) at 15 meter resolution (Figure 4) showed a slight bimodal distribution with the high count values at 401 and 450 panchromatic *dn*. Even at these resolutions, these vegetation types could be separated out at relatively high NDVI values.

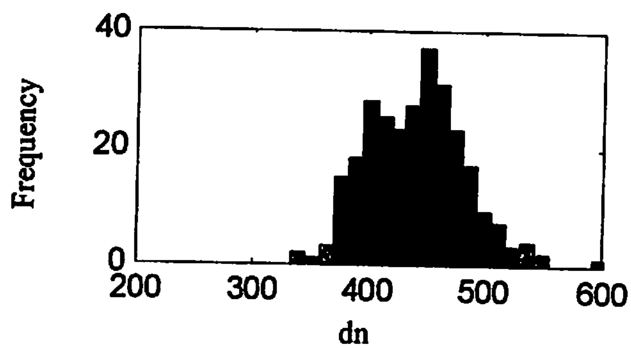

Figure 4. Histogram of a mixed shrub grassland area at 15-meter resolution, panchromatic band.

CONCLUSION

Combining panchromatic images with multispectral bands is a promising technique that merits further investigation. Even at Landsat resolutions, shrubs and grasses with relatively high NDVI could be distinguished by the bimodal distribution of the panchromatic data. Using this technique for historical panchromatic aerial photographs without coincident multispectal information would require making certain assumptions about the live biomass of the grasslands. For example, an aerial photograph acquired at the height of grassland greenup could be used to separate out shrubs from grasses using this histogram technique. Further research involves digitizing a historical black and white photograph, calibrating it to a panchromatic image using common invariant sites and compare the histogram of the historic black and white photo with that of the current panchromatic image for changes in bimodal distribution. Also, to draw quantitative conclusions based on the histograms, detailed field studies of the area imaged will be needed of grassland/shrubland sites.

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