USING HIGH RESOLUTION SATELLITE IMAGERY TO EVALUATE THE RELATIONSHIP BETWEEN HONEY MESQUITE CANOPY COVER AND FORAGE PRODUCTION ON CHIHUAHUAN DESERT

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ABSTRACT

Honey mesquite (*Prosopis glandulosa* Torr.) invasion can negatively impact grazing capacity, spatial livestock distribution, and forage production in Chihuahuan Desert rangelands. High spatial resolution remote sensing data can be used to develop maps of shrub encroachment for arid rangelands. The objective of this study was to use high resolution satellite imagery to map changes in honey mesquite abundance and to evaluate honey mesquite impacts at the Chihuahuan Desert Rangeland Research Center (CDRRC) in south-central New Mexico, USA. QuickBird Ortho-ready satellite image with spatial resolution of 2.4 m in multispectral bands and 0.6 m in panchromatic band was acquired for the study area on May 19, 2009. Maximum likelihood supervised classification algorithm was performed to distinguish honey mesquite from other land cover categories. Grass production (kg/ha) was measured in May, 2009 on 10 permanent, evenly spaced key areas in each pasture. Plots (12 x 60 m) were identified from the classified map and used to calculate honey mesquite canopy cover on the 40 transects across the study area. Areas classified as dominated by honey mesquite estimated from images analyses encompassed 143, 50, 92, and 136 ha in pastures 1, 4, 14, and 15, respectively. Regression analyses showed that increasing levels of honey mesquite canopy cover corresponded to lower perennial grass forage production ($r = + 0.73$, $n = 40$). Our findings indicate that classification of high-resolution satellite imagery is a very useful tool for mapping invasive shrubs and determining their influence on forage production in desert landscapes.

Key words: QuickBird imagery, arid rangelands, remote sensing, supervised classification

INTRODUCTION

Chihuahuan Desert rangelands are important for food production and ecosystem services in southern New Mexico. Many researchers in the southwestern United States have considered mesquite encroachment a major threat to livestock production (Buffington and Herbel 1965, Gibbens et al. 1992, Beck et al. 1994, Gibbens et al. 2005). Based on ground survey studies from New Mexico, honey mesquite canopy cover levels above 18 – 20 % appear to negatively impact perennial grass production (Warren et al. 1996, Moliner et al. 2002, Khumalo 2006). Remote sensing data has been successfully used in several rangelands applications including, classifying and mapping vegetation, assessing rangeland resources, detecting invasive plant species, mapping shrub encroachment, and assessing rangeland condition (Hunt el al. 2003, Laliberate et al. 2004, Everitt et al. 2006, Chopping et al. 2006, Laliberate et al. 2007).

High spatial resolution satellite imagery (IKONOS, QuickBird) provide an opportunity for more accurate assessments of shrub cover. The objectives of this study were: 1) to use QuickBird satellite imagery to map honey mesquite distribution and identify areas where honey mesquite is clearly the dominate species (an invaded site) within in four extensive pastures in the Chihuahuan Desert Rangeland Research Center (CDRRC) in south-central

New Mexico, USA, and 2) to evaluate the relationship between honey mesquite canopy cover and perennial grass forage production at the CDRRC.

MATERIALS AND METHODS

Study Area Description

The study was conducted in four pastures on the New Mexico State University Chihuahuan Desert Rangeland Research Center (CDRRC) (lat 32°32'30"N, long 106°52'30"W)) approximately 37 km north of Las Cruces, NM (Fig. 1). The CDRRC covers an area of 25546 ha and elevation varies from 1330 m at the Rio Grande River to 1945 m at the Peak of Summerford Mountain. The climate on CDRRC is arid, with an average of 200 days of frost-free days. Mean annual precipitation in the northern part of Chihuahuan desert is about 240 mm with 55% of the annual rainfall occurring during the summer peak growing season. Precipitation occurs in two main periods, summer rains during in July – September, and winter precipitation primarily in December to February. Soils of the CDRRC area are mainly sandy loams with underlying calcium carbonate (caliche). The soil depth varies from few centimeters to 1 m or more.

Vegetation Types at CDRRC

According to Paulsen and Ares (1962) vegetation on the Jornada del Muerto plain is classified as Chihuahuan desert grassland and shrubland. The main grassland types on the study area are black grama (*Bouteloua eriopoda*), tobosa (*Hilaria mutica*), dropseed (*Sporobolus spp*) and threeawns (*Aristida spp*). Forbs species on the CDRRC include leather leaf croton (*Croton pottsii* Lam), globemallow (*Sphaeralcea spp*), bladderpod (*Lesquerella fendleri* Gray) and desert holly (*Acourtia nana* Gray). The vegetation on the CDRRC is dominated by honey mesuite (*Prosopis glandulosa* Torr) and snakeweed (*Gutierrezia sarothrae* Pursh).

Historical Background

In 1991, pastures 1, 4, 14, and 15 were delineated and fenced on the CDRRC. The size of these pastures was 1219, 973, 922, and 1267 ha, respectively. Ten permanent transects were established in each of the 4 pastures, giving a total of 40 transects. Each transect consisted of a 61-m line located with a rebar stake at each end and one in the center of the line. These transects were selected on the basis of soil type, plant community, range condition class, mesquite density and distance from water. Transects were also identified by placing a T-post approximately 1.52 m from the first rebar stake. Transects locations were recorded with a GPS receiver and placed on USGS topographical survey maps. From 1995 to present pastures 1 and 15 were stocked with cattle at a light rate (about 25 % forage use), and pastures 4 and 14 were stocked at a conservative rate (about 35% forage use).

QuickBird Satellite Imagery

A QuickBird high-resolution Ortho-ready standard satellite image (DigitalGlobe Inc., Longmont, CO, USA) was acquired for the study area in May 19, 2009. The image covers an area of 4381 ha. The spatial resolution of the image is 60 cm in the panchromatic band and 2.4 m in Multispectral bands. The QuickBird satellite imagery contains four spectral bands: blue (450 – 520 nm), green (520 – 600 nm), red (630-690 nm) and NIR (760 – 900 nm). The image was radiometrically and geometrically corrected and rectified to the world geodetic survey 1984 (WGS 1984) datum and the universal transverse Mercator (UTM) coordinate system prior to delivery.

Image Analysis

In this study we used only the pan sharpened band which has 60 cm spatial resolution to distinguish both small and large honey mesquite shrubs from other land cover categories. Homogenous sites (8 points) of each of the primary vegetation types were located in the pastures using a GPS receiver and used as training sites to perform a supervised classification algorithm. Signatures from each of those homogenous sties were extracted using ERDAS imagine 9.3 software (ERDAS, Inc. 2009). The maximum likelihood classification technique was then used to classify the image of the study area into three main land cover classes, honey mesquite, grass-mix vegetation and bare soil. Both supervised and unsupervised pixel-based classification techniques have been successfully used to classify high resolution satellite imagery (e.g., IKONOS, QuickBird) (Wang et al. 2004, Everitt et al. 2006).

Classified map was evaluated in ArcGIS to calculate areas dominated by honey mesquite in pasture 1, 4, 14 and 15. Forty 12 x 60 m plots were identified from the classified map. Honey mesquite canopy cover was estimated on these 40 subsets (plots) located across the study area.

Accuracy Assessment

In order to determine the accuracy of image classification, we used ERDAS imagine 9.3 software (ERDAS, 2009) to assign 100 points in a stratified random pattern. A GPS receiver was used to navigate to these points for ground truthing. Accuracy assessment measurements including; producer's accuracy, which is the measure of omission error; user's accuracy, which is the measure of commission error; overall accuracy; and Kappa Coefficient were estimated using Erdas imagine 9.3.

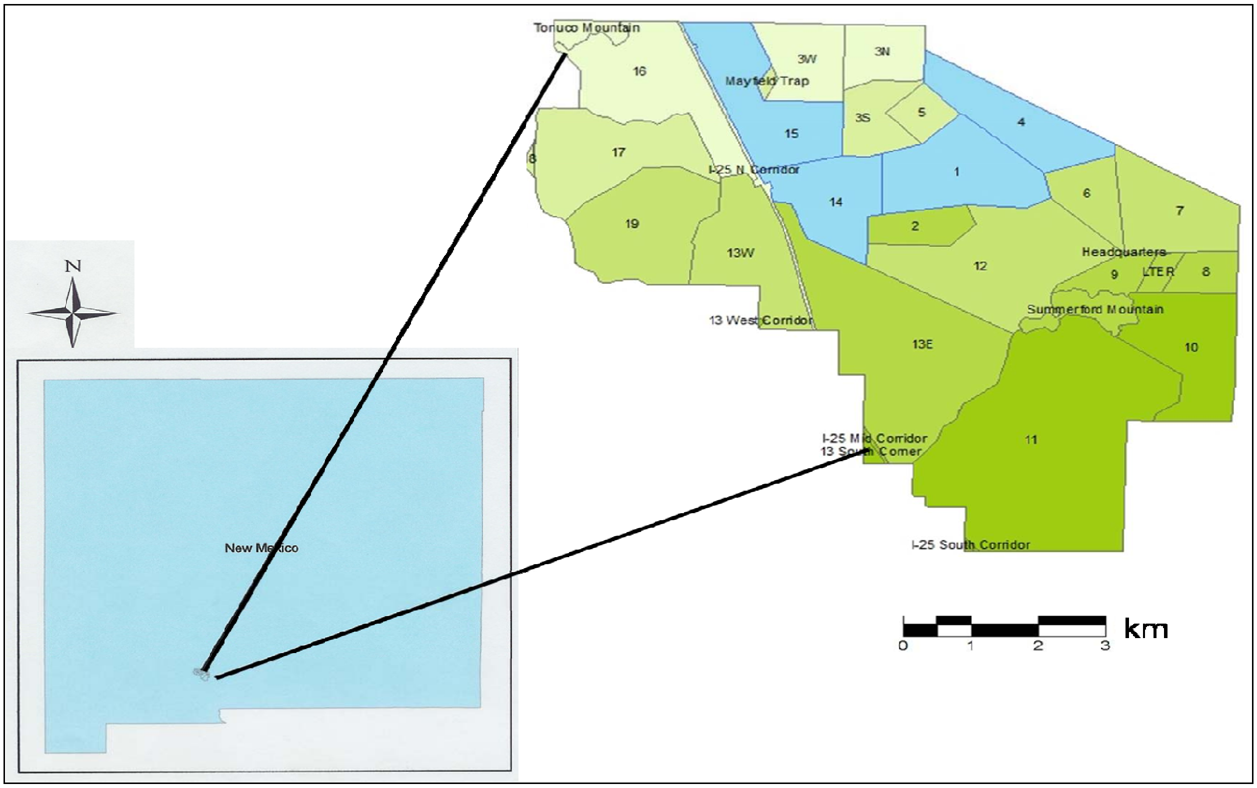

Figure 1. Location of the study area at the Chihuahuan Desert Rangeland Research Center at southern New Mexico.

Regression Analysis

Perennial grass production was measured in May, 2009 by clipping 10 (50 cm x 1 m) plots on each transect located within the 12 x 60 m plots. The primary grass species that were clipped on the study area were black grama, dropseed, and threeawns. Samples were dried for 48 hours at 50° C and then weighed. We evaluated relationship between perennial grass production determined from clipping and honey mesquite canopy cover estimated from the supervised classification of the QuickBird image using a simple linear regression analysis. The dependent variable was grass production and the independent variable was the estimated mesquite cover.

RESULTS AND DISCUSSION

Images Analyses

Large proportion of small honey mesquite shrubs were captured with the QuickBird image classification due to the high bit depth (11bits) in the QuickBird satellite imagery. The image was acquired in early summer; by this time of the year most of honey mesquite shrubs had turned green, while grasses and forbs remained dormant. The differential between mesquite and herbaceous vegetation was very helpful in the separation honey mesquite shrubs from the other types of vegetation. The user's accuracy of honey mesquite class was 93 percent, while the producer's accuracy for the same class was 87 percent (Table 1). About 90% of small and large honey mesquite shrubs were identified in the image classification. Most of the misclassified points occurred between honey mesquite and grass-mix vegetation classes. This confusion might be due to the fact that some of the small honey mesquite shrubs had similar brightness values in the panchromatic image as the grass-mix vegetation category.

Table 1. An error matrix generated from the supervised classification data and ground reference data for May 19, 2009 QuickBird satellite image of four pastures at CDRRC.

Classification data	Reference data					
	Honey mesquite	Grass-mix vegetation	Bare soil	water	Total	User's accuracy %
Honey mesquite	41	3	0	0	44	93
Grass-mix vegetation	6	29	2	0	37	78
Bare soil	0	3	14	0	17	82
Water	0	0	0	2	2	100
Total	47	35	16	2	100	
Producer's accuracy %	87	83	88	100		

Overall = 92,   kappa coefficient = 0.873

Our results indicate that maximum likelihood supervised classification technique combined with high spatial resolution satellite imagery can be used to produce vegetation maps for arid rangelands. Table 1 shows an error matrix comparing the supervised classified map (Fig. 2) with the ground reference data for the 100 ground truthing points within the study area. The user's accuracy of individual categories ranged from 78% for the grass- mix veget-

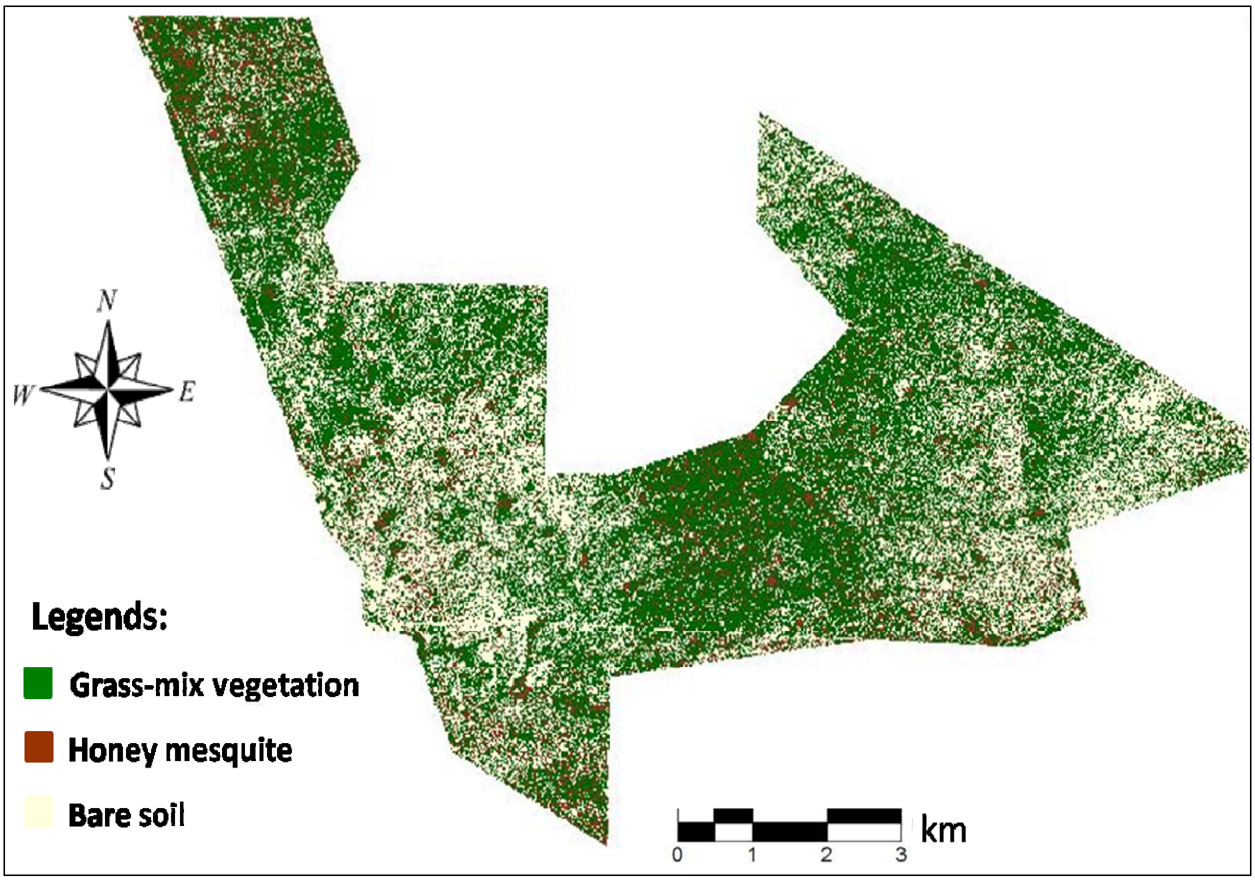

Figure 2. Classified QuickBird satellite image for pasture 1, 4, 14, and 15 at the Chihuahuan Desert Rangeland Research Center at southern New Mexico.

ation class to 100 % for the water storage tanks. The producer's accuracy ranged from 83% for the grass-mix vegetation to 100% for the water storage tanks. Overall accuracy shows that 92% of the all class pixels in the image were correctly identified in the classified map. The kappa coefficient was 0.873, indicating the supervised classification achieved an accuracy that is 87% better than would be expected from the random assignment of pixels to classes. Our findings regarding the accuracy of QuickBird satellite imagery pixels based classification algorithms were similar to other studies from the southwestern United States (Everitt et al. 2006, Everitt et al. 2008). These authors found that accuracy of pixel based classification of QuickBird images was 89 % and 93 %, respectively.

Mapping Honey Mesquite

Maximum likelihood supervised classification of the pan sharpened QuickBird satellite imagery of the study area is shown in Fig. 2. The study area covers 4 pastures that have an area of 4381 ha. Pastures 1, 4, 14 and 15 were enclosed 1219, 973, 922, and 1267 ha, respectively. Areas classified as dominated solely by honey mesquite estimated from images analyses were 143, 50, 92, and 136 ha in pastures 1, 4, 14, and 15, respectively. Results of this study regarding mesquite encroachment areas estimated from image analyses were similar to those determined in the same pastures from ground surveys by Molinar et al. (2002) and Khumalo (2006).

Relationship Between Honey Mesquite Canopy Cover and Perennial Grass Production

Honey mesquite canopy cover levels in the forty plots (12 x 60 m) ranged from a low cover level of 2 % in grass dominated areas to high cover levels of 30 % in honey mesquite dunes (Fig. 3). About 70 % of the plots used to estimate honey mesquite canopy cover had honey mesquite canopy cover levels of 16 % or less (Fig. 4). The other 30 % of those plots had honey mesquite canopy cover of 20 to 31 %. Regression analyses showed that increasing in levels of honey mesquite canopy cover corresponded to lower perennial grass forage production ($r = +0.73$, $n = 40$, $y = -14.355x + 430.248$). Our data shows honey mesquite can adversely affect perennial grass production even under proper grazing management. Several researchers reported that mesquite canopy cover less than 15 – 20 % had little effect on forage production; however, honey mesquite canopy cover above 15 – 20 % appears to negatively impact perennial grass production (McDaniel et al. 1982, Warren et al. 1996, Moliner et al. 2002, Khumalo 2006).

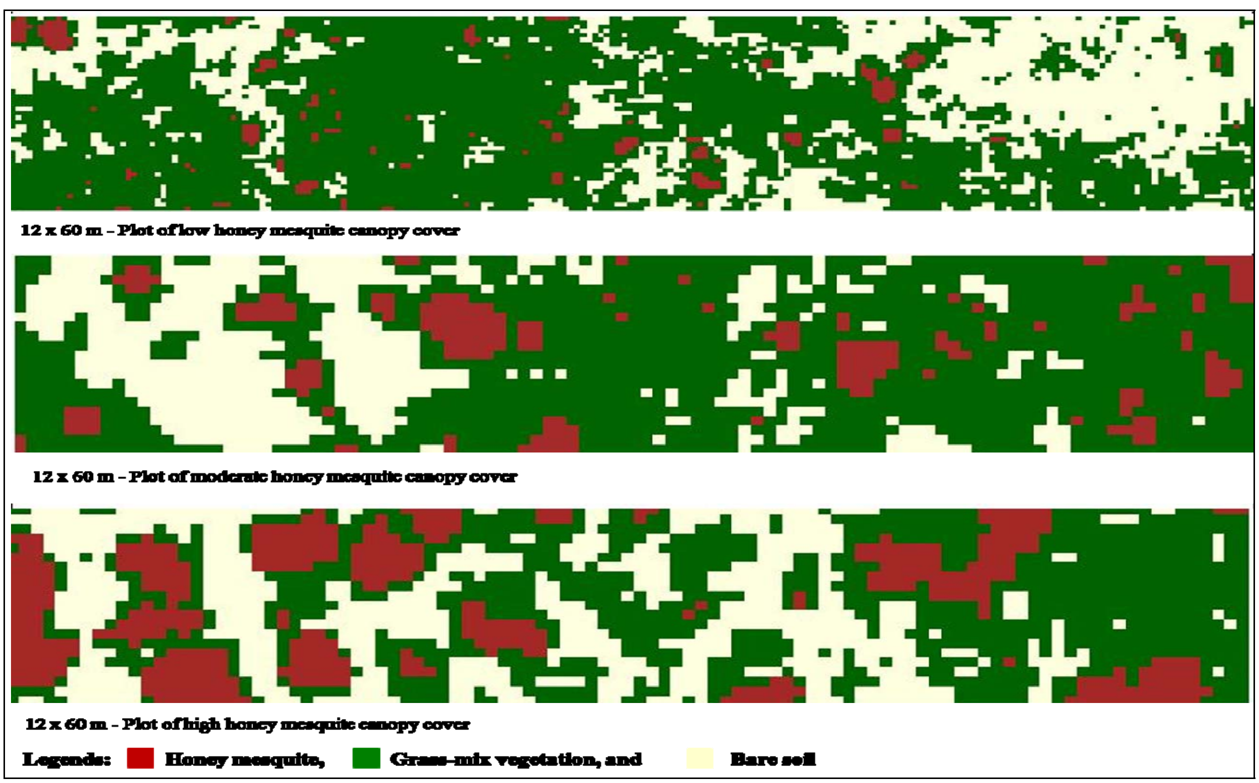

Figure 3. Examples of the various honey mesquite canopy cover levels at the study area at the Chihuahuan Desert Rangeland Research Center at southern New Mexico.

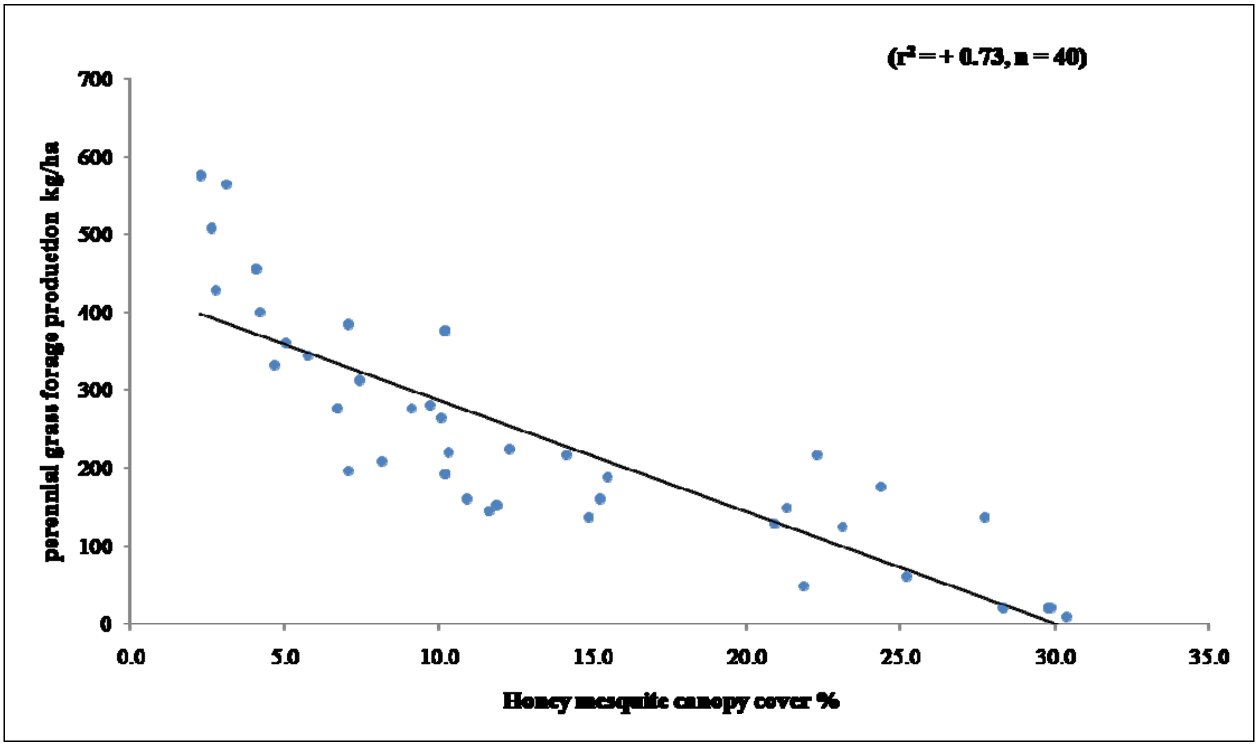

Figure 4. The relationship between honey mesquite canopy cover and perennial grass forage production for four pastures at the Chihuahuan Desert Rangeland Research Center at southern New Mexico.

CONCLUSION

Our results indicate that maximum likelihood supervised classification technique is an effective method to classify high spatial resolution satellite imagery for arid rangelands. QuickBird satellite imagery can be used to map honey mesquite and estimate mesquite invaded areas in the Chihuahuan Desert rangelands. Perennial grass production declines linearly as mesquite canopy cover increases. The classified map had an overall accuracy of 92%.

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