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# Remote Sensing of Giant Reed with QuickBird Satellite Imagery

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## ABSTRACT

QuickBird high resolution (2.8 m) satellite imagery was evaluated for distinguishing giant reed (*Arundo donax* L.) infestations along the Rio Grande in southwest Texas. The imagery had four bands (blue, green, red, and near-infrared) and contained 11-bit data. Three subsets of the satellite image were extracted and used as study sites. Unsupervised classification techniques were used to classify false color (green, red, and near-infrared bands) and normal color (blue, green, and red bands) composite images of each site. Accuracy assessments performed on the classification maps of the three sites had producer's and user's accuracies for giant reed that ranged from 86% to 100%. Both false color and normal color satellite imagery did an excellent job in distinguishing giant reed infestations.

*Key words:* QuickBird satellite imagery, false color imagery, normal color imagery, image analysis, accuracy assessment, *Arundo donax*.

## INTRODUCTION

Giant reed is a robust, perennial grass 2-8 m tall growing in many-stemmed, cane-like clumps. It is thought to be native to India, but has been widely introduced as an ornamental and for bank stabilization. Subsequently, it has become invasive in many tropical, subtropical, and warm-temperate regions of the world (Dudley 2000). Giant reed was introduced in California in the early 1800s and quickly became naturalized. It is now found throughout the southern half of the United States from Maryland to California, but is most invasive along creeks and rivers in the southwestern United States, with the densest stands growing along coastal rivers in California and along the Rio Grande in west and southwest Texas (Dudley and Collins 1995, Bell 1997, Tracy and Deloach 1998). Giant reed is a severe threat to riparian areas where it displaces native plants and animals by forming massive stands that pose a wildfire threat (Frandsen and Jackson 1994). It also consumes excessive amounts of water and alters channel morphology by retaining sediments and constricting flows (Bell 1997, Dudley 2000).

Everitt et al. (2004) recently described the light reflectance characteristics of giant reed and demonstrated the application of aerial photography and videography for detecting and mapping giant reed infestations in Texas riparian areas. In the past few years, high spatial resolution (2.4 to 4 m) satellite imagery from commercial satellite systems has become available for remote sensing applications. Image data from digital multispectral sensors on board the Space Imaging IKONOS and DigitalGlobe QuickBird satellites enable detailed observations in visible and near-infrared wavebands. The spatial resolution of these systems offers new opportunities for distinguishing noxious weeds from space platforms. The objective of this study was to evaluate QuickBird satellite imagery for detecting giant reed infestations in a riparian area in southwest Texas.

## MATERIALS AND METHODS

This study was conducted along the Rio Grande near Del Rio (29°17 W, 100°51 N) in southwest Texas. This area is in the Rio Grande Plain vegetational region of Texas (Hatch et al. 1990). Satellite imagery, computer image analysis, and ground truth were conducted for this study.

Multispectral satellite imagery from the DigitalGlobe, Inc.[3] (Longmont, Colorado) QuickBird high resolution (2.8 m) satellite was used for this study. The QuickBird satellite sensors consist of the blue (450 to 520-nm), green (520 to 600-nm), red (630 to 690-nm), and near-infrared (760 to 900-nm) bands. Satellite imagery of the giant reed study area was acquired on 15 September 2003. Prior to delivery, the imagery was radiometrically and geometrically corrected, and rectified to the world geodetic survey 1984 (WGS84) datum and the universal transverse Mercator (UTM) coordinate system. The pre-rectified standard imagery has an average absolute positional error of 23 m and a root mean square (RMS) error of 14 m. To improve the positional accuracy, the pre-rectified imagery was further rectified based on a set of ground points collected from the imaging area with a sub-meter accuracy global positional system (GPS) receiver. The RMS error of the rectified imagery was reduced to less than 5 m. The procedures for image rectification were performed using Erdas Imagine software (Erdas 2002).

For this study we used both normal color and false color (color-infrared) satellite imagery, as these are the standard image types used for aerial photography and many airborne electronic imaging systems. The normal color consisted of the blue, green, and red bands, while the false color consisted of the green, red, and near-infrared bands. Three subset images

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[3]Trade names are included for information purposes only and do not imply endorsement of or a preference for the product listed by the United States Department of Agriculture.

were extracted from the satellite scene of the entire study area and used as individual study sites. The subsets were located adjacent to the Rio Grande on the United States side of the border. Each subset image had giant reed and four other typical surface cover types within the study area. The same cover types were found on each subset image. The three locations were designated as sites 1, 2, and 3. Both conventional color and false color composite images were developed for each site.

The images of the three study sites were subjected to an Iterative Self Organizing Data Analysis (ISODATA) that performs unsupervised classifications on the basis of specified iterations and recalculates statistics for each iteration (Erdas 2002). The ISODATA technique uses minimum spectral distance to assign a cluster for each selected pixel. It begins with arbitrary cluster means, and each time the clustering repeats, the means of the classes are shifted. The new cluster means are used for each iteration.

Each unsupervised classification created five classes. The classes consisted of giant reed, mixed brush, dry grass/scrub brush, soil, and water. Mixed brush was dominated by honey mesquite (*Prosopis glandulosa* Torr.), blackbrush (*Acacia rigidula* Benth.), desert hackberry (*Celtis pallida* Torr.), and Mexican persimmon (*Diospyros texana* Scheele). The dry grass/scrub brush class is comprised of short grasses including red grama (*Bouteloua trifida* Thurb.) and three-awn (*Aristida* sp.), and short statured woody plants and cacti including guayacan (*Guaiacum angustifolium* G. Engelm.), knife-leaf condalia (*Condalia spathulata* Gray), lotebush (*Ziziphus obtusifolia* Torrey & Gray), cenizo [*Leucophyllum frutescens* (J. Berlandier) I. M. Johnston], and prickly pear cactus (*Opuntia lindheimeri* Engelm.).

For accuracy assessment, 100 points were assigned to the classes for each site in a stratified random pattern using Erdas Imagine software (Erdas 2002). For each site the geographic coordinates of the points were determined and the GPS was used to navigate to the points in ground truthing. The overall accuracy, producer's accuracy, and user's accuracy were calculated for each site (Congalton 1991, Congalton and Green 1999). Overall accuracy is the division of the total number of correct points by the total number of points. The producer's accuracy is the total number of correct points in a category divided by the total number of points of that category as derived from the reference data (ground truthing). The user's accuracy is the total number of correct points in a category divided by the total number of points of that category as derived from the classification data or map data.

## RESULTS AND DISCUSSION

The false color satellite image of the site 1 study area is shown in Figure 1A. The arrow points to the dark pink image tonal response of giant reed that can be easily distinguished from other surface types. Mixed brush has a dark red to reddish-brown response, dry grass/scrub brush has a variable blue-gray to gray color, and soil has a light blue to white tone.

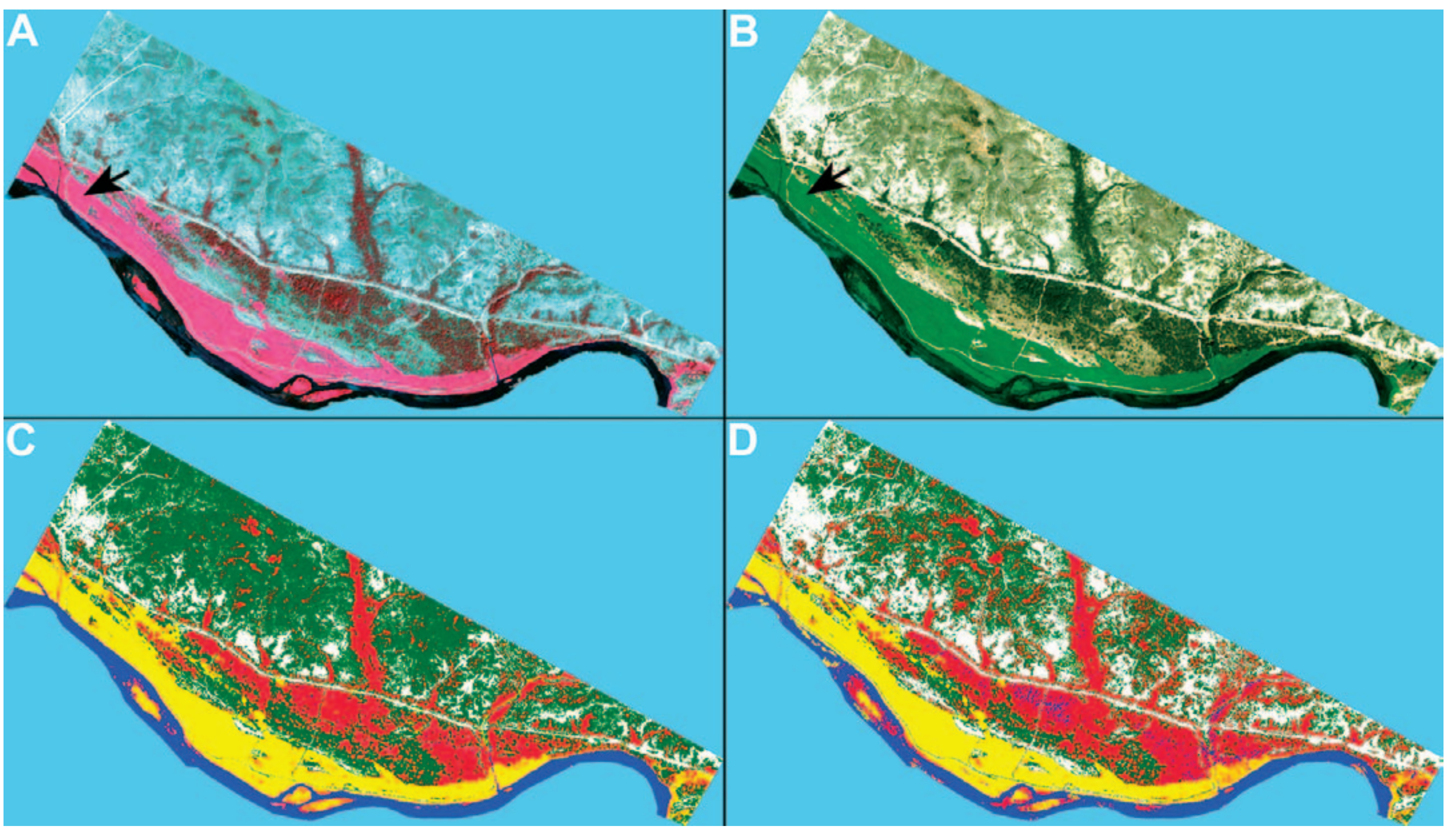


Figure 1. QuickBird false color (A) and normal color (B) satellite images of the site 1 study area on the Rio Grande near Del Rio, Texas. The arrows on the two images point to giant reed. Prints C and D show unsupervised classification maps for the false color and normal color satellite images, respectively. Color codes for the various surface types on the computer classifications are: yellow = giant reed, red = mixed brush, green = dry grass/scrub brush, white = soil, and blue = water.

TABLE 1. AN ERROR MATRIX GENERATED FROM THE CLASSIFICATION DATA AND GROUND DATA FOR THE SEPTEMBER 15, 2003 QUICKBIRD FALSE COLOR SATELLITE IMAGE OF SITE 1 ON THE RIO GRANDE NEAR DEL RIO, TEXAS.

| | Actual category | | | | | | |
|---|---|---|---|---|---|---|---|
| Classified category | Water | Giant Reed | Mixed brush | Dry grass/scrub brush | Soil | Total | User's accuracy |
| Water | 10 | 0 | 0 | 0 | 0 | 10 | 100.0% |
| Giant Reed | 0 | 17 | 0 | 0 | 0 | 17 | 100.0% |
| Mixed brush | 0 | 1 | 16 | 0 | 0 | 17 | 94.1% |
| Dry grass/scrub brush | 0 | 0 | 7 | 33 | 1 | 41 | 80.5% |
| Soil | 0 | 0 | 0 | 8 | 7 | 15 | 46.7% |
| Total | 10 | 18 | 23 | 41 | 8 | 100 | |
| Producer's accuracy | 100.0% | 94.4% | 69.6% | 80.5% | 87.5% | | |

Overall accuracy = 83.0%. Overall Kappa = 0.770.

The Rio Grande (dark blue to black tone) borders the lower portion of the image.

The distinct image response of giant reed was attributed to its high visible green and near-infrared reflectance (Everitt et al. 2004). Mixed brush species such as honey mesquite and blackbrush have low to moderate visible and near-infrared reflectance. Dry grass and scrub brush have low to moderate visible reflectance and generally low near-infrared reflectance (Everitt 1985, Everitt et al. 2004).

The unsupervised classification of the false color satellite image (Figure 1A) of the site 1 study area is shown in Figure 1C. Color codes for the various surface types are yellow = giant reed, red = mixed brush, green = dry grass/scrub brush, white = soil, and blue = water. A qualitative comparison of the classified map to the satellite image suggests that the unsupervised classification successfully identified giant reed and most of the other surface types.

The error matrix showing comparison of the classified data with the ground data for the 100 observations within the site 1 study area is presented in Table 1. The overall accuracy was 83%, indicating that 83% of the category pixels in the image were correctly identified in the classification map. The producer's accuracy of individual classes ranged from 69.6% for mixed brush to 100% for water. The user's accuracy ranged from 46.7% for soil to 100% for water and giant reed. Giant reed had a producer's accuracy of 94.4%. Giant reed and water were the easiest classes to identify. The lower producer's accuracy of mixed brush was due to its confusion with dry grass/scrub brush, whereas the poor user's accuracy of soil was due to its confusion with dry grass/scrub brush. The misclassification errors between these classes were attributed to their similar spectral signatures and grading from one surface type to the other. The kappa estimate was 0.770, indicating the classification achieved an accuracy that is 77% better than would be expected from the random assignment of pixels to classes (Congalton and Green 1999).

Giant reed (arrow) has a distinct bright green image in the normal color image of site 1 (Figure 1B). Mixed brush has a dark green response, dry grass/scrub brush has a light gray-green or tan image tone, soil has a white color, and water has a dark blue tone. The conspicuous image response of giant reed was attributed to its high visible green reflectance (Everitt et al. 2004).

The unsupervised classification of the normal color image is shown in Figure 1D. Color codes for the five surface types are the same as those used in the classification of the false color image. The computer classification color codes generally correspond to their respective surface types in the normal color image.

The error matrix showing comparison of the classified data with the ground data for the normal color image of site 1 is shown in Table 2. The overall accuracy was 79%. Giant

TABLE 2. AN ERROR MATRIX GENERATED FROM THE CLASSIFICATION DATA AND GROUND DATA FOR THE SEPTEMBER 15, 2003 QUICKBIRD NORMAL COLOR SATELLITE IMAGE OF SITE 1 ON THE RIO GRANDE NEAR DEL RIO, TEXAS.

| | Actual category | | | | | | |
|---|---|---|---|---|---|---|---|
| Classified category | Water | Giant Reed | Mixed brush | Dry grass/scrub brush | Soil | Total | User's accuracy |
| Water | 8 | 0 | 0 | 0 | 0 | 8 | 100.0% |
| Giant Reed | 0 | 17 | 0 | 0 | 0 | 17 | 100.0% |
| Mixed brush | 2 | 1 | 19 | 3 | 0 | 25 | 76.0% |
| Dry grass/scrub brush | 0 | 0 | 4 | 27 | 0 | 31 | 87.1% |
| Soil | 0 | 0 | 0 | 11 | 8 | 19 | 42.1% |
| Total | 10 | 18 | 23 | 41 | 8 | 100 | |
| Producer's accuracy | 80.0% | 94.4% | 82.6% | 65.9% | 100.0% | | |

Overall accuracy = 79.0%. Overall Kappa = 0.724.

Table 3. An error matrix generated from the classification data and ground data for the September 15, 2003 QuickBird false color satellite image of site 2 on the Rio Grande near Del Rio, Texas.

| | Actual category | | | | | | |
|---|---|---|---|---|---|---|---|
| Classified category | Water | Giant Reed | Mixed brush | Dry grass/scrub brush | Soil | Total | User's accuracy |
| Water | 10 | 0 | 0 | 0 | 0 | 10 | 100.0% |
| Giant Reed | 0 | 19 | 0 | 0 | 0 | 19 | 100.0% |
| Mixed brush | 0 | 2 | 9 | 1 | 0 | 12 | 75.0% |
| Dry grass/scrub brush | 0 | 0 | 8 | 27 | 0 | 35 | 77.1% |
| Soil | 0 | 1 | 0 | 8 | 15 | 24 | 62.5% |
| Total | 10 | 22 | 17 | 36 | 15 | 100 | |
| Producer's accuracy | 100.0% | 86.4% | 52.9% | 75.0% | 100.0% | | |

Overall accuracy = 80.0%. Overall Kappa = 0.739.

reed had a producer's accuracy of 94.4% and a user's accuracy of 100%, which was identical to the results from the classification of the false color image. The poor user's accuracy of soil was due to its confusion with dry grass/scrub brush. The kappa estimate was 0.724.

The error matrix showing comparison of the classified data with the ground data for the 100 observations from the false color image of site 2 is shown in Table 3 (satellite image and computer classification not shown). The overall classification accuracy was 80%. Water and giant reed were the easiest classes to identify. Giant reed had a producer's accuracy of 86.4% and a user's accuracy of 100%. The poorer producer's accuracy of mixed brush was due to confusion with dry grass/scrub brush. An accuracy assessment performed on the normal color satellite image of site 2 had an overall accuracy of 80% (data not shown). Giant reed had a producer's and user's accuracy of 91%.

The error matrix showing comparison of the classified data with the ground data from the false color image of site 3 is presented in Table 4 (satellite image and computer classification not shown). The overall classification accuracy was 77%. Giant reed had a producer's accuracy of 95% and user's accuracy of 100%. Giant reed and water were the easiest classes to identify. The poor user's accuracy of soil was due to its confusion with dry grass/scrub brush. An accuracy assessment performed on the normal color image of site 3 had an overall accuracy of 76% (data not shown). Giant reed had both a producer's and user's accuracy of 100%.

Results from this study indicate that QuickBird satellite imagery combined with image processing can be used successfully for distinguishing giant reed infestations along the Rio Grande in southwest Texas. Accuracy assessments performed on unsupervised classification maps of false color imagery from three study sites had mean producer's and user's accuracies of 92% and 100%, respectively. The same procedure performed on maps of normal color imagery from the same three study sites had mean producer's and user's accuracies of 95% and 97%, respectively. Based on these findings, false color and normal color imagery were deemed equal for distinguishing giant reed infestations. The accuracy assessment data presented in this study are comparable to those obtained from higher resolution aerial photographic and videographic imagery of giant reed in Texas riparian areas (Everitt et al. 2004). They are also in agreement with accuracy assessment data reported by Dipietro et al. (2002) and Underwood et al. (2003) who used AVIRIS hyperspectral imagery to map giant reed and other nonnative plants in southern California. Giant reed normally forms very dense stands in riparian zones and this characteristic along with its distinct spectral characteristics probably contributes greatly to the high computer classification accuracies obtained on this invasive weed. The ability to distinguish giant reed on satellite imagery

Table 4. An error matrix generated from the classification data and ground data for the September 15, 2003 QuickBird false color satellite image of site 3 on the Rio Grande near Del Rio, Texas.

| | Actual category | | | | | | |
|---|---|---|---|---|---|---|---|
| Classified category | Water | Giant Reed | Mixed brush | Dry grass/scrub brush | Soil | Total | User's accuracy |
| Water | 10 | 0 | 0 | 0 | 0 | 10 | 100.0% |
| Giant Reed | 0 | 19 | 0 | 0 | 0 | 19 | 100.0% |
| Mixed brush | 0 | 0 | 10 | 1 | 0 | 11 | 90.9% |
| Dry grass/scrub brush | 0 | 1 | 3 | 27 | 6 | 37 | 73.0% |
| Soil | 0 | 0 | 0 | 12 | 11 | 23 | 47.8% |
| Total | 10 | 20 | 13 | 40 | 17 | 100 | |
| Producer's accuracy | 100.0% | 95.0% | 76.9% | 67.5% | 64.7% | | |

Overall accuracy = 77.0%. Overall Kappa = 0.694.

should be useful to resource managers who are interested in mapping infestations over large and inaccessible areas. The satellite imagery can serve as a permanent geographically located image database to monitor future contraction or spread of giant reed over time. QuickBird imagery can be purchased for approximately $1900 for a 64 $km^2$ area.

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