J. Aquat. Plant Manage. 46: 77-82

Comparison of QuickBird and SPOT 5 Satellite Imagery for Mapping Giant Reed

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ABSTRACT

QuickBird (2.4 m resolution) and SPOT 5 (10 m resolution) multi-spectral satellite imagery were compared for mapping the invasive grass, giant reed (*Arundo donax* L.), along the Rio Grande in southwest Texas. The imagery had three bands (green, red, and near-infrared). Three subsets from both the QuickBird and SPOT 5 images were extracted and used as study sites. The same subsets were extracted from both images. The images were subjected to supervised image analysis. Accuracy assessments performed on QuickBird classification maps from the three sites had producer's and user's accuracies for giant reed that ranged from 92% to 100%. Accuracy assessments performed on SPOT 5 classification maps from the three sites had producer's and user's accuracies for giant reed ranging from 75.7% to 93.3%. The lower accuracies of the SPOT 5 image classifications were attributed to its coarser resolution.

Key words: accuracy assessment, *Arundo donax*, false color imagery, QuickBird satellite imagery, SPOT 5 satellite imagery, supervised image analysis.

INTRODUCTION

Giant reed (*Arundo donax* L.) is a weedy perennial grass 3 to 10 m tall growing in many-stemmed cane-like clumps, spreading from horizontal root stocks below the soil and often forming dense colonies. It spreads vegetatively by either rhizomes or plant fragments (Perdue 1958, Dudley 2000). Giant reed is believed to be native to the Old World from Spain to India, but has been widely introduced as an ornamental and for bank stabilization (Hitchcock 1971, Polunin and Huxley 1987). This species has been cultivated in the Old World for thousands of years and has been widely planted in North and South America in the past two centuries (Perdue 1958, Dudley 2000). Giant reed was introduced to California from the Mediterranean in the 1820s and quickly became naturalized (Hoshovsky 1987). It now occurs throughout the southern United States from Maryland to California, but is most invasive along creeks and rivers in the southwestern United States. The densest infestations of giant reed occur 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 uses about three times as much water as native vegetation (Iverson 1994), and under optimum conditions can attain growth rates of 0.7 m per week or 10 cm per day, putting it among the fastest growing plants (Perdue 1958, Bell 1997). It also alters channel morphology by retaining sediments and constricting flows and may reduce stream navigability (Bell 1997, Dudley 2000). In addition, giant reed is a threat to riparian environments where it displaces native plants and animals by forming massive stands that pose a wildfire threat (Frandsen and Jackson 1994).

Several researchers have used remote sensing techniques to distinguish giant reed. Dipietro et al. (2002) and Underwood et al. (2003) used AVIRIS hyperspectral imagery to map giant reed and other nonnative plants in southern California. Everitt et al. (2004) described the light reflectance characteristics of giant reed and used aerial color-infrared photography and videography, coupled with global positioning system (GPS) and geographic information system (GIS) technologies, to distinguish and map giant reed infestations in Texas. Everitt et al. (2005) used QuickBird multi-spectral satellite imagery (2.4 m) to map giant reed in a riparian zone in southwest Texas.

SPOT 5 multispectral satellite imagery (10 m) has shown value for vegetation assessment. Pasqualini et al. (2005) used SPOT 5 for mapping seagrass beds in the Mediterranean Sea. More recently, Weber et al. (2006) used SPOT 5 to map the invasive weed leafy spurge (*Euphorbia esula* L.) in southeastern Idaho.

To our knowledge SPOT 5 has not been used to assess giant reed. The objective of this paper was to compare QuickBird and SPOT 5 multi-spectral imagery for mapping giant reed.

MATERIALS AND METHODS

This study was conducted along the Rio Grande River near Del Rio (29°17W, 100°51N) in southwest Texas, an area with a large infestation of giant reed. QuickBird and SPOT 5 multi-spectral satellite imagery, followed by computer image analysis and accuracy assessments of image analysis maps, were used for this study.

Multispectral QuickBird imagery was obtained from DigitalGlobe, Inc. (Longmont, CO).[3] The QuickBird green (520 to 600 nm), red (630 to 690 nm), and near-infrared (760 to 900 nm) sensor bands were used in this study. The imagery

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was acquired from the study area on 25 August 2005. SPOT 5 multispectral imagery was obtained from SPOT Image Company (Reston, Va.). The green (500 to 590 nm), red (610 to 68 -nm), and near-infrared (780 to 890 nm) sensor bands were used. SPOT 5 imagery of the study area was obtained 31 August 2005. The green, red, and near-infrared bands from both satellites provided a false color composite image similar to that of color-infrared film. Imagery from both satellites was radiometrically corrected and georeferenced prior to delivery.

Three subset images were extracted from both satellite scenes of the entire study area and used as individual study sites. The same three subsets were extracted from both images. The subset images were rectified to a previously georeferenced QuickBird panchromatic satellite image (0.7-m resolution) of the study sites. A Trimble differential global positioning system (GPS) Pathfinder Pro XRS system that provided sub-meter accuracy was used in the field to establish control points on the panchromatic image (Erdas 2002). 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 types within the study area. The same cover types were found on each subset image. The three locations were designated sites 1, 2, and 3.

QuickBird and SPOT 5 images from the three study sites were subjected to supervised image analysis techniques. Five subsamples were selected from each of five surface types (classes) from each image to be used as training sites. The five classes consisted of giant reed, mixed brush, dry grass/scrub brush, soil, and water. The Maximum Likelihood classifier was used to classify the images (Erdas 2002).

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 was comprised of short grasses including red grama (*Bouteloua trifida* Thurb.) and three-awn (*Aristida* spp.), 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.).

To assess accuracy for the three sites (1, 2, and 3), 125, 150, and 100 points, respectively, were assigned to the classes in a stratified random pattern using Erdas Imagine software (Erdas 2002). The geographic coordinates of the points were determined and a GPS receiver was used to navigate to the points for ground truthing. Overall accuracy, producer's accuracy, user's accuracy, and overall kappa coefficient were calculated for each site (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 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. The overall kappa coefficient indicates how well the classification results agree with the reference data.

RESULTS AND DISCUSSION

The false color QuickBird and SPOT 5 images of study site 1 (Figure 1A, B) have similar tonal responses. The arrow on the QuickBird image points to the distinct dark pink image response of giant reed; mixed brush has a red image tone; dry grass/scrub brush has a light gray color; and soil has a white image response. The Rio Grande has a dark blue color and borders the lower portion of the images.

Supervised classifications (Figure 1C, D) and error matrices (Tables 1 and 2) for the QuickBird and SPOT 5 images compare classified data with ground data for the 125 observations within study site 1. The overall classification accuracies for the QuickBird and SPOT 5 images were 83.2% and 79.2%, respectively, indicating the percent of category pixels in each image that were correctly identified in the classification map.

For the QuickBird image (Table 1), the producer's accuracy for individual categories ranged from 60% for soil to 100% for water. Giant reed had a producer's accuracy of 93.3%. The user's accuracy ranged from 60% for soil to 100% for giant reed, mixed brush, and water. The poor producer's and user's accuracies of soil were due to its confusion with dry grass/scrub brush. The lower producer's accuracy of mixed brush was due to its confusion with dry grass/scrub brush. The misclassification errors between these classes were attributed to grading from one surface type to the other (Everitt et al. 2005). Thomlinson et al. (1999) set an overall accuracy target of 85% with no class accuracy lower than 70%. Based on these guidelines, the overall accuracy was slightly lower than acceptable. However, the producer's and user's accuracies for giant reed were excellent. The kappa estimate was 0.769, indicating the classification achieved an accuracy that is 76.9% better than would be expected from the random assignment of pixels to classes (Congalton and Green 1999).

The SPOT 5 site 1 image producer's accuracy for the individual categories ranged from 46.7% for soil to 100% for water. The user's accuracy ranged from 58.3% for soil to 100% for water. Giant reed had producer's and user's accuracies of 86.7% and 92.9%, respectively, both considered very good. The poor producer's accuracy of soil was due to its confusion with dry grass/scrub brush, while the poor user's accuracy of soil was due to its confusion with dry grass/scrub brush and giant reed. The kappa estimate was 0.713.

The error matrices comparing classified data with ground data for the 150 observations from the supervised classifications of the QuickBird and SPOT 5 images of study site 2 (Tables 3 and 4, respectively; images and computer maps not shown) show the overall classification accuracies for the QuickBird and SPOT 5 scenes were 85.3% and 76.7%, respectively. For the QuickBird image, giant reed had a producer's accuracy of 100% and a user's accuracy of 93.1%. Both the producer's and user's accuracies for giant reed from the SPOT 5 image classification were 77.8%. The misclassification of giant reed in the producer's and user's accuracies from the SPOT 5 classification was primarily due to it confusion with dry grass/scrub brush. The kappa estimates for the QuickBird and SPOT 5 image classifications were 0.789 and 0.657, respectively.

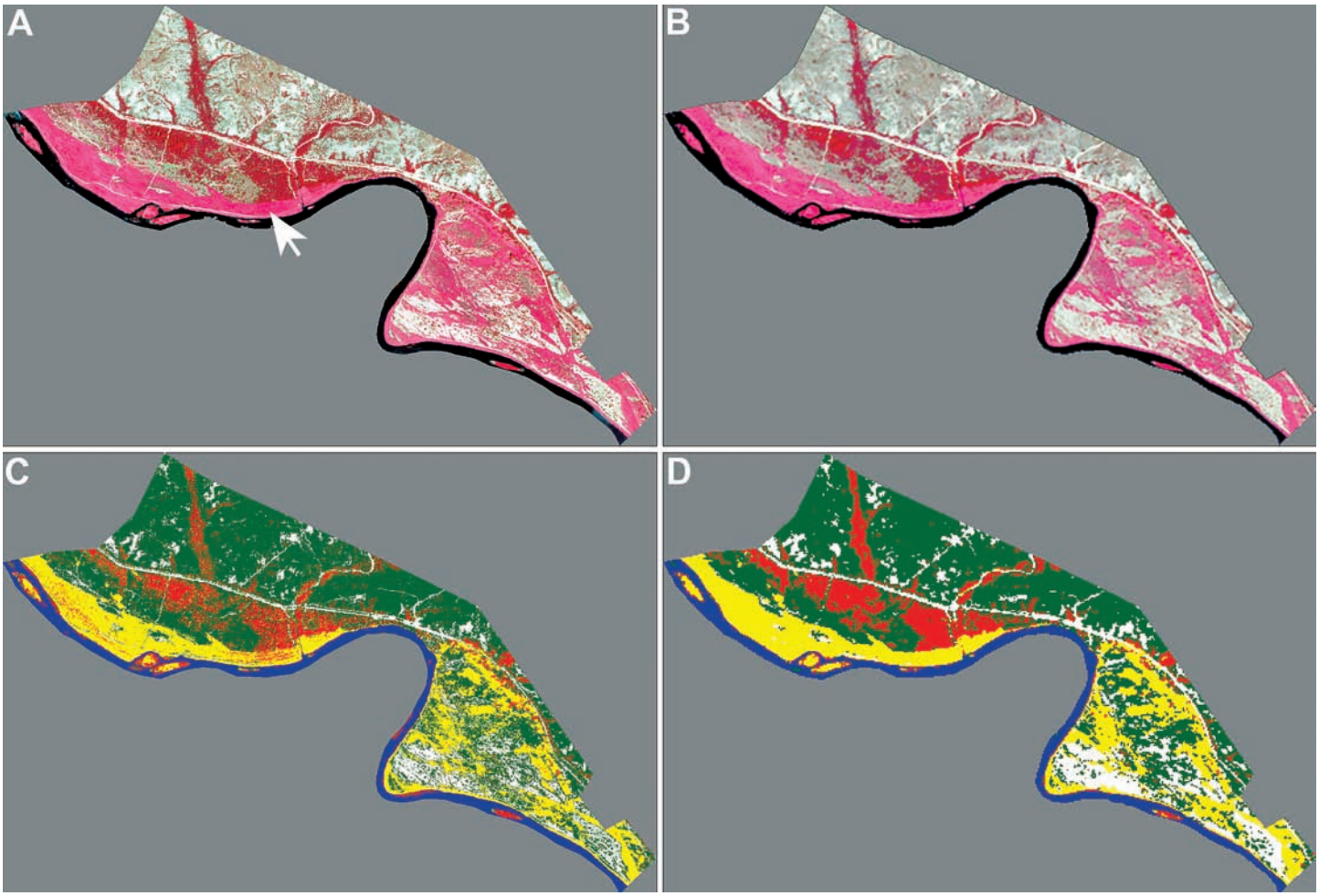

Figure 1. QuickBird (A) and SPOT 5 (B) false color satellite images of study site 1 on the Rio Grande near Del Rio, Texas. The arrow on print A points to giant reed. Prints C and D show supervised classification maps for the QuickBird and SPOT 5 images, respectively. Color codes for the various surface types (classes) on the computer classifications are: yellow, giant reed; red, mixed brush; green, dry grass/scrub brush; white, soil; and blue, water.

Error matrices comparing the classified data with the ground data for the 100 observations from the supervised classifications of the QuickBird and SPOT 5 images, respectively, of study site 3 (Table 5 and 6; images and computer classification maps not shown) show the overall classification accuracies for the QuickBird and SPOT 5 images were 86% and 72%, respectively. For the QuickBird classification, giant reed had producer's and user's accuracies of 91.9% and 100%, respectively. Giant reed had producer's and user's accuracies of 75.7% and 93.3%, respectively, in the SPOT 5 classification. The errors of giant reed in the producer's accuracy from the SPOT 5 classification were due to its confu-

Table 1. An error matrix for the supervised classification generated from the classification data and ground data for the August 25, 2005, QuickBird 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	11	0	0	0	0	11	100.0%
Giant reed	0	28	0	0	0	28	100.0%
Mixed brush	0	0	13	0	0	13	100.0%
Dry grass/scrub brush	0	2	7	43	6	58	74.1%
Soil	0	0	0	6	9	15	60.0%
Total	11	30	20	49	15	125	
Producer's accuracy	100.0%	93.3%	65.0%	87.8%	60.0%		

Overall classification accuracy = 83.2%. Overall kappa = 0.769.

Table 2. An error matrix for the supervised classification generated from the classification data and ground data for the August 31, 2005, SPOT 5 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	11	0	0	0	0	11	100.0%
Giant reed	0	26	1	1	0	28	92.9%
Mixed brush	0	0	13	3	0	16	81.3%
Dry grass/scrub brush	0	2	6	42	8	58	72.4%
Soil	0	2	0	3	7	12	58.3%
Total	11	30	20	49	15	125	
Producer's accuracy	100.0%	86.7%	65.0%	85.7%	46.7%		

Overall classification accuracy = 79.2%. Overall kappa = 0.713.

sion with dry grass/scrub brush. The kappa estimates for the QuickBird and SPOT 5 classifications were 0.814 and 0.620.

Our results showed that both QuickBird and SPOT 5 satellite imagery combined with supervised image analysis can be used to map giant reed infestations along the Rio Grande in southwest Texas. Accuracy assessments performed on supervised classification maps from QuickBird images of three study sites had mean producer's and user's accuracies for giant reed of 95.1% and 97.7%, respectively. Accuracy assessments performed on supervised classification maps from SPOT 5 images of the same three sites had mean producer's and user's accuracies for giant reed of 80.1% and 88%, respectively. The lower accuracies of the SPOT 5 imagery were attributed to its coarser spatial resolution.

The QuickBird accuracy assessment data presented in this study are in agreement with results from a previous study using QuickBird imagery for mapping giant reed (Everitt et al. 2005). They are also in agreement with accuracy assessment data obtained from aerial photographic and videographic imagery of giant reed (Everitt et al. 2004) and with those reported by Dipietro et al. (2002) and Underwood et al. (2003) using AVIRIS hyperspectral imagery for mapping giant reed and other nonnative plants in California. Weber et al. (2006) reported producer's and user's accuracies of 100% and 76%,

Table 3. An error matrix for the supervised classification generated from the classification data and ground data for the August 25, 2005, QuickBird 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	9	0	0	0	1	10	90.0%
Giant reed	0	27	0	2	0	29	93.1%
Mixed brush	0	0	21	3	0	24	87.5%
Dry grass/scrub brush	0	0	9	61	4	74	82.4%
Soil	0	0	0	3	10	13	76.9%
Total	9	27	30	69	15	150	
Producer's accuracy	100.0%	100.0%	70.0%	88.4%	66.7%		

Overall classification accuracy = 85.3%. Overall kappa = 0.789.

Table 4. An error matrix for the supervised classification generated from the classification data and ground data for the August 31, 2005, SPOT 5 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	6	1	1	0	0	8	75.0%
Giant reed	1	21	1	3	1	27	77.8%
Mixed brush	0	0	14	1	0	15	93.3%
Dry grass/scrub brush	1	5	12	62	2	82	75.6%
Soil	1	0	2	3	12	18	66.7%
Total	9	27	30	69	15	150	
Producer's accuracy	66.7%	77.8%	46.7%	89.9%	80.0%		

Overall classification accuracy = 76.7%. Overall kappa = 0.657.

TABLE 5. AN ERROR MATRIX FOR THE SUPERVISED CLASSIFICATION GENERATED FROM THE CLASSIFICATION DATA AND GROUND DATA FOR THE AUGUST 25, 2005, QUICKBIRD 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	11	0	0	0	0	11	100.0%
Giant reed	0	34	0	0	0	34	100.0%
Mixed brush	0	3	8	3	0	14	57.1%
Dry grass/scrub brush	0	0	4	23	4	31	74.2%
Soil	0	0	0	0	10	10	100.0%
Total	11	37	12	26	14	100	
producer's accuracy	100.0%	91.9%	66.7%	88.5%	71.4%		

Overall classification accuracy = 86.0%. Overall kappa = 0.814.

TABLE 6. AN ERROR MATRIX FOR THE SUPERVISED CLASSIFICATION GENERATED FROM THE CLASSIFICATION DATA AND GROUND DATA FOR THE AUGUST 31, 2005, SPOT 5 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	28	2	0	0	30	93.3%
Mixed brush	0	0	7	1	0	8	87.5%
Dry grass/scrub brush	0	9	3	25	12	49	51.0%
Soil	1	0	0	0	2	3	66.7%
Total	11	37	12	26	14	100	
Producer's accuracy	90.9%	75.7%	58.3%	96.2%	14.3%		

Overall classification accuracy = 72.0%. Overall kappa = 0.620.

respectively, for mapping leafy spurge with SPOT 5. Our findings for giant reed are comparable with their results. Although giant reed could not be as accurately mapped with SPOT 5 as with QuickBird imagery, our accuracy totals were considered good (Thomlinson et al. 1999). QuickBird imagery can be purchased for approximately $1,700 USD for a 64-km^2 area, whereas the cost of SPOT 5 imagery is $2,275 for a 450-km^2 area. Analysis of both types of imagery is comparable. If the user is planning on mapping a relatively small area, QuickBird data may be the better choice. Conversely, for larger areas SPOT 5 data is more economical to use. The capability to distinguish and map giant reed with satellite imagery and supervised image analysis techniques should be of interest to weed scientists and wildland resource managers.

ACKNOWLEDGMENTS

The authors thank Fred Gomez for his assistance in collecting GPS data and conducting the accuracy assessments. We also thank Isabel Cavazos for his help in georeferencing the imagery and for conducting the image analysis, and Mario Alaniz for preparing the illustration.

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