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Using Aerial Photography and Image Analysis to Measure Changes in Giant Reed Populations

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ABSTRACT

A study was conducted along the Rio Grande in southwest Texas to evaluate color-infrared aerial photography combined with supervised image analysis to quantify changes in giant reed (*Arundo donax* L.) populations over a 6-year period. Aerial photographs from 2002 and 2008 of the same seven fixed study sites were studied. Coverage of giant reed increased in all sites from 2002 to 2008, including increases ranging from 21.9 to 49.9% in six of the seven sites. Expansion of giant reed resulted primarily from its displacement of mixed herbaceous vegetation and encroachment on bare soil areas. These results indicate that color-infrared aerial photographs coupled with image analysis techniques can be useful tools to monitor and quantify changes in giant reed populations over time.

Key words: Arundo donax, change detection, color-infrared aerial photography, supervised image analysis.

INTRODUCTION

Giant reed (*Arundo donax* L.) is an invasive perennial grass that grows 3 to 10 m tall. The fleshy creeping rootstocks form compact masses that give rise to tough fibrous roots that penetrate deeply into the soil (Dudley 2000). In North America, giant reed is not known to produce fertile seed; however, it spreads very rapidly by vegetative means when either rhizomes or plant fragments are carried downstream, primarily during floods. Giant reed typically grows in riparian areas and flood plains on a variety of soil types ranging from loose sands and gravelly soils to heavy clays and river sediments (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 erosion control, thatching, basket weaving, and other fiber uses (Cheatham et al. 1995). It was introduced to California from the Mediterranean in the 1820s and quickly became naturalized (Hitchcock 1971, Polunin and Huxley 1987, Hosovsky 1987). Today, giant reed is an invasive weed throughout the southern United States and northern Mexico, with the densest stands growing along the Rio Grande in Texas and the coastal rivers of southern California (Bell 1997, Tracy and Deloach 1998, Everitt et al. 2004).

Giant reed consumes excessive amounts of water to supply its high growth rate (Iverson 1994). 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 serious threat to riparian areas where it spreads rapidly and can displace native plants, leading to degradation of wildlife habitat (Khudamrongsawat et al. 2004, Kisner 2004). Its massive stands also pose a wildfire threat (Frandsen and Jackson 1994).

Remote sensing techniques have been used successfully to detect giant reed infestations. AVIRIS hyperspectral imagery was used for distinguishing and mapping giant reed in riparian areas in California (Dipietro et al. 2002, Underwood et al. 2003). Aerial photography and videography have been used for detecting and mapping giant reed infestations in riparian areas in Texas (Everitt et al. 2004). More recently, QuickBird and SPOT 5 satellite imagery have proven useful for distinguishing giant reed infestations in riparian areas of southwest Texas and northern Mexico (Everitt et al. 2005, 2008, Yang et al. 2009). Accuracy assessments performed on aerial photographic and videographic image classification maps had producer and user accuracies for giant reed ranging from 78 to 100% (Everitt et al. 2004). Everitt et al. (2005, 2008) performed accuracy assessments on QuickBird satellite image classification maps and reported producer and user accuracies for giant reed ranging from 86 to 100%. Additional accuracy assessments performed on SPOT 5 satellite image classification maps had producer and user accuracies for giant reed ranging from 76 to 93% (Everitt et al. 2008). These findings indicate that giant reed populations can be mapped with relatively high accuracy using either aerial or satellite imagery.

Remotely sensed imagery is a valuable tool for measuring changes in landscape features. Computer image classification maps developed from imagery obtained on two or more dates can be compared to assess temporal changes in landscape cover types during known time intervals (Lunetta and Elvidge 1999, Jensen 2005). The objective of this study was to demonstrate the value of color-infrared aerial photographs coupled with image analysis to determine changes in giant reed populations in a Texas riparian zone over a 6-year time interval.

MATERIALS AND METHODS

This study was conducted along the Rio Grande near Del Rio (29°17N; 100°51W) in Southwest Texas, an area

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[2]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.

with a large infestation of giant reed (Everitt et al. 2004). Seven different giant reed populations were selected as study sites. These sites are located along the riparian corridor of the Rio Grande and included an area that is approximately 13 km long. Coverage of giant reed was evaluated with color-infrared aerial photography and computer image analysis techniques. Kodak[2] color-infrared (0.50 to 0.90 µm) type 2443 film was used for the aerial photography. Photography was obtained with a Fairchild type K-37 large format (23 by 23 cm) mapping camera. The camera had an aperture setting of f11 at 1/250 s and a 305 mm lens equipped with a Wratten 15 orange (minus blue) filter.

Aerial photographs were acquired on two dates: 25 June 2002 at an altitude of 3050 m above ground level and a scale of 1:10,000 and 17 November 2008 at an altitude of 3650 m above ground level and a scale of 1:12,000. All photography was obtained with a Cessna Model 404 airplane equipped with a camera port in the floor. The camera was maintained in a nadir position during image acquisition. All photography was acquired between 11:00 and 14:00 Central Standard Time under sunny conditions.

The color-infrared photographic transparencies of each study site on each date were scanned at 400 dpi and had a pixel resolution of 1 m. Seven subset images were extracted from both the 2002 and 2008 photographs and 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 submeter accuracy was used in the field to establish control points on the panchromatic image (Erdas, Inc. 2008). The subsets were located adjacent to the Rio Grande on the United States side of the border. The seven locations were designated sites 1 through 7.

The 2002 and 2008 color-infrared photographs from each site were subjected to supervised image analysis techniques. Five subsamples were selected from each cover type on each site to be used as training sites. Sites 1, 2, 3, 6, and 7 had five cover types (classes) that included giant reed, mixed herbaceous species, woody plant species, soil, and water. Sites 4 and 5 had four cover types that included giant reed, mixed herbaceous species, soil, and water. Mixed herbaceous species included both grasses and broad-leaved herbs. Common grasses were red grama (*Boutelou trifida* Thurb.), three-awn (*Aristida* spp.), sand dropseed (*Sporobolus cryptandrus* [Torr.] Gray), and buffelgrass (*Pennisetum ciliare* [L.] Link). Dominant broad-leaved herbaceous species included western ragweed (*Ambrosia psilostachya* A. P. de Candolle), false ragweed (*Parthenium confertum* Gray), and several species of mallows (Malvaceae).

Dominant woody plant species included honey mesquite (*Prosopis glandulosa* Torr.), blackbrush (*Acacia rigidula* Benth.), desert hackberry (*Celtis pallida* Torr.), and Mexican persimmon (*Diospyros texana* Scheele). The Maximum Likelihood classifier was used to classify the photographs (Erdas, Inc. 2008). Additional ground surveys were made following the 2008 photographs to confirm any changes in signatures among cover types from the previous accuracy assessments (Everitt et al. 2004, 2005, 2008).

RESULTS AND DISCUSSION

The color-infrared aerial photographic prints for study site 1 from 2002 and 2008 (Figure 1A and 1B, respectively) have similar tonal responses. The arrow on the 2002 photograph points to the pink image response of giant reed. Woody plant species have a dark reddish-brown to brown image, mixed herbaceous plant species have variable gray tones, and soil has a white image response. The Rio Grande has a dark blue color and borders the lower portions of the images. Comparison of the two photographs illustrates increased coverage of giant reed from 2002 to 2008. This is evident in the center and upper left portions of the 2008 photograph. Mixed herbaceous species show a decrease in cover from 2002 to 2008.

Supervised classification maps for the 2002 and 2008 photographs are shown for study site 1 (Figure 1C and 1D, respectively). In the 2002 photograph giant reed comprised 28.9% (25.4 ha) of the study area. In the 2008 photograph coverage was 41.5% (36.5 ha), which represented an increase of 43.6% over the 6-year period (Table 1). Conversely, mixed herbaceous species comprised 31.9% (28 ha) of the study area in the 2002 photograph, but 11.2% (9.9 ha) in the 2008 photograph, which represented a decrease of 64.8%. Clearly, some of the decrease in mixed herbaceous species over the 6-year period was due to displacement by giant reed. This decrease may also be attributed to periodic drought conditions over the 6-year period and removal of plants by livestock grazing. Coverage of soil and woody plants increased from 2002 to 2008, while water slightly decreased over the 6-year period.

In study site 2, coverage of giant reed was 29.9% (19.6 ha) in the 2002 photograph compared to 43.6% (29.3 ha) in the 2008 photograph, which represented an increase of 49.9% (Table 1). All other cover types decreased in area from 2002 to 2008. Most of the increase in giant reed was due to its displacement of mixed herbaceous species and woody plants.

Coverage of giant reed also increased in all the other study sites (sites 3-7) from 2002 to 2008 (Table 1). With the exception of site 3 where coverage of giant reed increased by 3.2%, these increases were substantial and ranged from 21.9% in site 7 to 44.9% in site 6 over the 6-year period. Most of the expansion of giant reed resulted from its encroachment on essentially bare soil areas and its displacement of mixed herbaceous species.

Our results showed that color-infrared aerial photographs and supervised image analysis techniques are useful tools for measuring the spread of giant reed populations over time. The aerial photographs provide a permanent record that can be stored and examined for comparative purposes over time. These findings indicate that giant reed populations have increased significantly in some sites along the Rio Grande over a 6-year period and that this species is displacing native vegetation that provides wildlife habitat and grazing land for both livestock and wildlife. Mixed herbaceous species were the principal cover type that was displaced by giant reed. Although not all decreases in mixed herbaceous species cover were attributed to their displacement by giant reed, comparison of the photographs from 2002 to 2008 showed that many

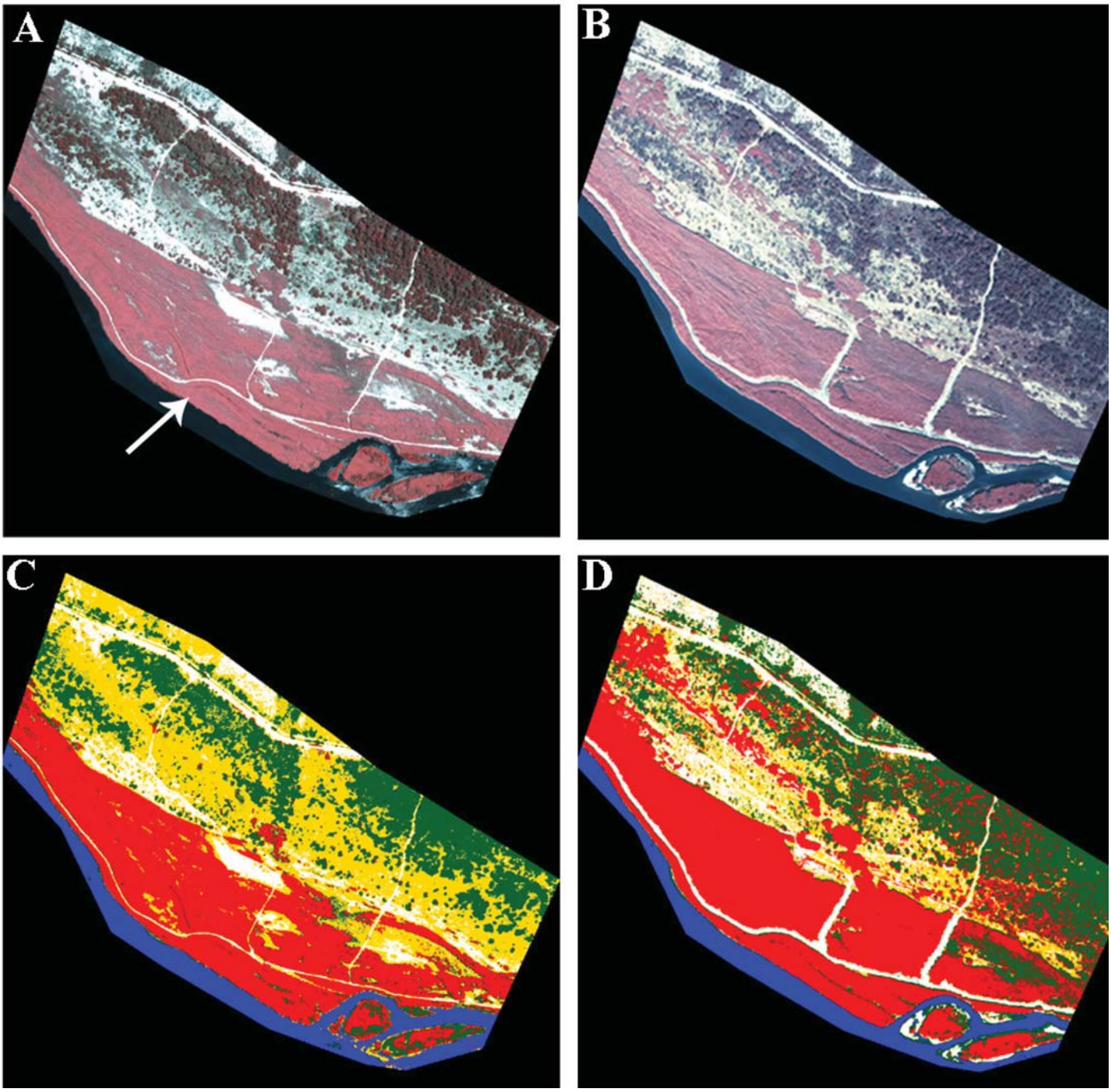

Figure 1. Color-infrared aerial photographs (A: 25 June 2002 and B: 17 November 2008) of study site 1 on the Rio Grande near Del Rio, TX. The arrow on print A points to giant reed. Prints C and D show the supervised classification maps for images A and B, respectively. Color codes for the various cover types on the classification maps: red, giant reed; yellow, mixed herbaceous species; green, woody plant species; white, soil; and blue, water.

areas where mixed herbaceous species occurred in 2002 were occupied by giant reed in 2008. The capability to measure changes in giant reed populations with aerial photographs and image analysis procedures can be useful to weed scientists and wildlife and rangeland resource managers.

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Table 1. Coverage and percent change of cover types derived from supervised image analysis of color-infrared aerial photographs from 2002 and 2008 of seven study sites along the Rio Grande near Del Rio, TX.

Site/Cover Type	2002		2008		% Change
	Area		Area		
Site 1	%	ha	%	ha	
Giant reed	28.9	25.4	41.5	36.5	43.6
Soil	8.7	7.6	14.8	13.0	70.6
Mixed herb.[1]	31.9	28.0	11.2	9.9	-64.8
Woody plants	21.8	19.1	24.8	21.8	13.8
Water	8.7	7.7	7.7	6.8	-12.0
Site 2					
Giant reed	29.1	19.6	43.6	29.3	49.9
Soil	19.0	12.8	17.9	12.0	-6.0
Mixed herb.	27.8	18.7	17.8	12.0	-36.0
Woody plants	17.4	11.7	14.5	9.8	-16.4
Water	6.8	4.6	6.2	4.2	-7.9
Site 3					
Giant reed	45.8	67.4	47.2	69.6	3.2
Soil	17.7	26.0	9.9	14.5	-44.1
Mixed herb.	22.3	32.8	18.1	26.6	-18.8
Woody plants	8.0	11.8	14.6	21.5	81.6
Water	6.2	9.2	10.2	15.1	63.9
Site 4					
Giant reed	43.7	48.2	53.6	59.2	22.8
Soil	30.2	33.4	13.9	15.3	-54.1
Mixed herb.	18.9	20.9	25.0	27.6	32.3
Water	7.2	7.9	7.5	8.2	3.9
Site 5					
Giant reed	32.8	40.1	45.9	56.0	39.8
Soil	11.6	14.2	15.9	19.5	37.2
Mixed herb.	47.8	58.4	30.1	36.7	-37.0
Water	7.8	9.5	8.1	9.9	4.2
Site 6					
Giant reed	38.4	51.8	55.6	75.1	44.9
Soil	26.2	35.4	21.3	28.7	-18.8
Mixed herb.	24.6	33.2	2.6	3.5	-89.4
Woody plants	3.9	5.3	15.2	20.6	285.7
Water	6.9	9.3	5.2	7.1	-23.9
Site 7					
Giant reed	45.4	32.4	55.3	39.4	21.9
Soil	4.3	3.1	4.9	3.5	13.3
Mixed herb.	26.5	18.9	15.5	11.0	-41.6
Woody plants	9.7	7.0	9.7	6.9	-0.6
Water	14.1	10.0	14.7	10.5	4.2

[1]Mixed herbaceous plant species.

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