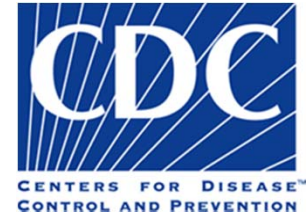


Object-based swimming pool extraction to support West Nile Virus control efforts

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West Nile Virus (WNV)



1 Potentially serious illness transmitted to humans primarily by the bites of infected mosquitoes

2 Symptoms of WNV¹

- No symptoms: most people (approximately 80% of infected people)
- Mild symptoms
 - Up to 20% of infected people: fever, headache, body aches, nausea, vomiting and so on
- Serious symptoms
 - Approximately one in 150 people: high fever, headache, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, vision loss, numbness and paralysis
 - Possible to last several weeks and have permanent neurological effects

¹ CDC. West Nile Virus Fact Sheet, URL: http://www.cdc.gov/ncidod/dvbid/westnile/wnv_factsheet.htm (Last date Accessed: April 3th, 2011).

WNV in United States

1 First emerged in New York City in late August 1999 and quickly spread westward across the United States except Maine in recent years (Figure 1(a))

2 According to the CDC WNV, a cumulative total of 29,681 WNV human cases were reported from 1999 to 2009.

3 The highest number of WNV human cases reported in Colorado, Nebraska, and California (Figure 1(b)).

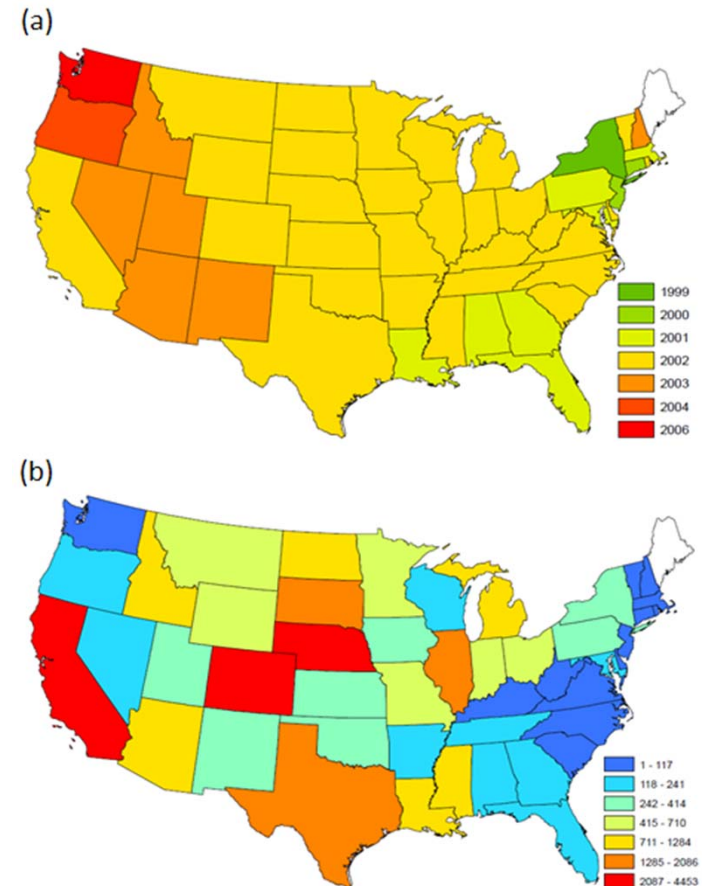


Figure 1. Starting year of reporting WNV human cases in each state in United States (a) and accumulated WNV human cases for individual states (b).



Aerial pool survey in California, United States

1 Neglected (or abandoned) swimming pools

- Increase in the numbers of home foreclosures and abandonments associated with parallel increases in WNV human cases in California, e.g., Kern County²
- In conjunction with dry weather, neglected swimming pools could be used as mosquito habitats³.
- Some counties in California have conducted neglected swimming pool survey with manual interpretation from digital aerial photographs.

² Reisen, W.K., R.M. Takahashi, B.D. Carroll, and R. Quiring, 2008. Delinquent mortgages, neglected swimming pools, and West Nile Virus, California, *Emerging Infectious Diseases*, 14:1747-1749.

³ Reisen, W.K., R.M. Takahashi, B.D. Carroll, and R. Quiring, 2009. Letter - Delinquent mortgages, neglected swimming pools, and West Nile Virus, California, *Emerging Infectious Diseases*, 15:508-509.

Neglected swimming pool



Figure 2. An example of abandoned swimming pool⁴.
Courtesy by Santa Clara County, CA.



Figure 3. Neglected swimming pool aided by aerial photograph in an urban area, Kern County, CA⁵.

⁴ URL source: [http://www.sccgov.org/portal/site/vector/agencyarticle?path=/v7/Vector%20Control%20District%20\(DIV\)/What's%20Bothering%20You?/Mosquitoes/Mosquito%20Abatement&contentId=83b3973adbd7a110VgnVCM10000048dc4a92_____](http://www.sccgov.org/portal/site/vector/agencyarticle?path=/v7/Vector%20Control%20District%20(DIV)/What's%20Bothering%20You?/Mosquitoes/Mosquito%20Abatement&contentId=83b3973adbd7a110VgnVCM10000048dc4a92_____)

⁵ Reisen, W.K., R.M. Takahashi, B.D. Carroll, and R. Quiring, 2008. Delinquent mortgages, neglected swimming pools, and West Nile Virus, California, *Emerging Infectious Diseases*, 14:1747-1749.



Neglected pool survey

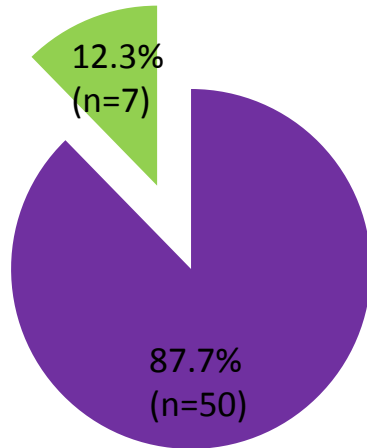
1 Questionnaire survey for vector control districts and environmental health departments in California (n=58)⁶

2 Selected questions

- 1) Has your district performed neglected pool surveillance in the past 5 years?
- 2) Has your district ever conducted aerial pool surveillance for neglected pools (i.e., high resolution photograph taken by airplane or helicopter)?
- 3) What was the greatest number of neglected pools your agency detected by aerial surveillance alone in a single year?
- 4) Did an aerial pool survey cover the entire area of your district?

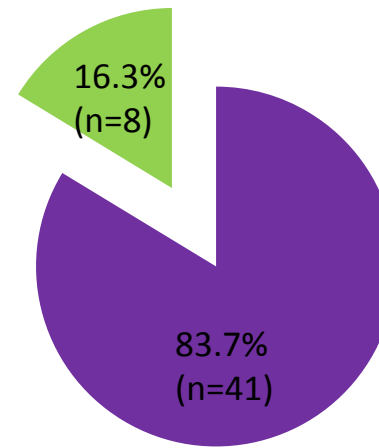
⁶ This survey was conducted by Kerry Padgett and Erin Parker who work at Vector-borne Disease Section, California Department of Public Health, United States.

Neglected pool survey (cont.)



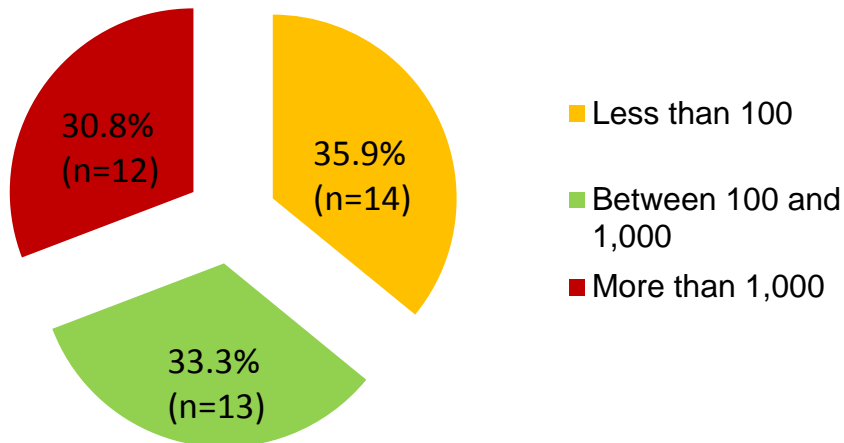
■ Yes ■ No

Figure 4. Answer for Question #1.



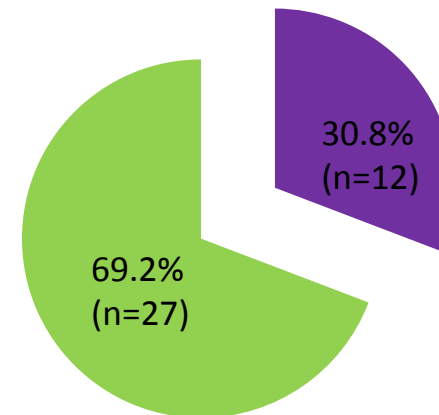
■ Yes ■ No

Figure 5. Answer for Question #2.



■ Less than 100
■ Between 100 and 1,000
■ More than 1,000

Figure 6. Answer for Question #3.



■ Yes ■ No

Figure 7. Answer for Question #4.



Potential limitations of the aerial pool survey

- 1 Manual interpretation: time-consuming and labor-intensive procedure
- 2 Acquisition of aerial photographs high cost to be conducted repeatedly over short time period

Geographic object-based image analysis with very high spatial resolution satellite imagery



- 1 Very high spatial resolution (VHR) satellite imagery
 - Providing equivalent spatial resolution compared with digital aerial photographs
 - Revisiting capability for the same place at 2-3 day interval

- 2 Geographic object-based image analysis (GEOBIA)
 - Emerged in late 1990s to be used for VHR remotely sensed imagery
 - Potential of emulating human interpreter's ability to identify geographic features on Earth in terms of spectral, spatial, and contextual information
 - Gaining increases attention among remote sensing scientists in recent years

- 3 GEOBIA with VHR satellite to automatically extract private swimming pools

Study area and data

1 Study area

- An urban community in Bakersfield City, located in Kern County, CA
- High unemployment rate in Bakersfield-Delano Metropolitan area compared with a national rate: 15.8% and 9.5% in 2010, respectively⁷

2 Data

- GeoEye-1 imagery acquired in 2009 and delivered from the U.S. National Geospatial-Intelligence Agency (NGA)

Table 1. Spatial and spectral characteristics of GeoEye-1 imagery

		Spatial resolution	Spectral resolution
Panchromatic image		0.40 m	450-800 nm
Multispectral image	Blue	1.65 m	450-510 nm
	Green	1.65 m	510-580 nm
	Red	1.65 m	655-690 nm
	NIR	1.65 m	780-920 nm

⁷ BLS (Bureau of Labor Statistics), 2010. *Labor force statistics from the current population survey*. Department of Labor, United States, URL: <http://www.bls.gov/cps/> (last date accessed: August 10th, 2010).

Study area and data (cont.)

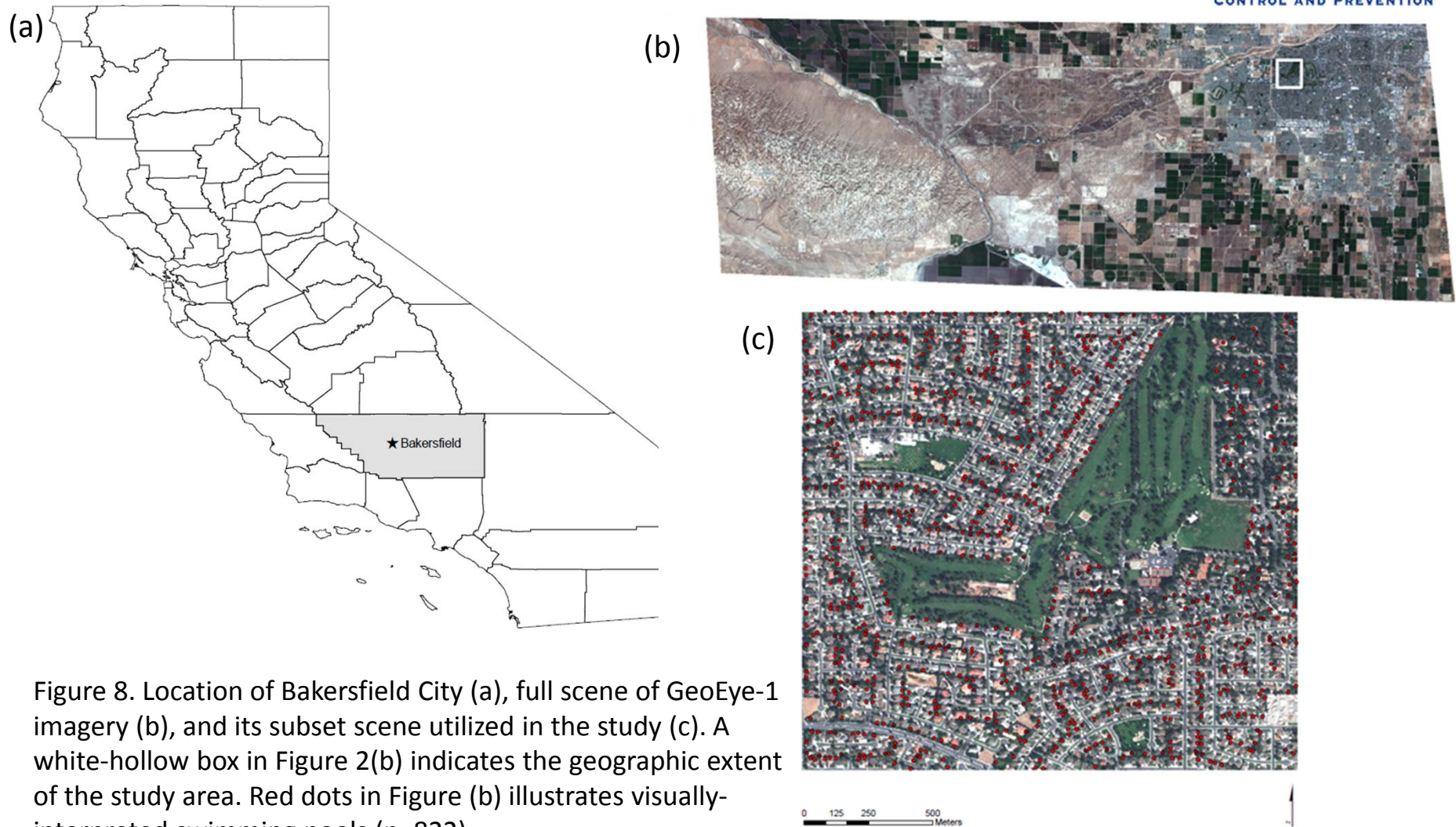
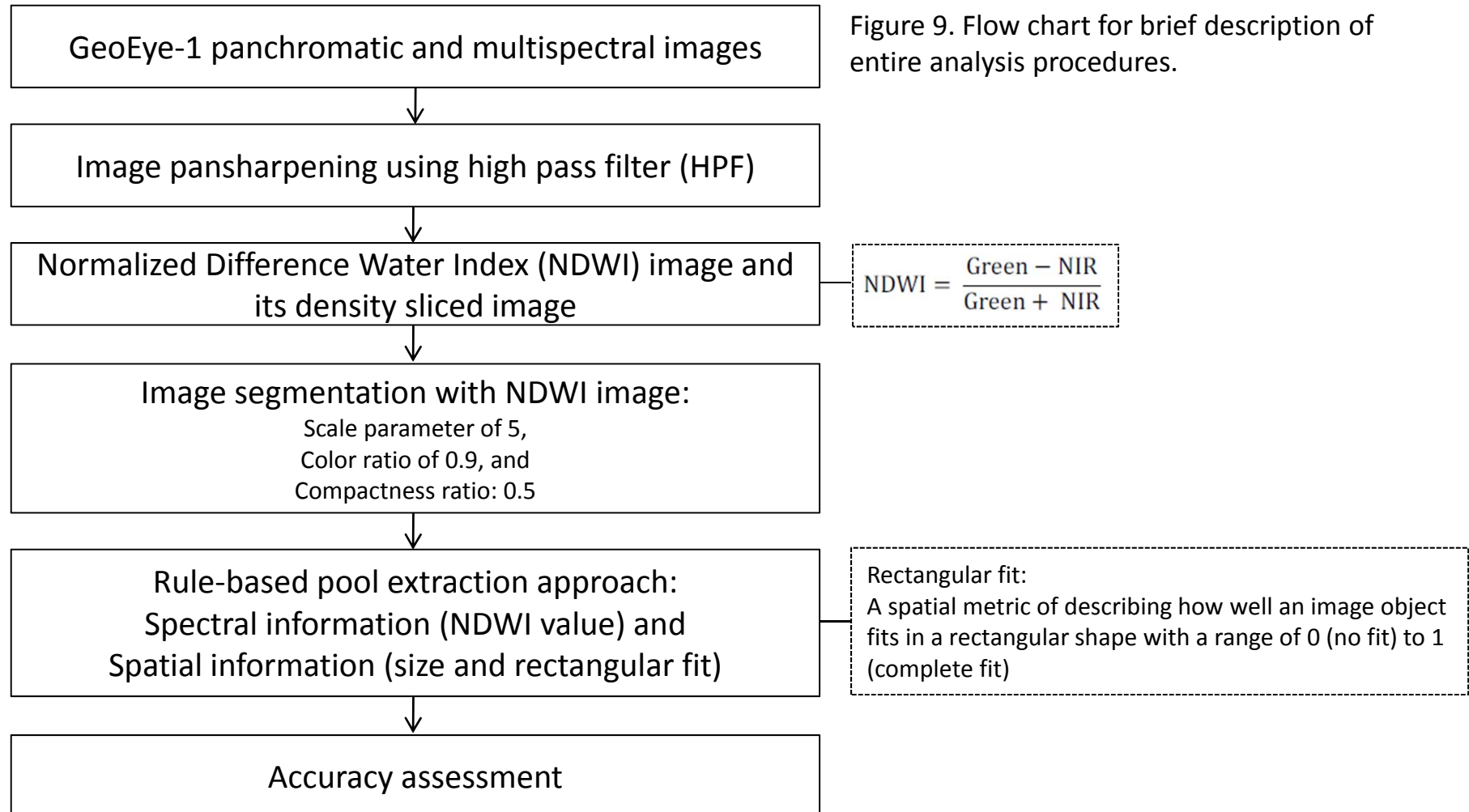


Figure 8. Location of Bakersfield City (a), full scene of GeoEye-1 imagery (b), and its subset scene utilized in the study (c). A white-hollow box in Figure 2(b) indicates the geographic extent of the study area. Red dots in Figure (b) illustrates visually-interpreted swimming pools (n=822).

Methods



NDWI and its density sliced image

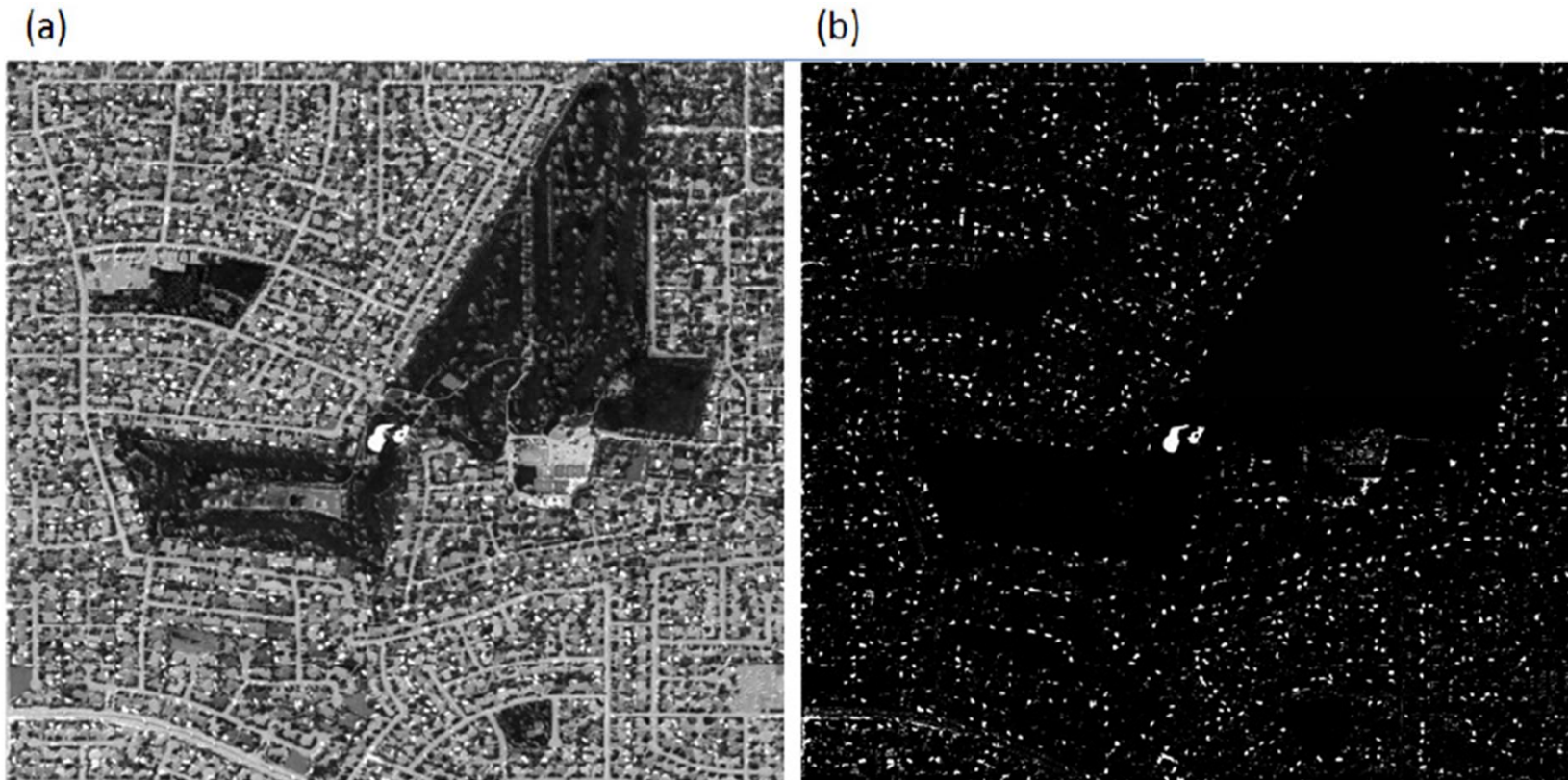


Figure 10. NDWI image (a) and its density-sliced version (b). The threshold of value 0 was utilized to mask out non-pool features from the original NDWI image.

Pool extraction rule: NDWI value

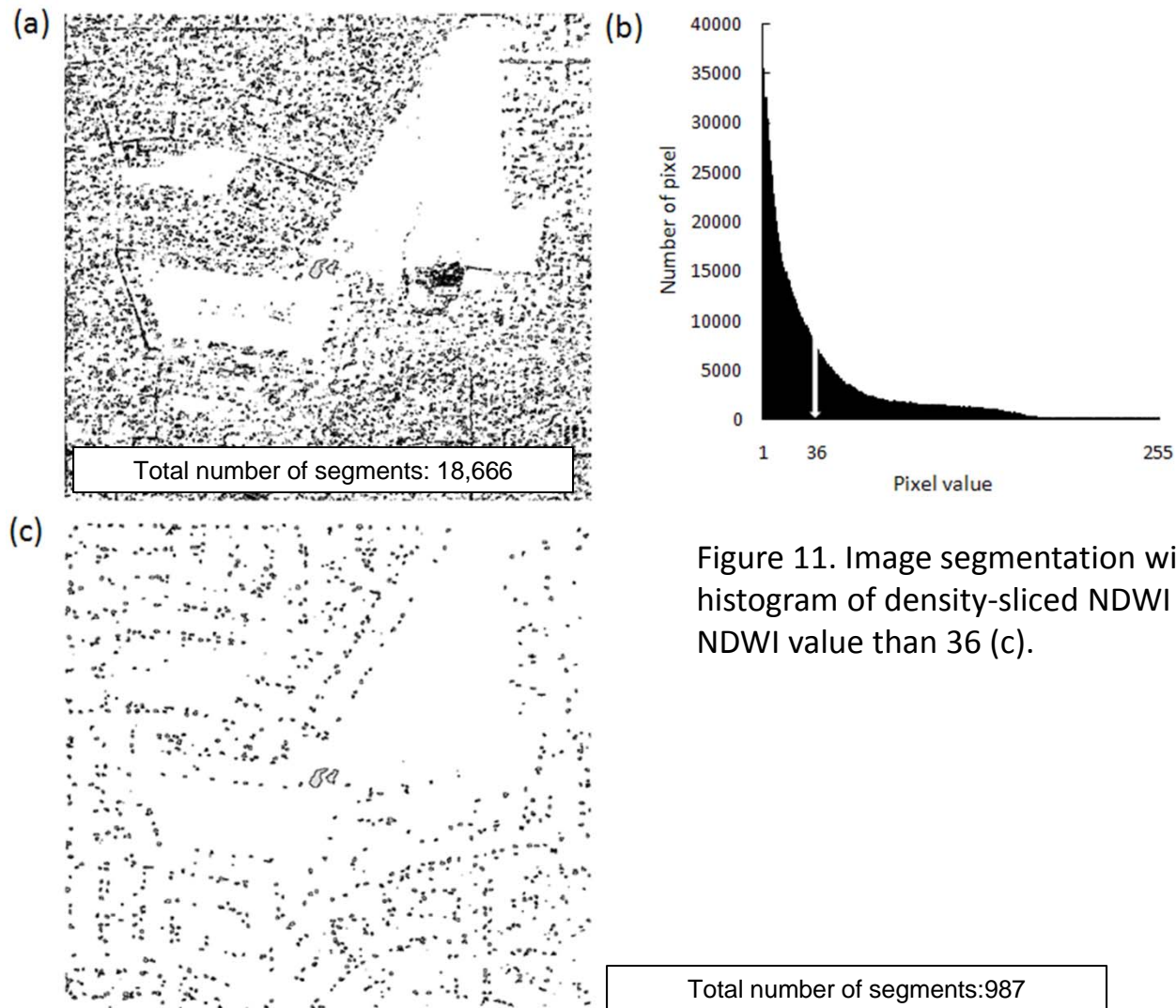


Figure 11. Image segmentation with scale parameter 5 (a), histogram of density-sliced NDWI (b), and image objects with higher NDWI value than 36 (c).

Error matrices of classification results

Table 2. Error matrix of a classification only with NDWI value.

Classification	Reference		User's accuracy
	Pool	Non pool	
Pool	775	192	80.1%
Non pool	47	608	92.8%
Producer's accuracy	94.3%	76.0%	

Overall accuracy: 85.3%, Overall Kappa coefficient: 0.70

Pool Kappa coefficient: 0.60

Non pool Kappa coefficient: 0.86

Table 3. Error matrix of a classification only with RF and size as well as NDWI value.

Classification	Reference		User's accuracy
	Pool	Non pool	
Pool	772	77	90.4%
Non pool	50	723	93.5%
Producer's accuracy	93.9%	90.9%	

Overall accuracy: 92.2%, Overall Kappa coefficient: 0.84

Pool Kappa coefficient: 0.82

Non pool Kappa coefficient: 0.86

Final pool extraction with spatial information

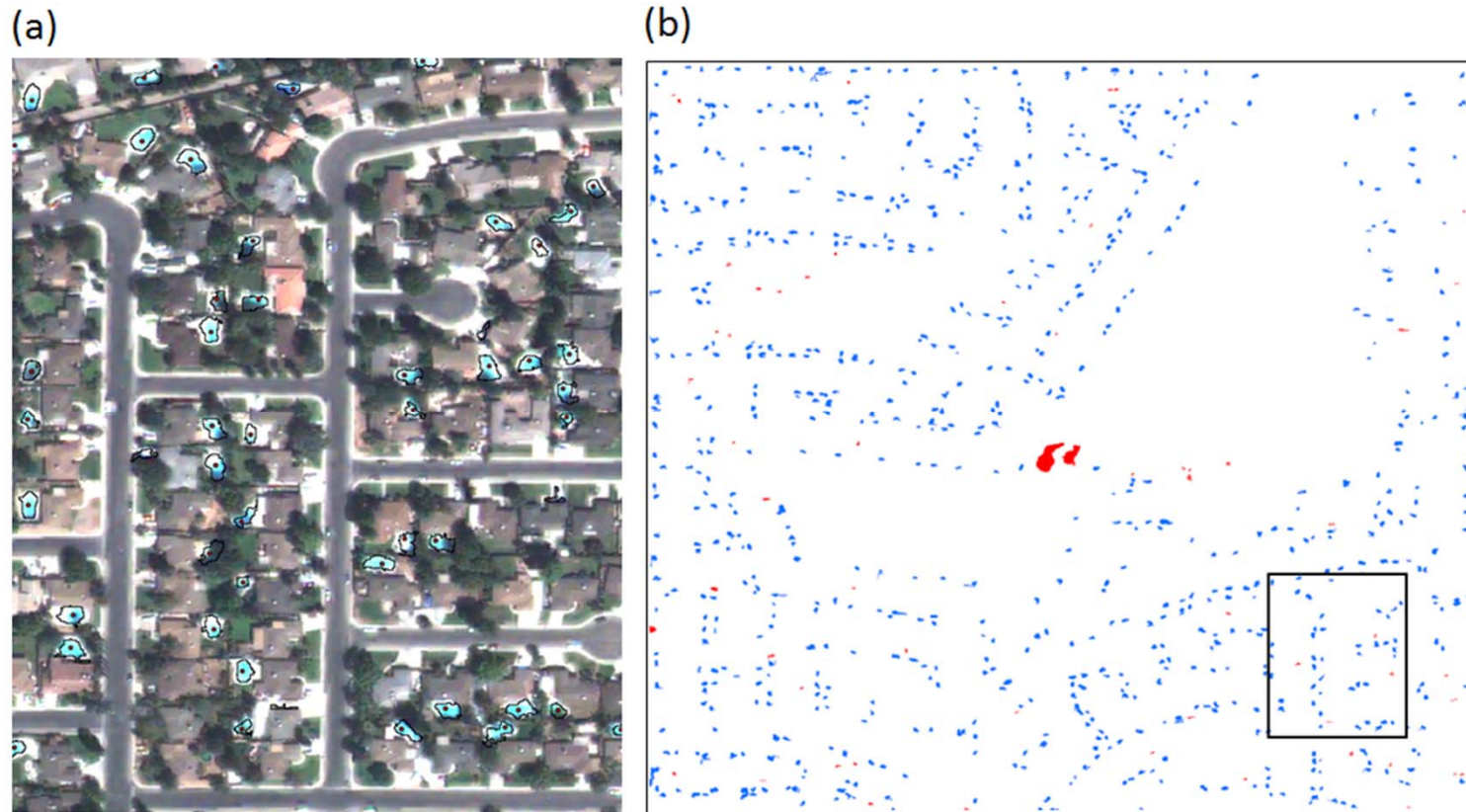


Figure 12. Extracted private pool segments: (a) an image portion overlaid on GeoEye-1 imagery and (b) final result across the study area. The black-hollow rectangle in Figure (b) indicates the location of the Figure (a).



Conclusions

- 1 GEOBIA with VHR satellite imagery is anticipated to construct accurate spatial database of private swimming pools.
- 2 In turn, a developed pool database facilitates the detection of neglected swimming pools in a built-up area to assist WNV control efforts of local government.
- 3 Following this study, we have a plan to develop methodology to differentiate neglected pools from maintained pools using VHR satellite imagery such as WorldView-2.



Acknowledgements

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- *We acknowledge that the findings and conclusions in this report are those of the authors and do not necessarily represent the official position of United States Centers for Disease Control and Prevention.*