Identification of Waste Tires Using High-Resolution Multispectral Satellite Imagery

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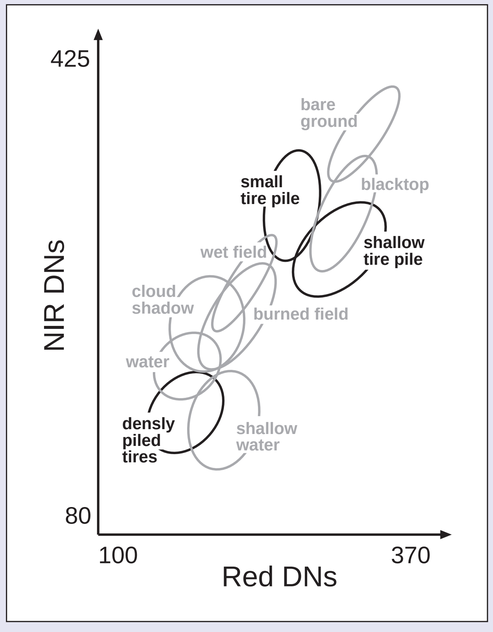
Unregulated stockpiles of waste tires pose a threat to human health and environmental safety. Waste tires are complex spectrally-variable targets, mixing geographically and spectrally with other land covers like water and shadow. The disposition of tires within each pile may alter the spectral signature of waste tires. Additionally, few training sets are available. We describe the use of a univariate decision tree, the Tire Identification from Reflectance (TIRe) model, to locate waste tire piles in 8, 498 sq km of QuickBird imagery along the United States-Mexico border. A total of 89 sites were identified as possible waste tire disposal sites and targeted for field inspection. Excluding two sites previously known to the analyst and eleven sites that were inaccessible to the inspectors, 66 (87%) of target sites were correctly identified as containing tires through the use of this methodology.

Study Area

The predominant land cover in the area is desert with fairly flat terrain, but agriculture, cities and towns, and mountainous regions occur as well. Most of the waste tire piles are located in desert areas near settlements, though many waste tires are also used as fences.

Remote Sensing Challenges

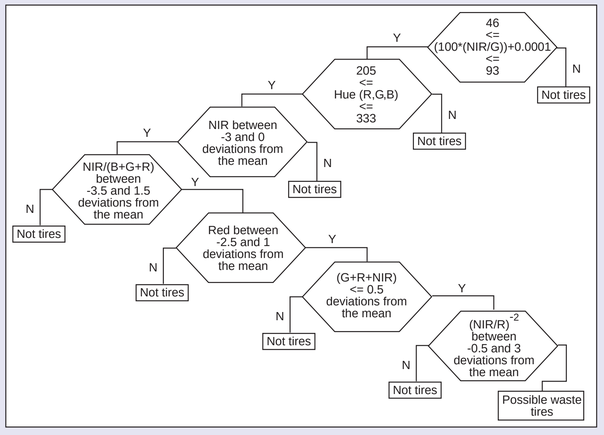
Waste tires have very low reflectance over all multispectral bands. In fact, the reflectance is so low that in many images, tires will be in the lowest 5% of reflectance in all bands. Tires have a similar spectral signature to water, shadows and other dark objects, and they often mix with these same dark objects geographically. A landowner may dispose of waste tires in a gully. The gully may also have standing or running water in it and, invariably, a portion of the gully is shadowed throughout the day. Additionally, waste tires are often disposed of among other wastes. Spectrally problematic wastes include asphalt, black plastic often found among agricultural wastes, and rusted metal.



Red vs. NIR feature space showing the signatures of tires (black) and land cover that may be spectrally similar to tires (gray).

Methods

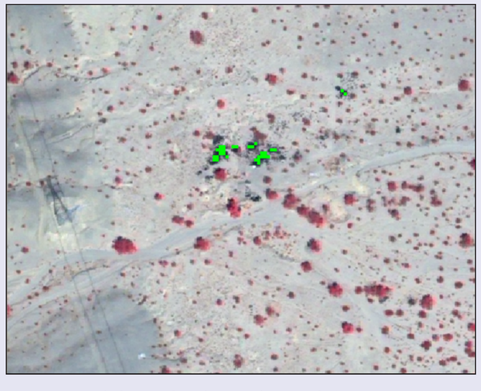
To address all of the spectral and spatial challenges in finding waste tire piles using high-resolution multispectral satellite imagery, a method combining computer and visual analysis was necessary. Using Model Maker in ERDAS Imagine 8.7, the TIRe model, a univariate decision tree, was developed to accommodate the need for general metrics addressing input images with varying ambient reflectance values and few training sets.



In a univariate decision tree framework, we chose a binary approach to divide the feature space into two classes: tires and not tires. We chose a univariate tree, containing only one test at each node, in order to make the tree as understandable and as easily tailored to future data sets as possible. Only a single decision at each node must be tested with the limited training set to allow for modification of the model. Each node's decision is based on a per-pixel test, though each pixel's relationship to the whole of the remaining feature space is determined in the last four nodes through the use of global standard deviation binning. Additionally, with the decision tree's in-sequence testing along with the application of standard deviation, we were able to arrange the tree for optimal performance.

Results

Sixty-six waste tire disposal sites of the 89 sites identified for inspection (87%) in the 8,498 sq km study area were correctly identified and contained tires. Two sites were previously known to the analyst and 11 sites were inaccessible to inspectors. These 13 sites were not included in these results. Seven uncertain sites (9%) included those with limited access and sites that have changed since satellite image collection but still include waste tires or evidence of tire burning. Three sites (4%) were false positives due to the presence of dark objects that were confused with tires. The vast majority of sites identified for inspection in this study were in Mexico and most were unregulated waste tire piles; only 2 sites were in the United States.



TIRe model results (green) overlain on pan-sharpened multispectral image, showing likely waste tire piles. DigitalGlobe Image, 2006.

Photograph of a small tire pile which appears in the image at left. Institute for Regional Studies of the Californias, San Diego State University, 2009

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