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Using Oblique Imagery to Identify Invasive Plant Species in Onondaga County, NY : a Feasibility Study

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Abstract

As the world becomes increasingly connected, the risk of species spreading across previously impermeable boundaries becomes much higher. Many plant and animal species are establishing themselves in entirely new environments, often with significant consequences for indigenous species. This study focused on three non-native plant species—*Lythrum salicaria* (purple loosestrife), *Fallopia japonica* (Japanese knotweed), and *Phragmites australis* (phragmites or common reed)— invasives abundant in Onondaga County. This study aimed to test the feasibility of using readily available oblique imagery to identify the presence of these invasive species. Imagery used in the study came from Google Maps Street View photographs of addresses reported to have dense populations of phragmites, Japanese knotweed, or purple loosestrife. Images were uploaded to ERDAS Imagine 2015 and extraction of plant species was tested using both pixel- and object-based classification approaches. Results largely showed these images were not suitable for positive species identification. The oblique images used for testing varied in spatial resolution and time of capture, which may have impacted success of the classifiers. For example, purple loosestrife is more easily separated from its surroundings when blooming; but the available images did not allow us to capitalize on such phenological distinctions. Future research requires a more targeted data set with confirmed species identification, ground validation, and more consistent image quality. Identifying the presence of invasive plant species within imagery is suggested as an important step toward invasive species mitigation efforts.

Introduction

Scientists argue the present rate of change of the Earth's atmosphere is greater now than it has ever been in the past (Mooney and Cleland, 2009). This accelerated alteration is often considered to be a result of the combination of a rapidly increasing global population and its consequent globalization. Tomlinson (1999) defined globalization as "the rapidly developing and ever-densing network of interconnections and interdependencies that characterize modern social life." As globalization occurs and the world becomes increasingly connected, the probability of species spreading across previously impermeable boundaries becomes much higher. These species, once introduced, can have a variety of impacts. Three such non-native species of significance in New York State (hereafter referred to as "invasives") are *Lythrum salicaria* (purple loosestrife), *Fallopia japonica* (Japanese knotweed), and *Phragmites australis* (phragmites or common reed).

Though native to Eurasia, purple loosestrife was known to be established in America by 1830 (Munger, 2002). It was introduced both accidentally in the ballast of ships traveling from Europe to America and deliberately as a plant used both medicinally and ornamentally. Negative environmental impacts of purple loosestrife include reduction of high quality bird habitat (Hickey and Malecki, 1997), reduction of plant biodiversity (Gabor et al., 1996), alteration of wetland function (Emery and Perry 1996), and crowding out of native species (Welling and Becker, 1993).

Japanese knotweed was introduced to the United States in the late 1800s, primarily as an ornamental plant (Stone, 2010). Previous studies have demonstrated areas with significant populations of Japanese knotweed have shown changes in biodiversity, including a decrease in invertebrate biodiversity anda decline in local green frog population (Gerber et al., 2008) , as well as changes in fungi distribution and altered rates of leaf litter decomposition (Lecerf et al., 2007).).

Phragmites species are native in the United States, though the more harmful invasive strains were introduced from Europe (likely similar to the way purple loosestrife was introduced, inadvertently via ship ballasts) in the 1800s (Saltonstall, 2002). Previous studies have shown the presence of Phragmites can lead to dramatic changes in wetland plant composition (Tulbure et al., 2007). This, in turn, can lead to a noticeable, potentially unpredictable change in the ecosystem services offered by wetlands (cite).

Unforeseen ecosystem alterations like the ones caused by these three invasives can have devastating and wide-spreading ecological impacts. As such, the scientific and wildlife management communities are tasked with developing efficient ways to detect and manage large areas of land afflicted by these problems. One such way is through use of remotely sensed data. Remote sensing is an approach that allows users to observe large geographic areas with comparatively minimal expenditures (Lillesand et al., 2004).

The focus of this study was to identify presence of purple loosestrife, Japanese knotweed, and phragmites within remotely sensed images of locations within Onondaga County. The imagery source was Google Maps' Street View, an archive available to anyone with an internet connection, which provides imagery covering most of the Earth's surface.

Materials and Methods

Study Area

Testing was limited to Central New York, specifically Onondaga County, which is an ideal study area for various reasons. It was convenient in that we did not need to travel far in order to collect required ground reference data from the reported location of these invasives. Additionally, oblique imagery was available, so there was a readily available dataset for us to explore with a broad applicability. Lastly, the New York Invasive Species Clearinghouse (http://nyis.info/) reports all three of the invasive species of interest exist in abundance throughout Central New York.

Datasets

Data were obtained from staff at the New York Natural Heritage Program (NYNHP; http://www.nynhp.org/). The dataset contained 9040 points corresponding to reported sightings of phragmites, purple loosestrife, Japanese knotweed, or water chestnut (*Trapa natans*) from 2000–2014. Water chestnut was not investigated due to time constraints and there were only four sightings in Onondaga County. Each point had associated information on plant species, UTM coordinates, identity of the observer, and County.

Normal color (red-green-blue) Google Maps oblique images of these areas were obtained by converting UTM coordinates from the provided dataset to street addresses and searching these addresses on Google. Once one of the plant species of interest was found (or not found) on Street View, the photo was downloaded for analysis.

For comparison, "ideal" photos of each invasive plant species were downloaded from various sources. Images were deemed ideal based on contrast, lack of shadows, spatial and spectral resolution. These images served as controls, in that the species of interest was definitely present in the photo and therefore should have been easily identifiable using the protocols tested.

Processing

All images were downloaded as JPEGs and imported into ERDAS Imagine 2015 for processing. Two different types of processing were done: pixel-based and object-based.

For pixel-based analysis, a simple unsupervised classification (Lillesand et al., 2004) was done using the three-band (red, green, blue) input images. This was chosen over a supervised classification in order to favor a minimalist approach. Given the fact that the goal of this study was to identify a simple method of species presence, an unsupervised classification seemed more appropriate. The unsupervised classification identified 36 classes, which were then processed for a maximum of 10 iterations. K-means clustering was used with a convergence threshold of 0.95.

For object-based analysis, the unsupervised image segmentation tool on ERDAS Imagine 2015 was used. This tool outputs an image which groups pixels into clusters based on both spectral and spatial similarity. Default ERDAS Imagine 2015 settings were used, which involved using all three spectral bands (red, green, blue) and object edge detection. Object growth was stopped at a pixel value difference of 15 and a variance of 3.50. This object segmentation is typically followed by object classification, which attempts to label groups based on similar spatial, spectral, or contextual characteristics.

Results and Discussion

Of the entire NYNHP dataset, there were thirteen purple loosestrife, eleven phragmites, and five Japanese knotweed points within Onondaga County. Addresses were all easily obtained via Google Maps, though some contained a range of possible building numbers and others simply provided street names within a certain zip code (Table 1). The reported species were spread throughout Onondaga County, though some were some clustered in the sightings reported (Figure 1). Of the observed points, not all had valid Street View images. Two purple loosestrife, two Japanese knotweed, and four phragmites images were used for analysis (their corresponding addresses are highlighted in Table 1). Unfortunately, classification results aiming to separate the invasive species from the surrounding vegetation were generally inconclusive.

Figures 2–4 show an example of the classification seeking to identify Japanese knotweed located at 3993 Fennell Street, Skaneateles, NY, 13152. Figure 2 shows the initial Street View image, Figure 3 shows the unsupervised pixel-based classification output, and Figure 4 shows results of object-based segmentation on the same input image. After performing an unsupervised classification, researchers typically merge the preliminary classes identified to generate a final set of classes; in this case, I sought to identify preliminary classes corresponding to Japanese knotweed. Unfortunately, the preliminary classes identified could not be clearly divided into binary groups separating Japanese knotweed from other surrounding vegetation. However, this was not unexpected, given the low spectral resolution of the imagery used. This is one of the reasons that researchers often seek object-based approaches, where spectral and spatial information can be more easily incorporated into the classification.

Figure 4 shows the output of the object-based segmentation of the Japanese knotweed image shown in Figure 2. This segmentation created 5331 different objects. These objects were left unclassified and all analysis was based on the raw output of the object segmentation tool.

The test image for Japanese knotweed can be seen in Figure 5. Following pixel- and object-based segmentation (Figures 6 and 7, respectively), the test image yielded 3004 objects. Table 2 shows the outputs of object-based segmentation for each usable image and the associated pixel-to-object ratio.

The results shown in Figures 3 and 4 were mirrored across all processed images. Figure 4 shows that certain larger objects were identified by the program, none of which correspond directly to the Phragmites shown in Figure 2. However, there is an apparent increase in segmentation within the portion of the image occupied by knotweed. This trend is the same for the control images, shown in Figures 5, 6, and 7.

Conclusions

The segmentation arrangement shown in Figure 4, which was present for most other segmentation outputs, can potentially be used as an intermediate step in species identification. For example, this approach can be used to exclude all areas that have too few objects, as fewer objects is indicative of a uniform surface. This was the case with Figure 4. By eliminating the smoother surfaces, only the uneven space in the center of the photo would remain, which corresponds to the location of the Japanese knotweed in Figure 2.

Most classification techniques are less robust when faced with low quality images. The image showing purple loosestrife at 6107 Seneca Turnpike in Jamesville (Figure 8) had an average of 345 pixels per object. The image is blurry, distorted, and includes a "Google Maps 2014" watermark; the algorithm confused the hazy pixels for singular objects. In general, image quality inevitably plays a role in the ability for automated image segmentation and classification. Consistency in pixel count, exposure, brightness, and contrast helps in defining an algorithm that can effectively classify a wide range of images. However, such image quality is difficult to obtain without carefully controlling data acquisition. While it would be fairly easy to manually obtain high-resolution photos of these species by organizing studies on the ground, the point of this study was to test whether that step was necessary or not.

Other factors playing key roles in invasive species presence determination process are shadows, timing, and seasonality. Figure 2 clearly shows a shadow in the middle portion of the Japanese knotweed patch. The impact of this shadow on the pixel value confuses the classification algorithm. This is evident in Figure 3, as the pixels that fall within the shadow fall into a different pixel class than those outside of the shadow. Due to this researchers should utilize band ratios to mitigate the impact of shadows in high spatial resolution imagery(Quackenbush et al., 2000).

Seasonality of image acquisition also comes into play in that the appearance of invasive plant species varies during different seasons. Purple loosestrife, for example, is much less recognizable when not in bloom. In an ideal dataset, all plant photos would be taken while subjects are in full bloom. While the test images did have plants in bloom, that may not always be the case. Relative timing is also important as it relates to the time difference between when the photos are taken and when they are being analyzed. The range of reported plant sightings was years 2000-2014. Google Maps' Street View images are on a separate, unknown timeline. This time difference makes it very difficult to effectively test images, because the certainty of the plant sighting/presence is further called into question.

Because of a variety of the aforementioned faults (seasonality, inaccurate addresses, relative timing, and shadows, amongst other potential factors), the dataset was reduced from its original 29 observations to just 8 used for testing. Of additional concern was the method of data collection. Sightings were organized by geographic location. The file had them labeled as latitude and longitude, but they actually corresponded to UTM coordinates. In addition, many of the plants were reported as being identified at the same exact location, or at locations that did not correspond to an actual street address. If reported sightings were not specific enough to locate via Google Maps, then I was unable to verify or nullify the automated identification.

Overall, there is hope that the focus of this study can be extended in future projects. Unsupervised, pixel-based classification of raw imagery turned out to be somewhat ineffective, but incorporating band ratios or moving to classification of object-based segments may serve as a stepping stone toward automated species classification.

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Appendix

Table 1: Addresses of reported species sightings in Onondaga County. Highlighted rows indicate points with corresponding Street View imagery.

Species	Address
Purple Loosestrife	6117-6167 East Seneca Turnpike, Jamesville, NY 13078
	6107 East Seneca Turnpike, Jamesville, NY 13078
	Route 12, Utica, NY, 13502
	3260-3298 Apulia Road, Jamesville, NY 13078
	2250 Apulia Road, LaFayette, NY 13084
	6107 East Seneca Turnpike, Jamesville, NY 13078
	335 W Fayette St, Syracuse Onondaga NY, 13202-1201
	Interstate 90, Warners, NY 13164
	Interstate 90, Jordan, NY 13080
	Interstate 90, Memphis, NY 13112
Japanese Knotweed	6107 East Seneca Turnpike, Jamesville, NY 13078
	5982 US Route 20,La Fayette Onondaga NY, 13084-3400
	345 West Fayette Street, Syracuse, NY 13202
	3993 Fennell St, Skaneateles, Onondaga NY, 13152-9316
Phragmites	5748-5756 Green Lakes Park Drive, Fayetteville, NY 13066
	8100-8298 Green Lakes Park Terrace, Fayetteville, NY 13066
	6107 East Seneca Turnpike, Jamesville, NY 13078
	6285 East Seneca Turnpike, Jamesville, NY 13078
	3260-3298 Apulia Road, Jamesville, NY 13078
	6333-6369 U.S. 20, LaFayette, NY 13084
	9050 Brewerton Rd, Brewerton Onondaga NY, 13029-8502
	7301 Wakefield Drive, Fayetteville, NY 13066
	Interstate 90, Warners, NY 13164
	Interstate 90, Jordan, NY 13080

Table 2: Results of object segmentation on usable images.

Species	**Address**	**Objects**	**Pixels**	**Pixels/ Object**
Purple Loosestrife	6107 East Seneca Turnpike, Jamesville NY 13078	966	333680	345
	Route 12, Utica, NY, 13502	9467	825015	87
	Test image	18130	1579807	87
Japanese Knotweed	345 West Fayette Street, Syracuse, NY 13202	1193	255301	214
	3993 Fennell St, Skaneateles NY, 13152	5331	420853	79
	Test image	3004	123590	41
Phragmites	9050 Brewerton Rd, Brewerton NY, 13029	2350	349265	149
	3260-3298 Apulia Road, Jamesville NY 13078	1320	168526	128
	7301 Wakefield Drive, Fayetteville, NY 13066	2123	434055	204
	6107 East Seneca Turnpike, Jamesville, NY 13078	1369	109718	80
	Test image	17585	1917096	109

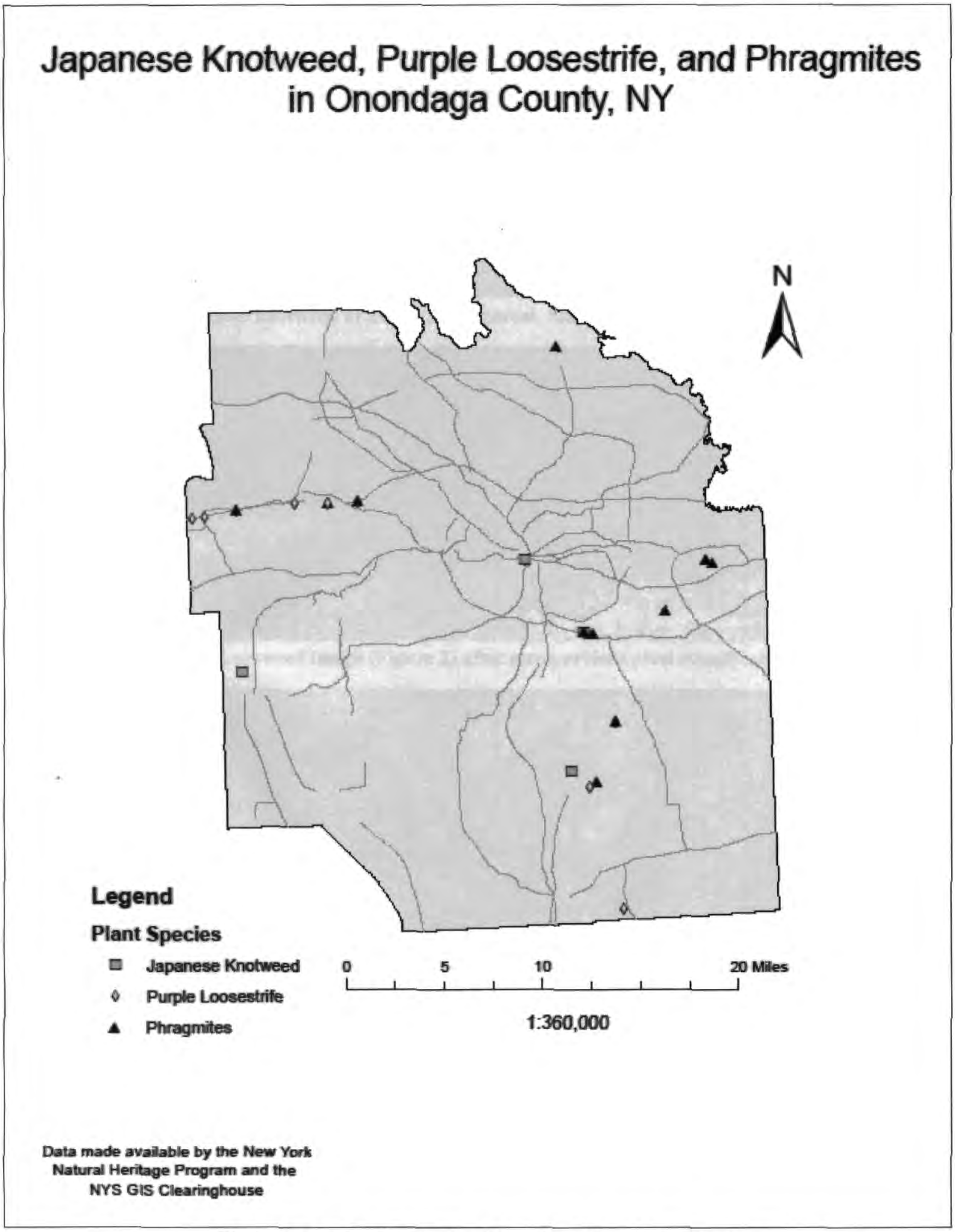

Figure 1: Species distribution throughout Onondaga County.

Figure 2: Japanese knotweed at 3993 Fennell Street, Skaneateles, NY. Source: Google Maps.

Figure 3: Japanese knotweed image (Figure 2) after unsupervised pixel classification into 36 classes.

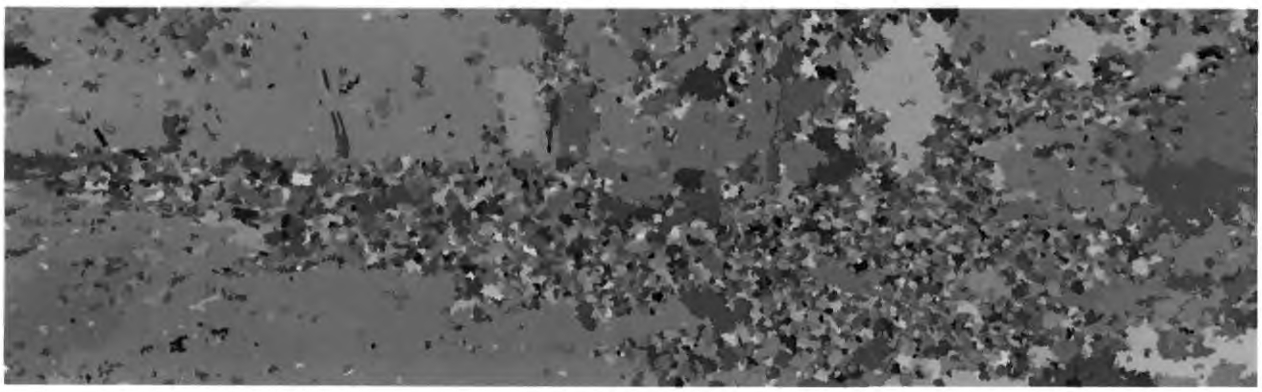

Figure 4: Japanese knotweed image (Figure 2) after image segmentation.

Figure 5: Test Japanese knotweed image. Source: Royal Horticultural Society.

Figure 6: Figure 5 after unsupervised pixel classification into 36 classes.

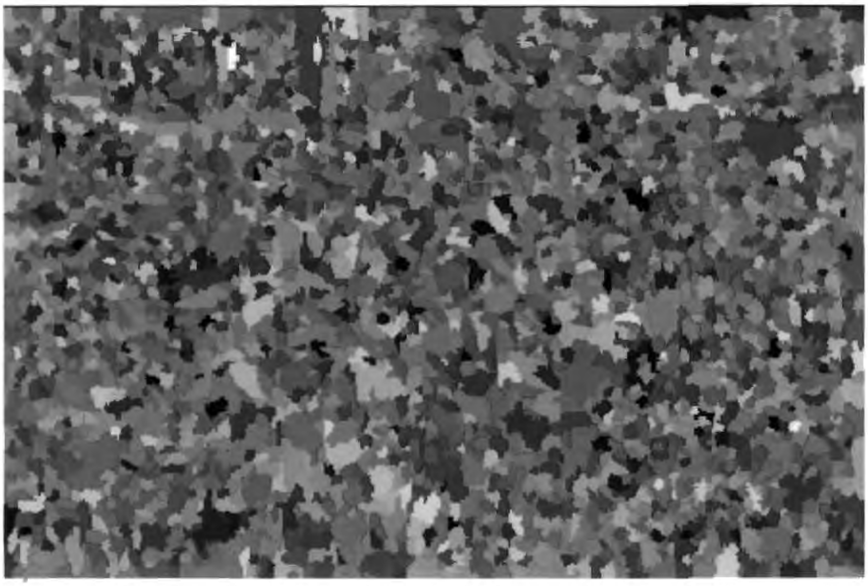

Figure 7: Figure 5 after object-based segmentation.

Figure 8: Purple loosestrife at 6107 Seneca Turnpike, Jamesville, NY.