Using hyperspectral imagery and LiDAR data to detect plant invasions

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Background

Only in my final term as an undergraduate student in University of British Columbia's Faculty of Forestry did I study remote sensing. While I had four years of exposure to ecological concepts, learning about remote sensing tied them together, by proving the ability to provide quantitative high spatial resolution data across large areas. I realized that this blossoming field may expedite ecological findings and open avenues to previously inexplorable research. Later in 2014, I started full-time work as a remote sensing and geographic information systems (GIS) assistant at St'at'imc Government Services and the Integrated Remote Sensing Studio, tasked with mapping land cover for grizzly bear habitat in a 56 000 km^2 area in Southwest British Columbia using Landsat satellite imagery. During this hands-on experience, I was exposed to working with numerous amount of GIS software namely ArcPy and ArcMap. The end results of this project were maps showing land cover and disturbance history to inform policy-making for resource managers and ecologists. During this time, I published a paper detailing the implications of terrain-based shadow corrections on Landsat pixel-based forest change detection algorithms. Most of the processing for this paper was coded in ArcPy. In May 2015, I changed gears from focusing on large regions to mapping the distribution of plant invasions in the City of Surrey as my Master's project. Thus far, I have published one paper from this project (Chance et al. 2016) which concentrates on spectral detection of Himalayan blackberry (*Rubus armeniacus*) and English ivy (*Hedera helix*) across open areas in the city. This scholarship application briefly covers the subject of the next part of my thesis.

Introduction

Non-native invasive vegetation, whether introduced to an area by agriculture, forestry, or home gardening, can dominate an ecosystem at the expense of native flora and fauna, and potentially human health. The reduction in ecosystem services caused by plant invasions costs upwards of $34 billion annually in the United States alone. As such, land managers have economic and ecological incentives to remove these plants.

Urban areas are particularly important in mitigating the effects of invasive species as they are often where invasions start. Additionally, natural areas in urban environments are often the only interaction that people have with nature, thus maintain the integrity of these areas is critical. In Surrey, British Columbia, a fast-growing suburb of Vancouver, Himalayan blackberry and English ivy are two invasive plant species that park managers are actively attempting to eradicate. Himalayan blackberry displaces both native plants and birds. English ivy can kill trees by growing on them, increasing the risk of trees falling on park paths.

Current strategies to remove Himalayan blackberry and English ivy require field crews to locate them first. This system, while successful at removing plants that are detected, may be inherently inefficient. Remote sensing may augment this approach by providing quantitative data about the location of these plants in parks and natural areas. Previous research has shown that light detection and ranging (LiDAR) data can model plant distributions, but these studies are largely absent for urban areas. Hyperspectral imagery can detect plant species at detailed spatial resolutions.

This part of my research aims to demonstrate and assess the capability of using LiDAR data and hyperspectral imagery to map the presence to Himalayan blackberry and English ivy invasions.

Methods and Results

Overview

Ground plots in the city of Surrey are used to train a random forest classifications to detect Himalayan blackberry and English ivy. Numerous rasters of environmental data from LiDAR data and ancillary datasets are created to act as inputs to the binary classification. Hyperspectral imagery is classified using a spectral angle mapper classification (SAM) with ground-based spectra as an input to produce a map indicating spectral similarity to Himalayan blackberry or English ivy at the pixel level. Multiple computing programs, including python, ArcMap, FUSION, ENVI, and R are used for processing and analysis.

Data

In April and May 2013 the City of Surrey acquired aerial LiDAR data and aerial hyperspectral imagery. Both datasets have high spatial resolutions. The LiDAR includes up to 25 points per square metre. The hyperspectral imagery has a 1 m pixel size. Additionally, the hyperspectral imagery has 72 spectral channels ranging from 367 nm to 1047 nm.

The City of Surrey also maintains an active invasive plant species monitoring program, in which locations of Himalayan blackberry, English ivy, and other invasive plants in parks and natural areas are recorded to a database, providing information about species presences and absences. Points are screened on orthophotos to ensure that they line up with the area they are meant to.

Finally, ground-based spectra were collected in spring of 2015 to coincide with the growth stage of the plants in the spring of 2013 (when the imagery was acquired) using an Analytical Spectral Devices spectrometer.

Raster Processing

Currently, 20 rasters have been created so far: diffuse, and direct irradiance; distances to water, roads, and paths; a topographic wetness index (TWI); mean summer and annual precipitation (MSP and MAP); leaf area index (LAI); kurtosis; skewness; coefficient of variation; heights at 75^{th}, 90^{th}, and 95 percentiles; cover below 2.5 m; aspect; slope; soil surface; and curvature. All rasters are produced at a 1 m pixel resolution to match the hyperspectral imagery.

Diffuse and direct irradiance rasters (Figure 1) are produced using python as a programming language, and ArcPy for some tools. To create these layers, the irradiance is calculated for each hour on the 15^{th} day of each month at 2.5 metres above the ground. This means that these irradiance layers are independent of most understory shrubs (and thus would not be influenced by the presence of blackberry or ivy), and account for canopy light interception. These scripts use LiDAR points and a LiDAR-derived digital elevation model (DEM) as inputs.

Distances to water, roads, and paths are created in ArcMap using the Euclidean Distance tool with data from the City of Surrey as inputs. The TWI (Figure 1) is also created in ArcMap using the Flow Accumulation, Flow Distance, and Raster Calculator tools. Aspect, slope and curvature are also produced in ArcMap by inputting the DEM into the Aspect, Slope, and Curvature tools. Leaf area index, kurtosis, skewness, coefficient of variation, height percentiles, and cover metrics (Figure 1) are produced in FUSION, a LiDAR processing program designed for forestry applications. Finally, the SAM classification is run in ENVI on 8-10 bands of the hyperspectral imagery (Chance et al. 2016). The SAM classification produces an output of the angle difference between each pixel and the target spectra. In other words, this is a metric of how closely the pixel and the target spectra match, and is called a rule image.

As many of these processes are memory intensive, I created a python script using some Arc tools to tile the study area before running many of them.

Analysis

Two masks are created. One masks areas outside of parks and natural areas as there is not training data from private lands. The second masks pixels that have no understory cover below 2.5 m using the cover below 2.5 m raster.

A random forest classifier, which is a non-parametric ensemble of decision trees, is used in R to classify the remaining pixels as with presence or absence of Himalayan blackberry or English ivy. Each of the rasters, including the SAM rule image, are used as input variables in the classifier. The random forest algorithm provides a ranking of variable importance. By iterating the random forest and eliminating weak and correlated variables, the classification accuracy may increase. **Figure 2** shows a preliminary map of Himalayan blackberry presence using this procedure.

References

Chance, C.M., Coops, N.C., Crosby, K., and Aven, N. 2016. Spectral wavelength selection and detection of two invasive plant species in an urban area. Canadian Journal of Remote Sensing.

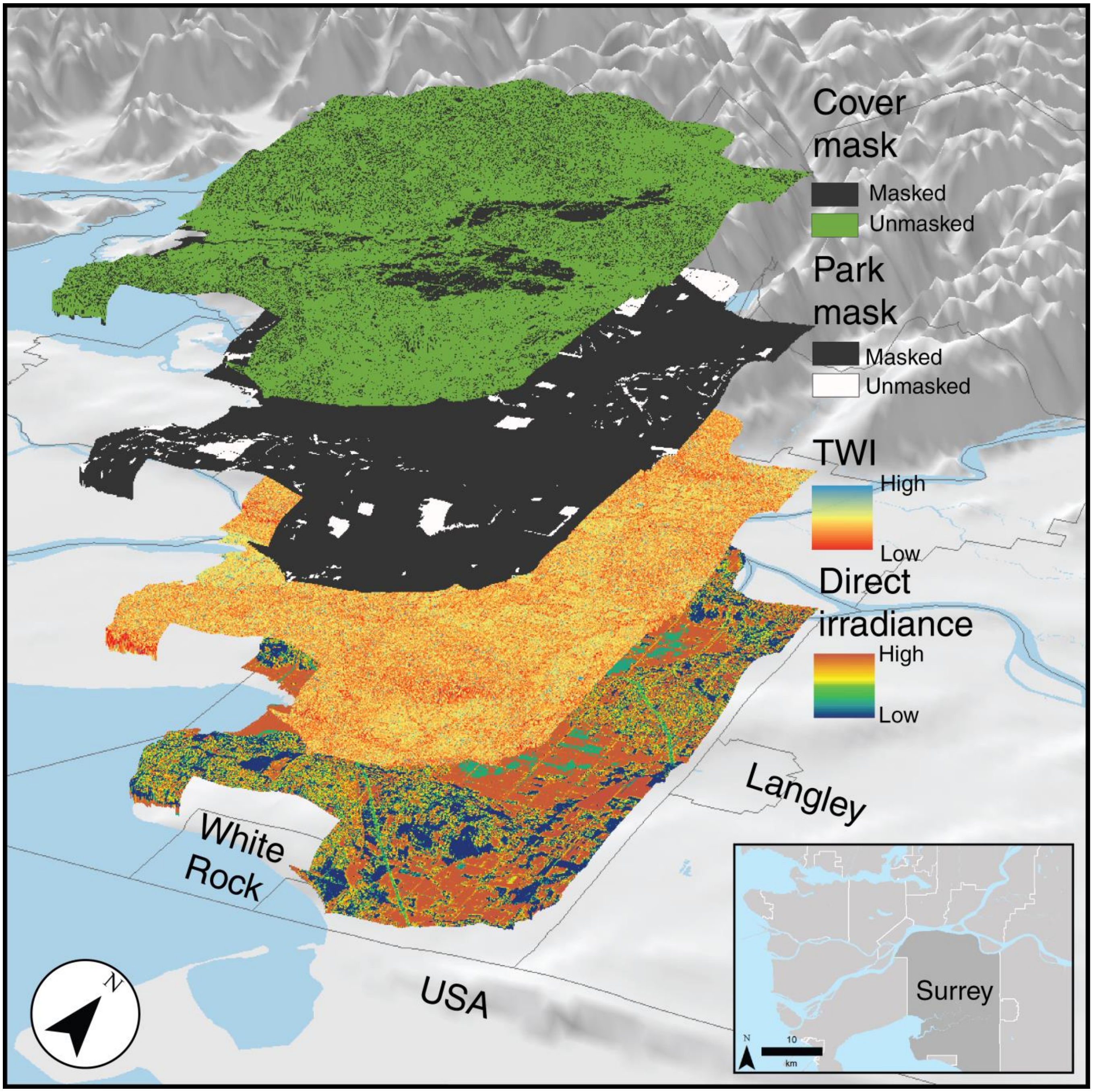

Figure 1. Examples of some of the rasters used as masks (Cover Mask and Park Mask) and environmental variables (Topographic Wetness Index [TWI] and Direct Irradiance) used as input into the random forest classification for detection of Himalayan blackberry and English ivy in Surrey, British Columbia.

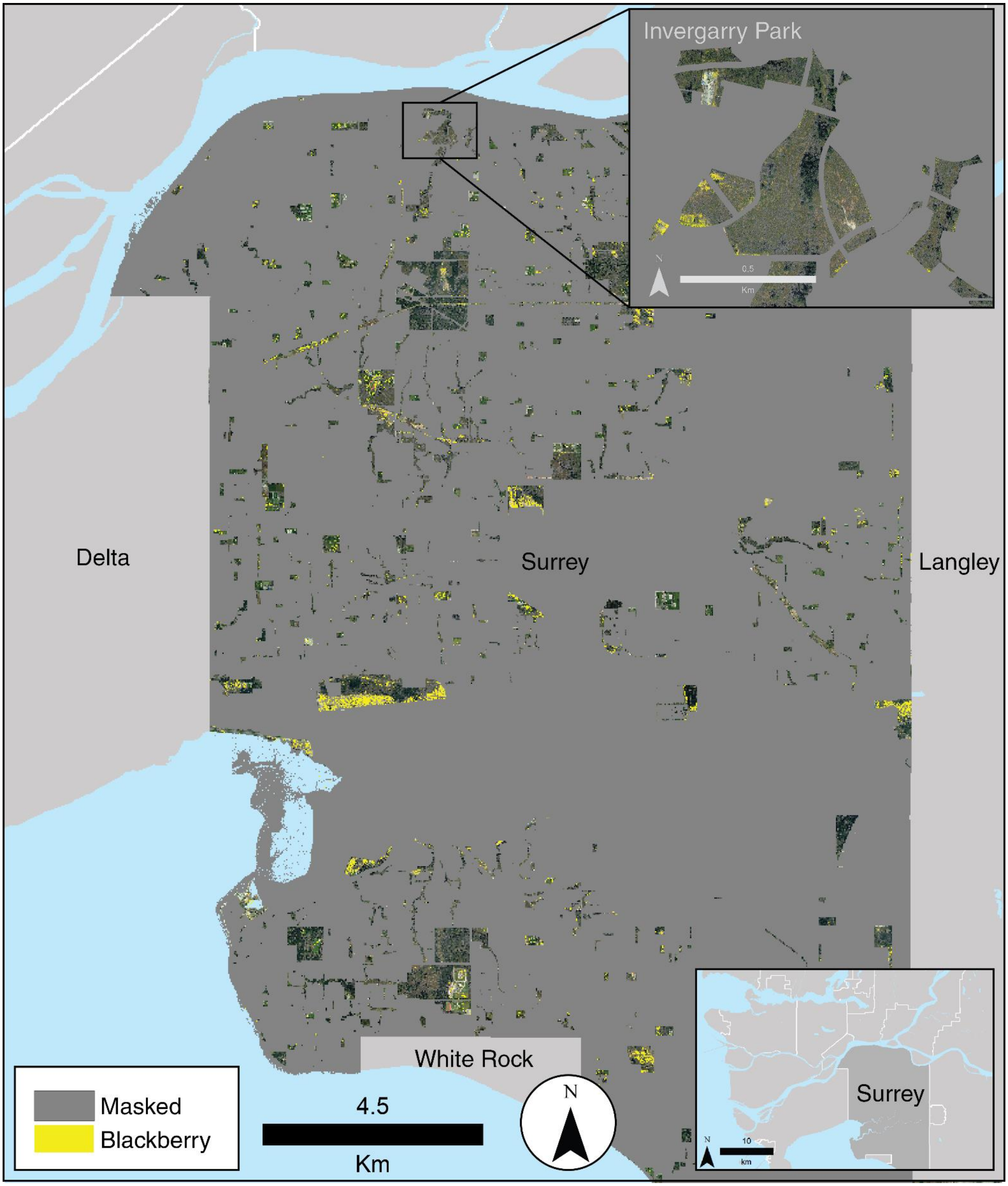

Figure 2. Preliminary results of the random forest classification showing the distribution of Himalayan blackberry in public parks and natural areas across Surrey, British Columbia.