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A SIMULATION APPROACH TO USING LANDSAT 8 IMAGERY TO DETERMINE A THRESHOLD FOR DETECTING CHANGES ALONG A STREAMSIDE MANAGEMENT ZONE: A CASE STUDY IN LOUISIANA.

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Abstract. Satellite data is often employed to assess land use/land cover changes, particularly over larger areas. However, little attention is given to how much area can change before a given land use/cover classification is detected using satellite data. This is an important consideration, particularly in the use of image classifications to assess best management practices (BMPs). To determine these changes, and their corresponding impacts on land cover classification, Landsat 8 data was acquired and an area selected where two land cover classes meet (i.e., forest and field). The Landsat pixels were subset into 900 one square meter (1 m^2) pixels and the average pixel values for grass were utilized to simulate tree/forest removal. The objective is to determine how many pixels would be converted from forest to field before an unsupervised classification detected the change. Approximately 25 percent of the area changed before one Landsat pixel (30m) changed classes and 43 % of pixels changed before a row, representing a streamside management zone (SMZ), changed. This indicates that image resolution should be considered when using satellite imagery to assess BMPs/land cover changes.

Keywords: i-Tree Canopy, municipal management, small urban areas, urban canopy benefits.

1 Introduction

Streamside management zone (SMZ) delineation is a part of the development of best management practices (BMP) related to forest management. An SMZ is an area of vegetation near a body of water left alone from mechanical action (e.g., harvest, treatment, etc.) to serve as a buffer or filter to mitigate surface water runoff and erosion (Gregory et al., 1991; Williams et al., 2004). The benefits extend beyond runoff and erosion mitigation, ranging from the regulation of water temperature to the provision of wildlife habitat (Pennington et al., 2008; Sugden et al., 2019). In the southeastern United States, BMPs are typically voluntary/non-regulatory. Regardless of whether BMPs are regulatory, implementation rates range from 84% to 99% and SMZ implementation averages 93.2% throughout the southeast (Cristan et al., 2016).

SMZ guidelines are dependent upon stream classification (intermittent, perennial, etc.) and slope within the SMZ. In Louisiana, SMZs range from 15 feet (4.6 meters; for ephemeral drains) to 100 feet (30.5 meters) for perennial streams greater than 20 feet (6.1 meters) wide; these are base-level guidelines and additional distances are recommended for increased slope or wildlife conservation (Natural Resources Conservation Service, 2013). Generally, state forest agencies monitor the implementation of SMZs. To accomplish this, geographic information systems (GIS), aerial photography, and satellite images are employed (Narumalani et al., 1997; Goetz, 2006). This allows for the determination of recommended SMZ widths and whether the areal extent of the buffer was met by harvests or other management activities (Lemoine et al., 2006; Johansen et al., 2011; Wasser et al., 2015). To evaluate SMZ compliance over large spatial scales (e.g., throughout a state or across the region), satellite imagery is employed because of its accessibility and spatial and temporal resolution (Klemas, 2014). Landsat data can be useful for assessing SMZs of 100 feet as the spatial resolution of each pixel is 30 meters. Classification of land use/land cover types via satellite data allows for the assessment of change on a per-pixel basis. When significant change occurs within an SMZ, it is possible to determine land cover classes that can guide site visits (Klemas, 2014).

While installation of SMZs as a management practice in forested and agricultural areas is important for water quality and habitat conservation, it removes acreage from production for a landowner. The acreage that remains inaccessible may vary in timber type and quality and some timber recovery may be possible (Wu et al., 1996; McConnell et al., 2020). It is also possible that harvesters, inadvertently or not, encroach on SMZs during harvest. The opposite is also possible- reserving more acreage for streamside protection than legally obligated, which can cost producers future income opportunity. Regardless of whether select cutting is allowed within an SMZ or its boundaries were accurately marked, the utilization of satellite data to delineate and assess SMZs will only be as effective as the spatial and spectral resolution of the sensor allows. To assess the efficacy of Landsat data for assessing SMZs, this study seeks to determine the extent of pixel change along an SMZ required to change the classification of a given pixel. This will provide an estimate of the degree of change required in SMZ encroachment and detectability of changes using Landsat data.

2 Methods

Effective monitoring of SMZs incorporates remotely sensed data to select monitoring/sample locations. To assess the applicability of moderate resolution satellite data for monitoring SMZs, a study was designed to determine the amount of change that could occur in a 30 meter Landsat 8 pixel before the land use classification would be impacted (Klemas, 2014). An area of representative forest and short vegetation (e.g., grass) in a Landsat image covering Lincoln Parish, LA, was acquired (from June 2018) and reflectance values for visible blue, green, red, and near-infrared were extracted. This area was selected in an area identified as pine forest and short vegetation (i.e., grass/field) to minimize the influence of spectral mixing in pixels. A case study was designed to assess approximately 10 acres of field adjacent to a SMZ. The reason for this assessment was the idea of SMZ encroachment by an agricultural field (e.g., corn, grass/hay, etc.). The area selected was a seven-pixel by seven-pixel (10.9 ac/4.41 ha) portion of the SMZ.

The 30 meter pixels were subsampled into one-meter sub-pixels, creating a total 900 sub-pixels for each pixel (Figure 1a). These pixel values were perturbed by replacing the forest reflectance value with the average short vegetation values using a meter by meter incremental encroachment into the SMZ. One row in each spectral band was changed, to simulate a systematic harvest/encroachment into the SMZ (Figure 1b). This process was repeated multiple times to determine the area loss before the classification change occurred. Scenarios assessed are for 30, 180, 210, 240, 270, 300, 330, 360, 390, and 450 perturbed pixels. This process was repeated until the classification of the pixel changed from forest to short vegetation. Following each iteration, the layers were stacked to create an image file and unsupervised classification was performed using ERDAS Imagine.

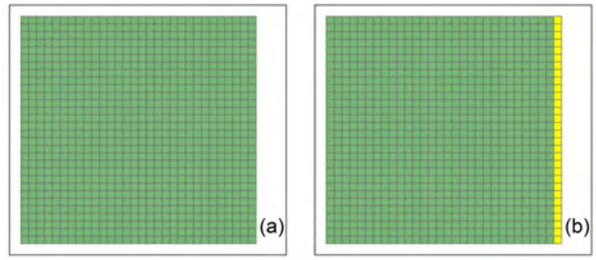

Figure 1: A 30 meter Landsat pixel sub-divided into 900 1 meter pixels (a) and the incremental change to each pixel (b).

3 Results

The initial perturbation of pixels being changed from pine forest to grass (i.e., changing 30 pixels), resulted in no change to the classification (2a-2b). No classification change occurred (i.e., from forest to field) until an encroachment of seven meters into the forest pixel was completed, consisting of 210 one-meter pixels within each 30 meter pixel, or 23% of the pixels in the buffer zone. This resulted in a change of one of the pixels in the area changing (Figure 2c). Continuing with the encroachment scenario (Figure 2d - 2h), demonstrates the amount of change that can occur to all pixels before a detected change occurs to the entire buffer area.

The entirety of the row of 30 meter pixels representing the SMZ did not completely change classification to short vegetation until an encroachment of 13 meters, or 390 one-meter pixels – 43% of the total number (Figure 2i). On an area basis, this represents approximately 0.1 ac of change per pixel; for the entire block of pixels assessed in the buffer area/SMZ, this is 0.7 ac. From a simple timber value perspective, for every \$1,000 per acre of timber value this equated to \$100/acre on an area basis, and \$700/acre for the entire block of pixels along the stream. The classification from pine to grass varied, with two pixels changing with 270 pixels losing forest cover (Figure 2e) to not more than the single line of forest pixels changing with half of the one-meter pixels being perturbed (Figure 2j).

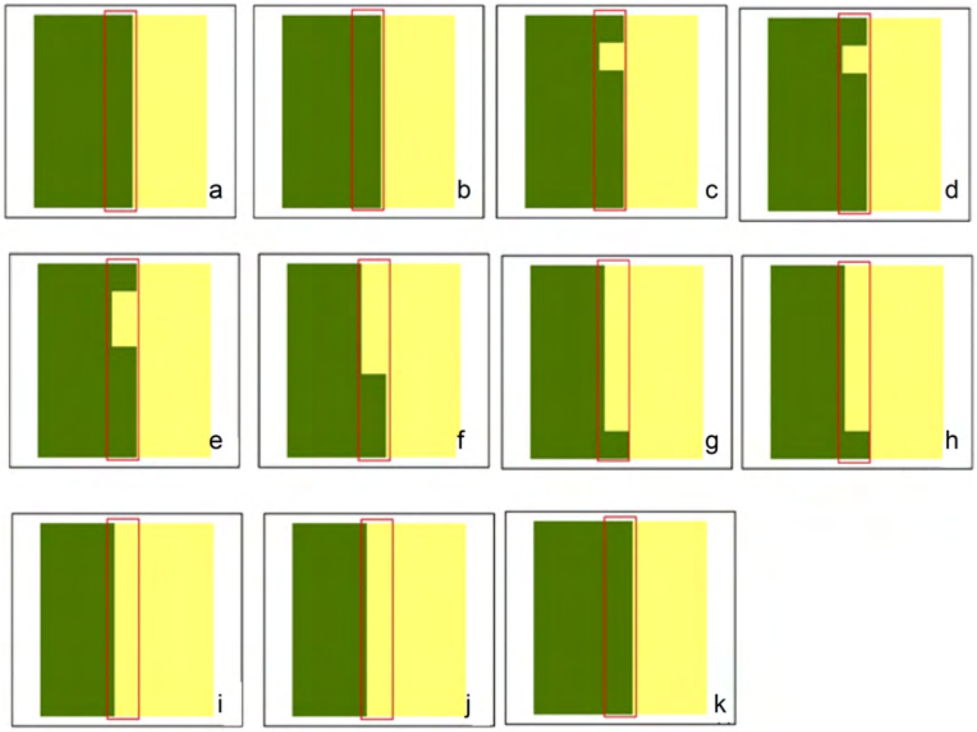

Figure 2: Classification based on scenarios for 1meter pixels perturbed (indicated by the red polygon) – (a) 30, (b) 180, (c) 210, (d) 240, (e) 270, (f) 300, (g) 330, (h) 360, (i) 390, (j) 450, and (k) is the original image.

4 Discussion

Encroachment into forest area is possible without detection using Landsat data. In this study, 43% of the pixels classified as forest were converted to spectrally represent short vegetation before the strip of pixels representing a buffer/SMZ changed. The implication is that encroachment could occur, accidentally or intentionally, without detection. Louisiana has a high implementation rate for BMPs (Cristan et al., 2016) but whether these are continuously observed after establishment is unknown. The value of timber within an SMZ may incentivize the allowance of at least some harvest or encroachment within the buffered area (McConnell et al., 2020). It would be useful to evaluate the impacts of partial harvests to assess and quantify the impacts on ecosystem services and their spatial variability within watersheds (Van Looy et al., 2017).

In the scenario assessed in the present study, the change from values in a pure pine forest changing to short vegetation took a large percentage of pixels to change before classification of the pixel was altered. This illustrates the difficulty of utilizing common image classification techniques to assess changes in an SMZ. If an area were mixed pine-hardwood or mixed land cover types, spectral mixing would need to be addressed, perhaps through some spectral mixture analysis or hybrid classifiers (Powell et al., 2007; MacLachlan et al., 2017; Phiri and Morgenroth, 2017). Because of its widespread availability, Landsat data is widely used to assess forests for disturbance or harvest and determine field survey sites (Mississippi Forestry Commission, 2019; Georgia Forestry Commission, 2019). Large areas of disturbance will likely be found via image classification; however, caution should be used if relying solely on medium resolution satellite data and additional data/information incorporated into management decisions (Klemas, 2014). Other, higher resolution, image sources can be utilized (e.g., Google Earth, NAIP imagery) but temporal resolution may preclude their use for assessing SMZs.

Even at a medium resolution such as Landsat data, there is a risk of detection and future research should consider both a larger, operationally-sized area and the probability of detection and any punitive damages. In the case of trespass and theft, for example, higher resolution imagery would be required to verify the location of individual stems in order to award damages (McConnell et al., 2019). It may be beneficial to support the analysis of some watersheds with higher spatial resolution data such as aerial photography. This could be accomplished on a local scale with Unmanned Aerial Vehicles, which can also be combined with Landsat data to provide biomass estimates (Yang et al., 2018).

5 Conclusions

This study assessed sub-pixel level changes between two land cover types and the degree of change that would occur before a land cover classification changes. This study assessed a small area and two land cover types (i.e., pine forest and short vegetation/grass). This study could be expanded to assess multiple land cover types over a larger area and incorporate higher spatial resolution data (e.g., MacLachlan et al., 2017) to address subpixel spectral differences in land cover types. While the present focus was on SMZ encroachment and detection, the methodology could be expanded to include multiple vegetation and forest types in a more holistic assessment of forest ecosystems. Expanding the methodology and scale would allow for the consideration of multiple scenarios imagined at a finer scale than that covered by a 30-meter pixel and expand on larger scale assessment of natural resource systems (Corona, 2016).

The ability to quantify the amount of change that can occur in an image is important, particularly in the case of medium resolution imagery such as Landsat that is employed in ecological assessments. While the present study was a hypothetical scenario, the applicability extends to multiple land use/land cover change scenarios that may underestimate the level of change following disturbance. The scenario presented is not intended to discourage the implementation of SMZs specifically or BMPs generally nor encourage encroachment, theft, or cheating SMZs. The illustration of the change that occurs before land cover change classification takes place will hopefully discourage the reliance on a single imagery or monitoring source and encourage resource managers and policy-makers to support multiple modes of remote and in-situ assessment.

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