

Land Cover Change Analysis using MSAVI2 for Orchard Project

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ABSTRACT

A remote sensing land cover change analysis was performed using MSAVI2 to quantify vegetation changes. WorldView2, WorldView3, and Landsat 8 imagery were used to conduct the analysis in Idrisi Taiga. Phenological synchronization was used to detect all changes between October 2013 and October 2014 and avoid misrepresentation of results common to products of anniversary date analysis. Six individual analyses were used to further understand land cover changes in the aforementioned phenological time span. Statistical thresholds were determined to better interpret image differencing outputs. Adjustments were also made for multi-sensor comparisons. Results of this study indicate WorldView imagery is more sensitive to recording change than Landsat 8 (although WorldView imagery was only available for a portion of the Orchard Combat Training Center study area). Landsat 8 imagery allowed for increased coverage at coarser sensitivity. Overall, both sensors showed reasonable agreement in detected change.

KEYWORDS: vegetation, land cover change, MSAVI2, remote sensing, GIS

INTRODUCTION

Anthropological forces are considered the cause of current land surface change (Yuan 1998). The forces may be direct (urban development) or indirect (pollution). This study examines a direct form of change; the effect of military exercises at the Orchard Combat Training Center (OCTC) in Idaho, USA. The primary objective of this study was to quantify the amount vegetation change at the OCTC as a result of annual training (AT) events during May 2014. Satellite remote sensing land cover change (LCC) methods were used to assess and quantify these changes.

LCC processes can be approached in one of two ways: 1) between-class change and 2) within-class change. Between-class change occurs when a land cover classification changes from one type to another over time (Yuan 1998). For example, a dense coniferous forest is transformed into barren slopes via a tree harvesting event (a transformation between land cover types). In contrast, within-class changes occur within the same land cover type (Yuan 1998). Detection of within-class changes are primarily concerned with the quality of a particular land cover type over time relative to ecosystem services or wildlife habitat (Yuan 1998). The latter approach was applied to this particular study.

Remote sensing techniques have been used as an effective means of analyzing land cover change processes for decades (Singh 1989). The use of pre- and post-satellite imagery allows for assessment of quantifiable vegetation change (Singh 1989). A refinement applied in this study was the use of phenologically synchronized imagery to avoid misrepresentations of change that may be caused when using anniversary date change detection methods (Weber 2001). Precipitation, the primary driver of vegetation dynamics in semiarid regions such as the OCTC, was also considered and included in the interpretation of within-class change.

To detect land cover changes, we applied an indices of photosynthetic activity or vegetation greenness known as the Modified Soil Adjusted Vegetation Index (MSAVI2). Indices like these are created using the red and near infrared (NIR) bands of imagery from sensors such as Landsat and WorldView (Singh 1989). MSAVI2 is a robust approach best used when land cover is extensively intermingled with exposed soil (Qi et al 1994). MSAVI2 has been shown to increase vegetation sensitivity in the presence of high soil background signals (Qi et al 1994). Conditions at the OCTC suggested the choice of the MSAVI2 vegetation index.

METHODS

WorldView2 (WV2) data were used for the pre-event imagery and WorldView3 (WV3) data were used for the post-event imagery. Four Landsat 8 (LT8) scenes were also gathered from the U.S. Geological Survey Eros data center to compare and contrast data

types over various phenological periods. WorldView (WV) multispectral imagery uses a pixel size of 2m x 2m. LT8 pixels were 30m x 30m. In addition to the satellite imagery pre-processing and analysis, monthly (October 2013 through September 2014) precipitation reports were prepared using data from the nearest weather station, a US Bureau of Reclamation AgriMet station at Grand View Idaho (figure 1).

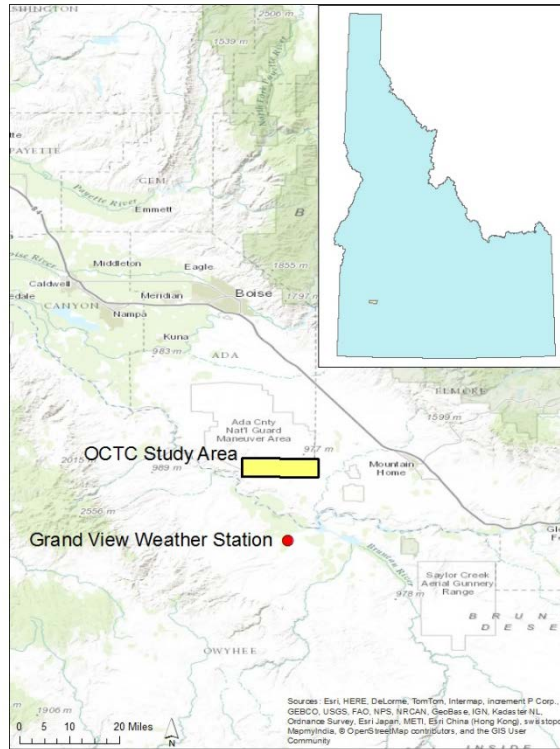


Figure 1: Orchard Combat Training Center study area and location of the Grand View weather station from which precipitation data was acquired.

Prior to analysis, all imagery was corrected for atmospheric effects using the Cos(t) method (Chavez 1996). Red and near infrared bands were used to create MSAVI₂ (figure 2) primary productivity indices for each imagery date from both WV and Landsat sensors.

$$MSAVI_2 = \frac{2\rho_{NIR} + 1 - \sqrt{(2\rho_{NIR} + 1)^2 - 8(\rho_{NIR} - \rho_{red})}}{2}$$

Qi et al 1994

Figure 2: MSAVI₂ band ratio equation used in this study

Image differencing of MSAVI₂ was applied to detect changes using the standard class image differencing option in Idrisi Taiga (Singh 1989). This technique takes two images, pre- and post-change, and produced an output separated into six classes according to the

magnitude of change determined using standard deviations (SD) from the mean (figure 3). SDs were used to determine statistical thresholds of vegetation change over the selected time period. Of all the change that occurred, it was necessary to define a threshold value within which all reported change would be considered anomalous or insignificant (i.e., background noise). Classified change within one SD of the mean were henceforth considered areas of no change.

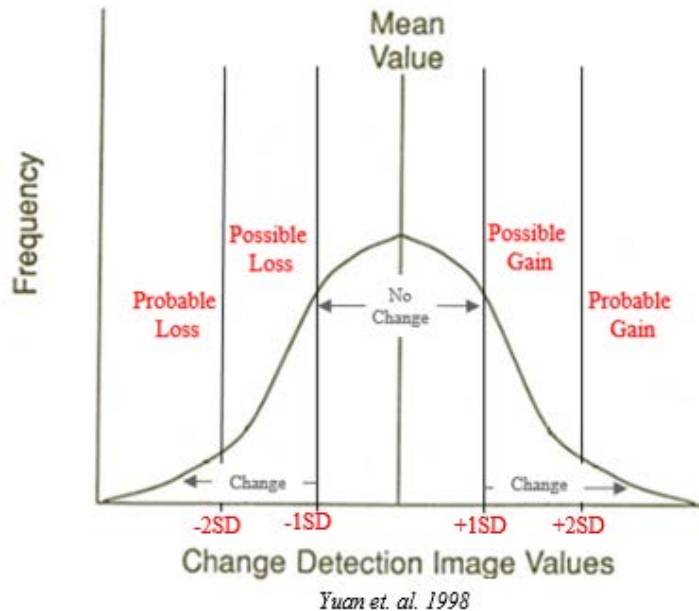


Figure 3: Land cover change thresholds were based on standard deviations from the mean.

Any classified changes beyond one SD of the mean were considered representative of areas of change. Further divisions of change occurred between one and two SD above and below the mean and were defined as possible change; data beyond two SD from the mean were defined as probable change.

LCC with WV imagery was accomplished using both WV2 (pre-event imagery) and WV3 (post-event imagery). While these sensors are similar they are not identical. Furthermore, because WV satellites are considered deployable sensors (they do not follow a pre-set orbit of specific paths as does Landsat) the imagery used in this study was collected at varying sun azimuth and satellite sensor angles. To accommodate this variability WV results are reported using the more conservative probable change threshold (+/- 2 SD from the mean).

For display and interpretation of resulting imagery, the aforementioned thresholds were applied to the LCC data using a raster Boolean calculator in Idrisi Taiga. A statistical

summary was then generated for each raster layer representing gains and/or loss for each time period. Pixel count reports were converted to acres for this report.

Six time periods were analyzed in this study: one using WV imagery and five using LT8 imagery (figure 4).

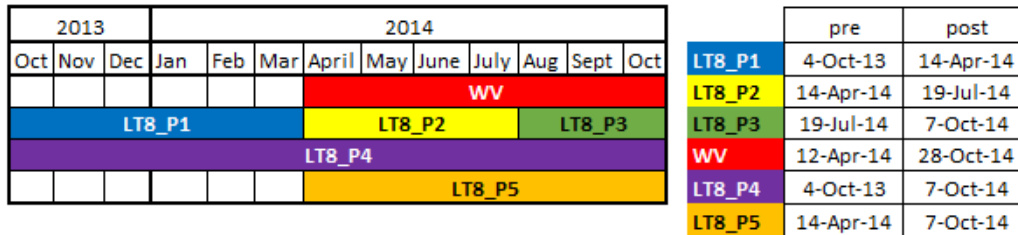


Figure 4: Time periods analyzed for land cover change.

LT8 Period 1 (LT8_P1) captures LCC prior to the WV period. LT8_P2 and LT8_P3 LCC effectively split the WV period of change in half. LT8_P4 captures the phenological period from Oct 2013 to Oct 2014. Lastly, LT8_P5 is a direct comparison across the same WV time period (April through October 2014).

RESULTS & CONCLUSION

A summary of the results for each time period are shown in Table 1. The WV time period (with +/- 1 SD threshold) shows an overall change of 25.9% with 12.4% of pixels indicating vegetation gain and 13.5% of pixels indicating vegetation loss. Using the more conservative threshold of +/- 2 SD, LCC with WV is more comparable with LT8 LCC results and average approximately 2-4% change across the OCTC study area.

Table 1: Results represented in acres and percent pixel coverage

Sensor/Time Period	Change		No Change		Gain		Loss	
	Acres	%	Acres	%	Acres	%	Acres	%
WV +/- 1SD	5,198	25.9	14,809	74.1	2,490	12.4	2,708	13.5
WV +/- 2SD	782	3.9	19,225	96.1	308	1.5	475	2.4
LT8_P1	912	3.4	25,775	96.6	900	3.4	12	0.0
LT8_P2	228	0.9	26,459	99.1	0	0.0	228	0.9
LT8_P3	383	1.4	26,304	98.6	375	1.4	8	0.0
LT8_P4	567	2.1	26,120	97.9	535	2.0	32	0.1
LT8_P5	643	2.4	26,044	97.6	71	0.3	572	2.1

Examining LCC across the various time periods, LT8_P1 indicates nearly all change was vegetation gain. This result was expected as the vegetation in October 2013 (pre-change imagery) was senesced or dormant while vegetation in April 2014 (post-change imagery) was actively growing during this spring season. In contrast, the next time period, LT8_P2, shows nearly all detected change as vegetation loss. This again is ecologically

understandable as the flush of spring vegetation has senesced. This result also suggests the presence cheatgrass (*Bromus tectorum*) in the OCTC study area which follows a phenological cycle very similar to that seen here. LT8_P3 concludes the phenological time span with mostly gains which is likely due to a vegetation response to rains that fell in September 2014 (figure 5). LT8_P5 reports a summary overall net change from LT8_P1-P3.

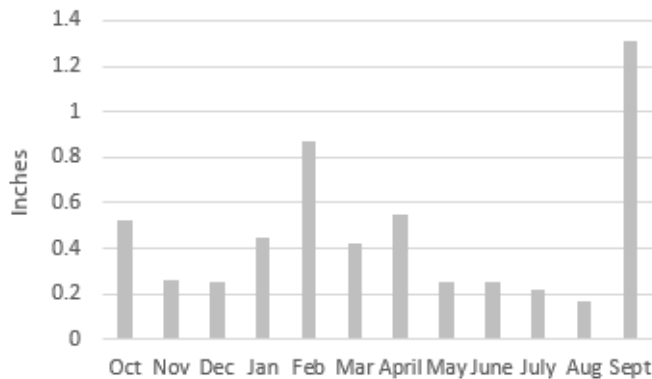


Figure 5: Monthly total precipitation from the Grand View weather station for October 2013 through September 2014.

These results of gains and losses corresponds well with observed fluctuations in precipitation. For example, LT8_P3 shows mostly gains that may likely be associated with the largest spike in precipitation, at 1.3 inches, out of the eleven month, 0.46 inch average, record.

LT8_P2 and LT8_P3 divide LT8_P5 approximately in half. This LCC time period (LT8_P5) is effectively equivalent to the WV LCC time period. The sum of change in LT8_P2 and LT8_P3 is 611 acres which is comparable to changes detected during LT8_P5 (643 acres of change) (figure 6a). Throughout this same time span WV results (782 acres of change, using a threshold of +/- 2 SD from the mean) report modest agreement with LT8 results (figure 6b). In contrast, the same WV time period using a +/- 1 SD threshold from the mean, results in over 5,000 acres of change; over 20% greater than all other results (figure 6c).

A few important conclusions can be drawn from these results: 1) WV imagery is a lot more sensitive to recording vegetation changes even when adjusted for multi-sensor variability. This is likely associated with the spatial resolution of the WV sensor as the pixel size is 225 times smaller than a LT8 pixel, 2) total coverage of the OCTC study area by WV imagery is not complete but indeed 25% smaller (20,007 acres) than the original study area (26,687 acres). This shortage is a result of available imagery limitations. LT8 imagery however, was able to completely cover the study area. 3) While an increased quality of analysis for land cover change may be available from WV imagery, this sensor

is restricted to smaller coverage areas and is more difficult and costly to obtain. LT8 imagery is widely available but produces coarser results.

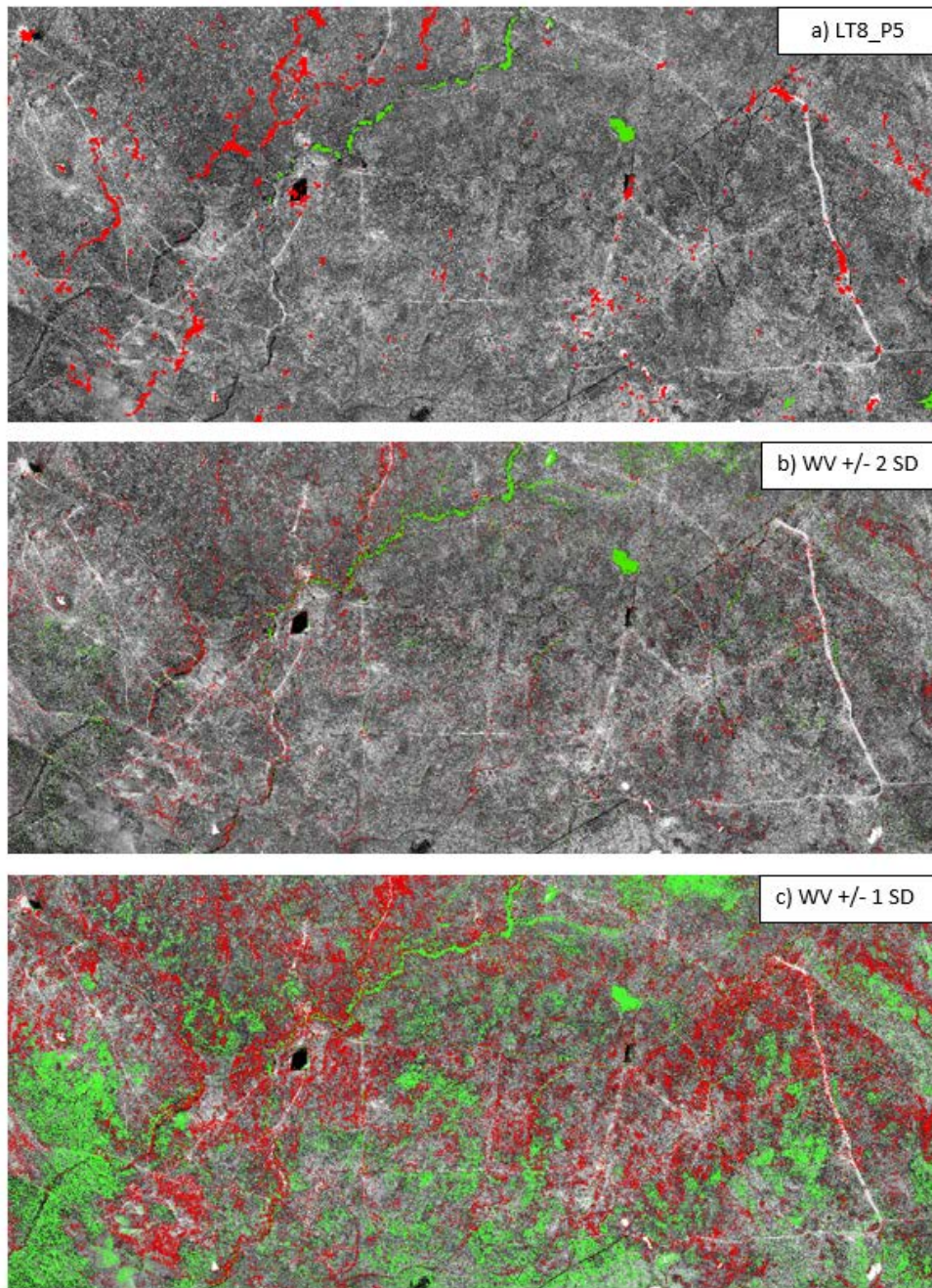


Figure 6: Resulting land cover change analyses from various sensor platforms (green = gain, red = loss) Background is post-change panchromatic Worldview3 image. Land cover change from Landsat period 5 is shown in map A, while land cover changes from Worldview are given in maps B-C. The difference in detection threshold is illustrated in B-C

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