THE INFLUENCE OF SOLAR INCIDENT ANGLE ON TEMPORAL CHANGE ANALYSIS

Satellite imagery with varying solar incident angles were used to assess the effect on land cover change detection results and the practical applicability of BRDF corrections.

Abstract:

Land cover change assessment is a relatively common technique employed today. Typically, anniversary date synchronization is used. However, a more recent approach uses phenological synchronization. The latter approach tends to reduce or eliminate the effect of differing phenological status but could potentially induce an error due to variation in solar incident angle and the effect known as bi-directional reflectance distribution function (BRDF). This study investigated the effect of varying solar incident angle and BRDF on land cover change detection using image-differencing techniques and LUCCAS software. The level of agreement between uncorrected imagery and imagery that has been corrected for BRDF was used to determine the potential error caused by varying solar incident angle and assess the practicality and necessity of the BRDF-correction technique. The author found that where solar incident angle variation between imagery was <6.69 degrees, the effect of BRDF was negligible and corrections unnecessary.

Introduction:

We used phenologically synchronized (Weber 2000) Landsat satellite imagery to perform land cover change analysis of the upper Snake River plain and Greater Yellowstone ecosystem (fig. 1). These images were acquired as early as June 9 and as late as July 16. While these dates were considered phenological analogs, the potential existed for varying solar incident angles to detrimentally influence land cover change analysis due to bi-directional reflectance distribution function (BRDF, Schott 1997). This study explored the practical effects of BRDF to determine the degree to which BRDF influences land cover change analysis and the point at which BRDF corrections must be made.

Methods:

We used Pheno-Calc software (available from http://giscenter.isu.edu/software) and two surrogates of plant phenology (growing-degree days and accumulated precipitation) to describe the environmental conditions during 1987 and 1997. These data were also used to identify a phenological match within the two years of interest (e.g., June 9, 1987 and July 1, 1997). Once two dates were specified, we established a ‘temporal window’ around these dates representing a period where the phenology was considered effectively equivalent (e.g., we used a tolerance of +/- 20% of the accumulated precipitation on the phenological match dates (June 9, 1987 and July 1, 1997)). The resulting temporal window ranged from May 18, 1987 through July 16, 1987 and from May 25, 1997 through July 23, 1997 (fig. 2).

We obtained Landsat satellite imagery acquired on dates within the specified temporal window and closest to the ideal dates identified by Pheno-Calc (i.e., June 9, 1987 and July 1, 1997). Other considerations besides phenological synchronization were cloud contamination, image quality, and image availability. The dates of the satellite imagery acquired for our study were June 25, 1987 and June 20, 1997. Additional imagery was also acquired to provide more extreme solar incident angle variation.

All imagery was terrain-corrected and geo-registered. All cloud contamination was removed from the analysis using ancillary data sets (e.g., digitized cloud boundaries). We used an image differencing technique with LUCCAS software (Yuan, et. al 1998, Pacific Meridian 1999) to detect and quantify the areas that had experienced changes in land cover over the past 10 years. To determine the effect of varying solar angle on land cover change analysis, the same image differencing procedure was repeated using imagery that was corrected for solar incident angle (e.g., each pixel’s value was divided by the SIN of the solar incident angle (Lillesand and Kiefer 2000)). The correction technique used (Lillesand and Kiefer 2000) adjusts each image to an ideal lambertian surface (Schott 1997) and thereby, removes the effect of solar incident angle. The number of pixels classified as increased vegetation, decreased vegetation, and no vegetation change were compared to determine the level of agreement between corrected (i.e., imagery that has been adjusted for solar angle effect) and uncorrected images.

A standard error matrix was then calculated to quantify user's, producer's, and overall accuracy as it relates to the agreement between corrected and uncorrected imagery.

Results:

Three tests were performed. The first assessed BDRF effects where solar incident angle variation was minimal (0.46 degrees), the second where solar incident angle variation was moderate (3.34 degrees), and the third where solar incident angle variation was considered high (6.69 degrees). In each test > 7000000 pixels were classified. The overall agreement between corrected and uncorrected imagery ranged from 99.7% (minimal variation) to 98.5% (high variation)(Tables 1 and 2).

The relationship between agreement of corrected and uncorrected imagery was fitted to a line using a standard linear regression technique (fig. 3). The adjusted R^2 indicates that nearly 90% of the variation seen in the agreement between corrected and uncorrected imagery can be explained by solar incident angle variation.

Discussion:

This study demonstrates the general lack of need to calculate solar incident angle corrections when performing land cover change assessment using imagery with slightly different dates and subsequently, minor variations in solar incident angle (e.g., <6.69 degrees).

Since a perfect relationship between agreement of corrected and uncorrected imagery was not established by linear regression, it is possible that the relationship is not linear. Moreover, since only three observations (each with >7000000 pixels) were used it is very difficult to extrapolate beyond the points used in this study. If however, we permit an extrapolation of the linear regression we learn that the agreement between corrected and uncorrected imagery does not fall below 95% until solar incident angle approaches 24.75 degrees. I should stress however, that this value (24.75 degrees) could be substantially different in practice. To explore this further, I have attempted to obtain imagery with large solar incident angle variation. Such imagery was found nearest the solstice periods. A solar incident angle variation of 41.0 degrees exists between the winter and summer solstice. While landcover change could be assessed with this imagery, its results would be meaningless due to stark differences in season (i.e., summer vs. winter). Thus, for all practical purposes, correcting for solar incident angle is not necessary.

References:

Lillesand T. M. and R. W. Kiefer. 2000. Remote Sensing and Image Interpretation. 4th ed. John Wiley and Sons, New York, NY., 724 pp.

Pacific Meridian Resources. 1996. LUCCAS: Land Use and Cover Change Analysis System. User's manual.

Schott 1997. Remote Sensing: The Image Chain Approach. Oxford, NY.

Weber, K. T. 2000. A Method to Incorporate Phenology into Land Cover Change Analysis. Journal of Range Management (in press).

Yuan, D., R. S. Lunetta, and C. D. Elvidge. 1998. Survey of Multispectral methods for land cover change analysis, Remote Sensing Change Detection: Environmental Monitoring Methods and Applications (R. S. Lunetta and C. Elvidge, editors), Ann Arbor Press, Chelsea, Mich., pp. 21-39

Figure 1: The study area of this research project.

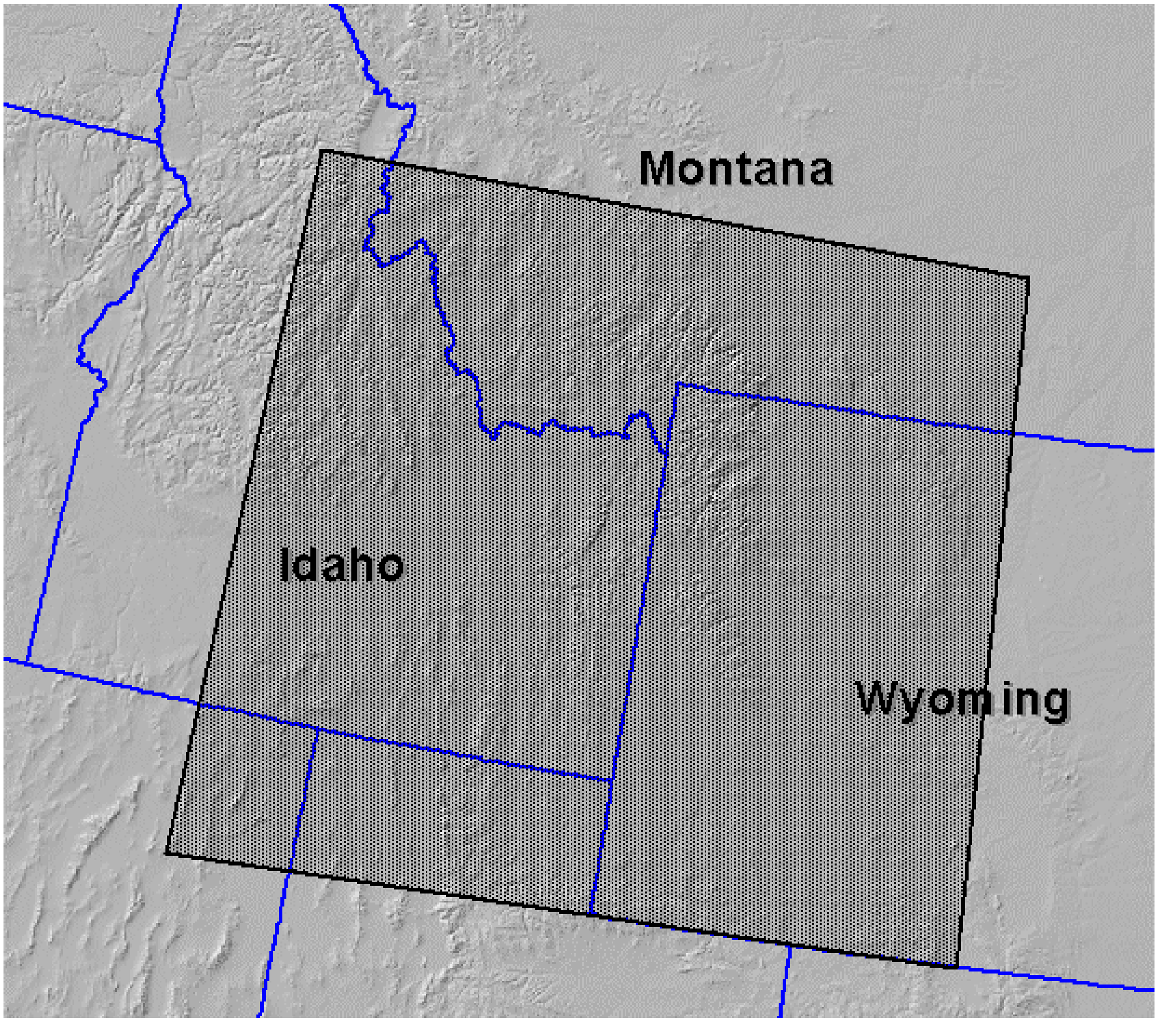

Figure 2: Illustration of how phenological synchronization (based on accumulated PPT) is applied and how the temporal window was identified.

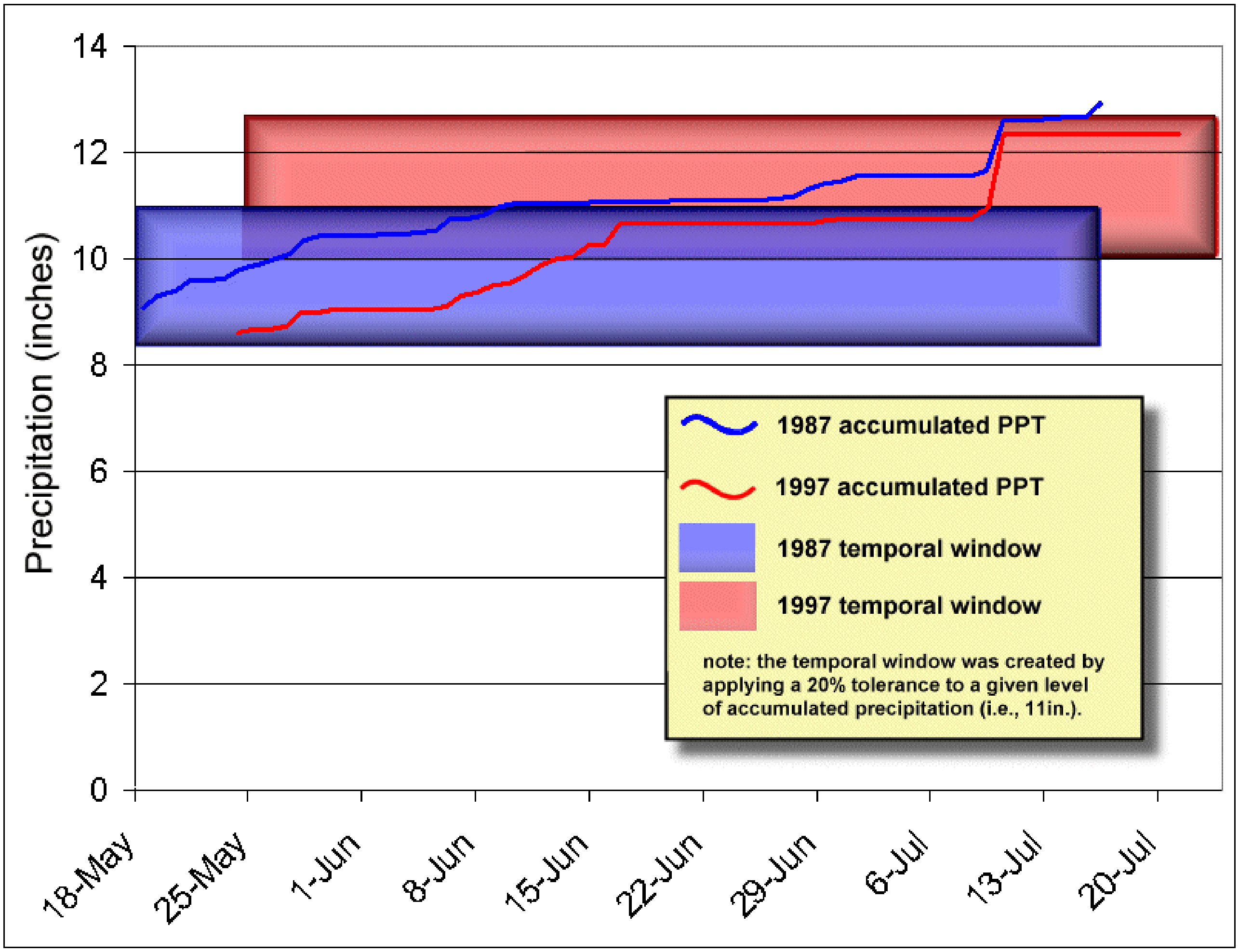

Figure 3: Overall agreement between corrected and uncorrected imagery for three different levels of solar incident angle variation.

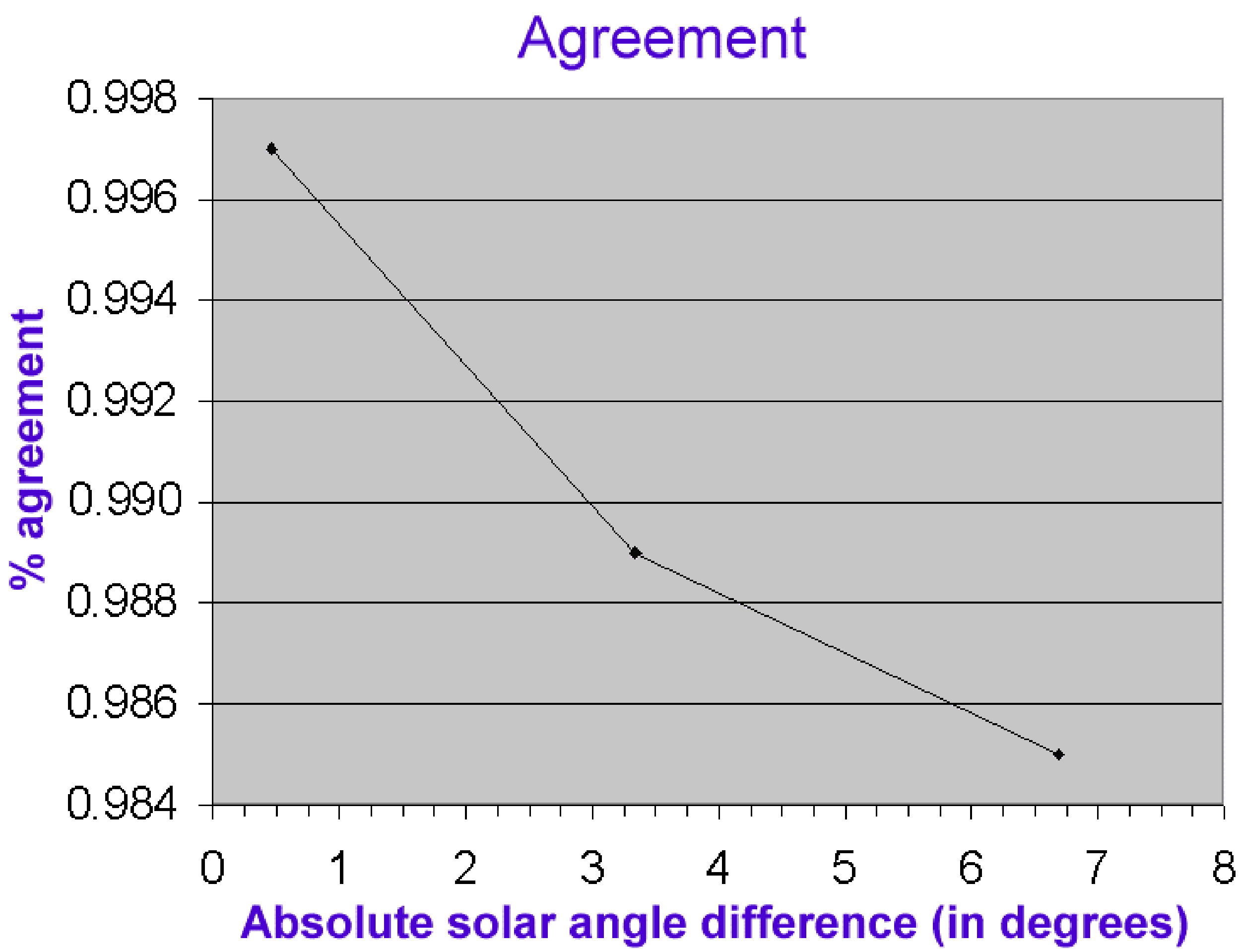

Table 1: Agreement between corrected and uncorrected imagery where solar incident angle variation was considered minimal (0.46 degrees).

		Uncorrected data (pixels)				
		Increase	Decrease	No Change	Total	Producers agreement
Corrected data (pixels)	Increase	550694	0	0	550694	1.000
	Decrease	0	534806	3643	538449	0.993
	No Change	19604	42	6230411	6250057	0.997
	Total	570298	534848	6234054	7339200	
	Users agreement	0.966	1.000	0.999	Overall agreement: 0.997	

Table 2: Agreement between corrected and uncorrected imagery where solar incident angle variation was considered minimal (6.69 degrees).

		Uncorrected data (pixels)				
		Increase	Decrease	No Change	Total	Producers agreement
Corrected data (pixels)	Increase	861996	0	9038	871034	0.990
	Decrease	0	855564	41711	897275	0.954
	No Change	41088	15922	5502789	5559799	0.990
	Total	903084	871486	5553538	7328108	
	Users agreement	0.955	0.982	0.991	Overall agreement: 0.985	