ANALYSIS OF BINARY LAND COVER CHANGE DETECTION METHODS USING OPTICAL AND RADAR DATA

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ABSTRACT

This work evaluates change classifications obtained using four binary change detection methods based on region, applied to optical, Synthetic Aperture Radar (SAR) and fused data. Although optical data has presented the best results, in the cases that such data is unavailable, it is possible to detect changes with high accuracy using SAR data. The use of fused images didn't improve change classification when compared to the use of single optical or SAR data.

***Index Terms*—** Change Detection, data fusion, SAR

1. INTRODUCTION

Change detection is the process of identifying changes in the state of an object or phenomenon by observing it at different times. Because remotely sensed data can be related to landscape condition and acquired repeatedly, remote sensing based change detection studies can provide information to better understand the causes of natural or human induced changes and also the resulting impacts along time [1].

According to [2], the Amazon region can be considered as a key place of global change. It is also one of the last frontiers of economic and territorial expansion, in which numerous investment programs have been implemented.This scenario, subjected to rapid changes, has prompted the rise of several deforestation or land use and land cover change focused technical-scientific programs, like PRODES (Program for the Estimation of Deforestation in the Brazilian Amazon), DETER (Real Time Deforestation Monitoring System) and LBA (Large-Scale Biosphere-Atmosphere Experiment in the Amazon). The majority of these programs are focused in optical remotely sensed data. However, such data usefulness is subject to weather conditions and the lighting of the scene. Synthetic Aperture Radar (SAR) can provide data almost independently from atmosphere conditions and totally independent to solar light [3]. Because of these characteristics, the usage of SAR data has been growing, mainly in areas like Amazon, where the clouds cover is constant during the year. However, as optical and SAR data have different natures and record different properties of the objects in landscape, these data are complementary [3]. Also, studies like [4] has shown that the combined usage of optical and SAR data can improve change detection.

Given the crescent interest in change detection studies in Amazon region and the possibility to substitute optical change detection to SAR change detection, or even to improve change detection using these data combined, this work evaluates change classifications obtained using region based binary change detection methods applied to optical, SAR or fused images, from two separated dates. For each pair of images of the same kind, binary change classifications (Change and No Change) are generated using different thresholds for four change detection methods (based in percentage thresholds, standard deviation, paired T-test and unpaired T-test of digital numbers in each region). Results were evaluated using overall accuracy (OA) index and a Monte Carlo approach. This work is an improvement of [5], in which the authors classified optical and SAR data, using percentage and standard deviation based thresholds in order to obtain binary change maps.

2. METHODOLOGY

In this work, an area of approximately 412 km^2 covering part of BR-163 (Cuiabá- Santarém Highway) and a parcel of Tapajós National Forest was studied. This area is located at Brazilian Amazon, more specifically in Belterra, Pará state and is illustrated in Figure 1.

Four images, from two different sensors, were used. Two of these images are from Thematic Mapper (TM) sensor, on board of Landsat 5. These images date back of June 23 2008 and June 29 2010. The other two images are from Phase Array L-Band Synthetic Aperture Radar sensor (PALSAR) on board of Advanced Land Observing System (ALOS), acquired in FBD 1.1 mode (HH and HV polarizations in L-band). These images date back June 15 2008 and June 21 2010.

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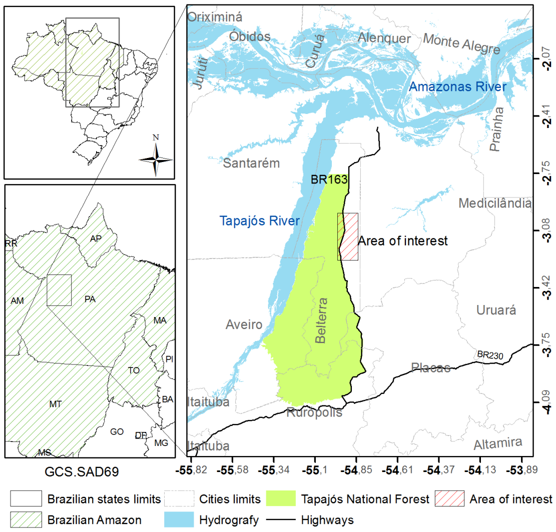


Fig. 1. Area of interest to this study.

All images were processed in order to form three pairs of data, in which there is one image from 2008 and one from 2010. The three pairs are denominated:

- PALSAR: orthorectified and speckle filtered ALOS/ PALSAR images. These images were geocoded in ASF MapReady 3.0 software, in which they were projected to UTM WGS84, 21S zone, and re-sampled to 15 by 15 meters pixels. They were, then, orthorectified using Shuttle Radar Topography Mission 4 (SRTM 4) data and the Rational Function Model (RFM) present in PCI 13.0 software. The orthorectified data was filtered using Stochastic Distances Nonlocal Means (SDNLM) filter [6]. These images were used in amplitude format;

- TM: bands 1 to 5 and 7 from LANDSAT5/TM images, also orthorectified using RFM and SRTM 4 data. These data were used in original spatial (30 meters) and radiometric (8 bits) resolutions;

- Fusion: TM and PALSAR (with pixels resampled to 30 meters) data fused using Selective Principal Component Analysis (SPC-SAR).

All these images were normalized to mean 127 and standard deviation 42.

Considering each data pair, images of different dates were segmented individually. Four segmenters with different parametrization were analyzed: region growth (TerraPixel 1.04), Multiresolution Segmentation (eCognition 8), Multiseg [7] and Idrisi Selva's watershed based one. The 2010 images of each pair were used for selecting segmenters and their respective parameters. For TM and Fusion, the optimal segmentation was chosen based on Weighted Index for Segmentation Evaluation (WISE) [8] results. The chosen segmentations were those obtained by Multiresolution Segmentation with shape and compactness 0.3 and scale parameter 30 for TM data and scale parameter 35 for Fusion. For PALSAR data, using visual analysis, we selected the segmentation obtained by Idrisi, with similarity 40, window size 3; mean factor weight and variance factor weight 0.5.

The segmented images of each pair were combined to generate a unique segmented image for each data type. The unification of the segmented images was performed so that each segment represents a homogeneous region in both 2008 and 2010 images. Regions with less than 100 pixels were grouped with those that shared the longest border.

Using each pair of images and the corresponding unified segmentation, the pixel values of a given region in a 2010 image are compared to the values of the pixels in the same region in the 2008 image. This comparison was made using two approaches: comparing each band individually and considering all the pixels in a region in all bands together (Gl). From this comparison several binary change images were generated, in which the pixels are labeled as Change and No Change. Four methods of comparison were used:

- Percentage thresholds (%T): if the mean value of pixels in a given segment of 2008 image and the mean of the same segment in the corresponding 2010 image differs in or beyond a certain percentage threshold, this segment is labeled as Change. If the difference is less than the chosen parameter, the segment is labeled as Non-Change. The tested thresholds varied among 5 to 25%, in increments of 5%;

- Standard Deviation (SD): consider $C_1 = [f * s_1 - m_1; m_1 + f * s_1]$ and $C_2 = [m_2 - s_2 * f; f * m_2 + s_2]$ in which m_1 and m_2 are the means of the pixels values of a given segment in 2008 and 2010 images, respectively, s_1 and s_2 the standard deviation of pixel values and f is a constant factor. If there is an intersection between C_1 and C_2, the segment being analyzed is labeled as No-Change. Otherwise, the segment is labeled as Change. In this work, f ranges from 0.2 to 2 in increments of 0.2 units;

- Unpaired T-test: an unpaired T-test was performed to compare if the mean of values in a given segment in both images can be considered equal, for some level of significance. Tested significance levels are 1%, 5% and 10%;

- Paired T-test: the same as the above method of change classification, but employing paired T-test.

In order to evaluate the resulting change images, ten land cover classes were defined : primary forest, degraded forest, secondary vegetation in three stages of development (initial, intermediate and advanced), pasture with and without shrubs, cultivated areas, fallow land and bare soil. Considering these cover classes, we identified areas of Change (different covers on each date) and No-Change (same cover on both dates) and collected test samples. With these samples, the change classifications were evaluated using a Monte Carlo strategy. Without repetition, 100 pixels for each change class (total of 200) were randomly selected and used to build the confusion matrix, from which OA was calculated. This process was repeated 1000 times, and the results were evaluated according to the mean and standard deviation of the OA values.

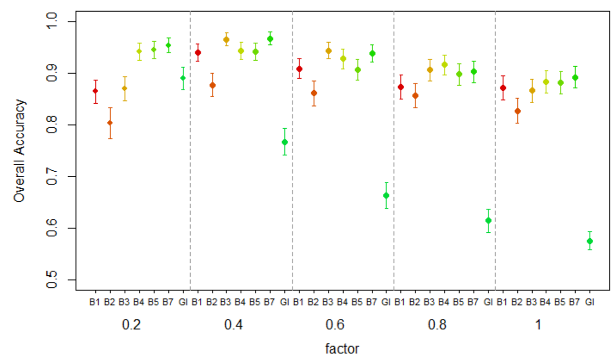
3. RESULTS

Based on OA results, the best change classification for each datum (a specific band in a pair of images or all the bands in Gl) was selected. The mean and standard deviation of OA values of the best classification for each datum, and the method and threshold used to achieve it, are shown in Table 1. It is possible to see that the majority of TM results are better than PALSAR and Fusion ones, although the values are high. Fusion of TM and PALSAR data, considering the adopted methodology, did not improve change detection when compared to TM or PALSAR data alone. Also, the OA of the best results using each kind of data are similar themselves, with the exception of band 2 and Gl of TM data and the R component of Fusion data.

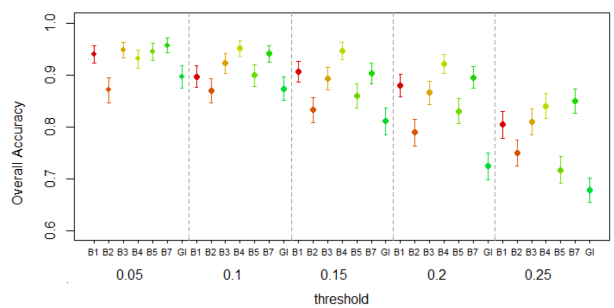
Table 1. Mean and standard deviation of OA values for the best results using each datum.

Classified data	Method	Threshold	OA
TM band 1	SD	$f = 0.4$	0.94 ± 0.02
TM band 2	SD	$f = 0.4$	0.88 ± 0.02
TM band 3	SD	$f = 0.4$	0.97 ± 0.01
TM band 4	%T	10%	0.95 ± 0.02
TM band 5	SD	$f = 0.2$	0.94 ± 0.02
TM band 7	SD	$f = 0.4$	0.97 ± 0.01
TM Global	%T	5%	0.90 ± 0.02
PALSAR HH	%T	15%	0.87 ± 0.02
PALSAR HV	%T	10%	0.90 ± 0.02
PALSAR Global	%T	10%	0.88 ± 0.02
Fusion R Component	SD	$f = 1.0$	0.75 ± 0.03
Fusion G Component	SD	$f = 1.0$	0.90 ± 0.02
Fusion B Component	SD	$f = 1.2$	0.89 ± 0.02
Fusion Global	%T	15%	0.88 ± 0.02

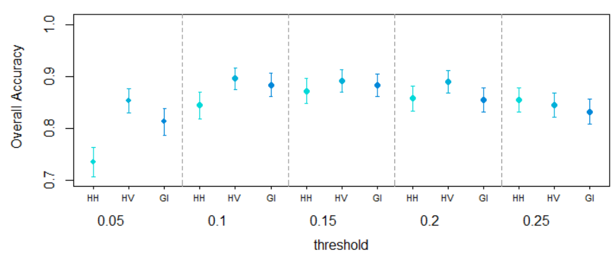
For TM data, although some classifications has been selected for comparison in Table 1, highest values of OA for each band and in Gl are statistically equal for classifications obtained using SD and %T methods. For PALSAR data, best results were obtained using the %T method, although there are high OA values obtained by SD method as well. For Fusion data best results are from SD method, with the exception of Gl, in which the best results were obtained by the %T method. The mean and standard deviation of OA values for the classifications obtained using the appointed methods and respective datum are shown in Figure 2. Since the best results using the SD method are shown using the lowest factors for TM data and higher for Fusion, the OA values showed in this figure are from classifications obtained with different ranges of f, for better visualization.



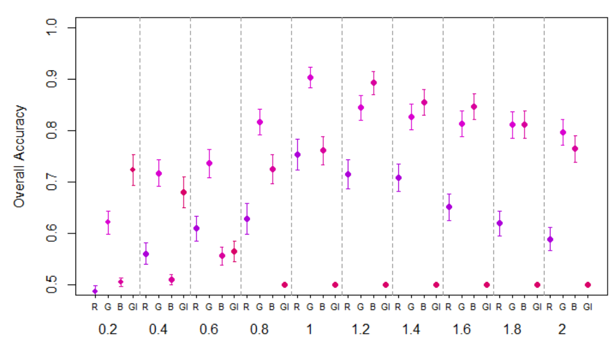
(a) TM classifications using SD method



(b) TM classifications using %T method



(c) PALSAR classifications using %T method



(d) Fusion classifications using SD method

Fig. 2. Mean and standard deviation of OA for change classifications.

For TM data, the highest OA value for each method and threshold was obtained using band 4, and the lowest using band 2 or GI. In that respect, the lowest OA value of band 4 of TM data classification was 0.73, obtained with SD method and $f = 2$. For PALSAR data, highest OA values were obtained using HV polarization, although results obtained using HH polarization or GI were also good. For Fusion data, GI presented the best results using %T method, for all tested thresholds and SD using low f values (0.2 and 0.4). For highers f values, the best results for Fusion data were showed by G and B components. T-Test based methods provided change classifications OA values higher than 0.70 only using bands 4 and 5 of TM, wherein the higher values were obtained by Unpaired T-Test with level of significance equal to 1% (0.86 for band 4 and 0.81 for band 5).

A spatial subset of the best result obtained using TM, PALSAR and Fusion data is shown in Figure 3, as well as the same subset in original images. The mean confusion matrix for the whole classification is also shown in this figure. In the best change classification of Fusion data, some large Change features were classified as No Change. Meanwhile, using PALSAR data, small regions classified as Change are scattered along the area.

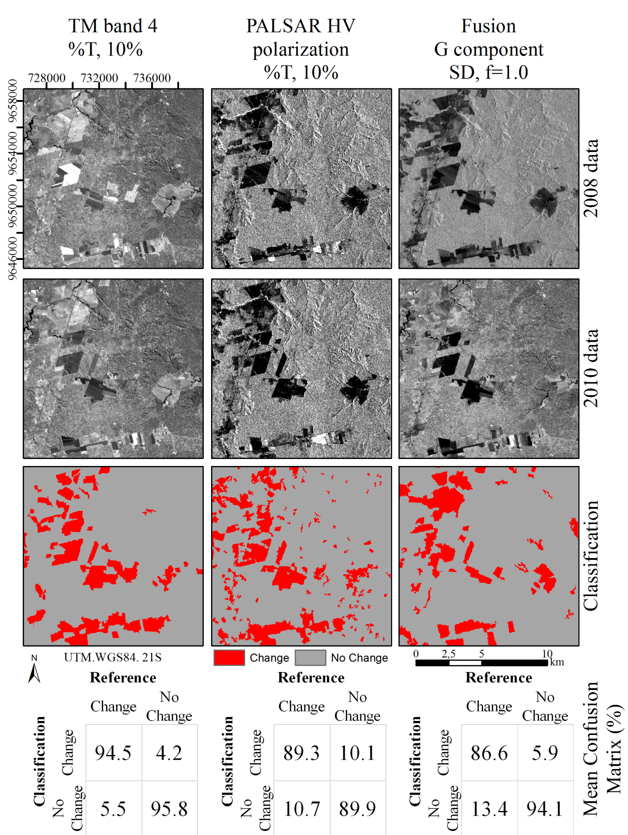


Fig. 3. Spatial subset of the best results obtained using TM, PALSAR and Fusion data, as well as original data and mean confusion matrix.

4. CONCLUSION

Using SPC-SAR fused ALOS/PALSAR and LANDSAT5/TM data in different binary change detection methods has not improved the change detection using single ALOS/PALSAR or LANDSAT5/TM data, although all data sets has shown high overall accuracy values. When optical data is unavailable, it is possible to detect changes in Amazon using SAR data and fairly simple methods, with high accuracy values. In future works, it is important to evaluate other optical/SAR fusion methods and other binary change detection methods, including those based in stochastic distances.

5. REFERENCES

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