A COMPARATIVE STUDY OF URBAN CHANGE DETECTION TECHNIQUES USING HIGH SPATIAL RESOLUTION IMAGES

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ABSTRACT:

This paper describes various urban change detection methods using high spatial resolution images such as Quickbird and Wolrdview-2. Compared to low spatial resolution images used before, like Landsat TM and ASTER, high spatial resolution images were found to show robust details in the resultant change maps. Various methods were tried to get better results. Simple waveband arithmetic such as image differencing and image ratios using multiple and single wavebands were tried. Major disadvantage encountered in these methods is the fact that they could not distinguish what changed but just demonstrating where the changes occurred. Moreover, other factors such as atmospheric effects, sensor orientation and image reflectance differences were found to affect the quality of change maps. Apart from the above, change vector analysis (CVA) and statistical methods such as Euclidian distance and Bhattacharya distance were also tried. NDVI difference images were used to create change maps and also used in combination with visible and infrared difference images. Finally a post-classification change detection is also tried to analyze the quality of change maps. All these methods were carefully analyzed for their suitability in urban change detection.

1 INTRODUCTION

Changes in land cover is an inevitable phenomenon occurring in the human inhabited areas of the world, irrespective of the fact that a country is developed or developing. Some regions in the world are undergoing rapid urbanization and deforestation, especially in developing countries like Brazil, India and China. Majority of the population in these countries are living and/or working in urban settlements. Urban area expansion in many of these regions are not sustainable compared to that found in developed countries like the United Kingdom and Germany. Moreover, lack of proper planning during construction works and rapid expansion of settlements were found to make life in these region very difficult. Monitoring urban changes became an important process in the current world and is required for urban planning, environmental impact assessment and for the development of proper infrastructure.

Land cover classification and change detection are the most widely used applications in remote sensing, after the emergence of remote sensing as an advanced technique in geomorphology. The lack of high spatial resolution images was definitely a hindrance to change detection algorithms in the past decades. Due to the emergence of improved quality, multi-spatial and multi-temporal remote sensing data along with advanced image processing algorithms, it is now possible to monitor urban changes and urban sprawl in a timely and cost-effective manner (Yang et al., 2003). Change detection using remotely sensed multi-spectral images can be based on either post-classification comparison (categorical change extraction or CCE) or direct change detection algorithms (change mask development or CMD) (Dai and Khorram, 1999). There are change detection methods based on the changes in the surface elevation changes using 3D digital surface models apart from the above mentioned methods (Shaoqing and Lu, 2008). Some authors suggest object based image analysis, which are considered to be advanced level "beyond pixel" applications (Blaschike, 2010).

Generally, change detection of land surfaces having similar spectral signatures is a hard task (Mas, 1999), but in a rapidly growing urban area, it is a bit easier because the spectral signatures may vary abruptly. High spatial resolution data such as Quickbird and Worldview-2 help us to get detailed images of land cover, similar to aerial photography as well as with geometric quality, homogenity and periodicity proper to satellite imagery. It also provide a level of detail compatible with urban mapping in terms of spatial resolution (Elhadi and Zomrawi, 2009). High-resolution satellite images provides cost benefits compared to aerial photos as an outcome of larger footprints which means that less ground control and less processing are needed for ortho-rectification. Moreover due to frequent revisits, high-resolution satellite images has higher potential for automatic feature change detection compared to aerial photography. In other words, the gap between aerial photography and satellite imagery is bridged in higher spatial resolution imagery (Malpica and Alonso, 2008). Even though the use of high-resolution images increases both the amount of information acquired and geometric accuracy, the algorithms needed for processing these images are more complex compared with lower-resolution ones.

2 DATA, METHODOLOGIES AND RESULTS

High-resolution Quickbird and Worldview-2 images acquired in May 2004 and June 2008 respectively, from São Paulo city, Brazil, were used in this study (figure 1). Ground resolution of Quickbird and Worldvew-2 sensors in multispectral and panchromatic wavebands are given in table 1. Quickbird data has 4 multispectral wavebands (Blue, green, red, NIR) and Worldview-2 has 8 multispectral wavebands (Coastal, blue, green, yellow, red, red edge, NIR1 and NIR2), both are having a panchromatic waveband. All the image processing works were done using Erdas Imagine 2011, ENVI 4.7 and ArcGIS 9.5 software packages

Sensor	Resolution	
	Multispectral	Panchromatic
Quickbird	2.44m	0.61m
Worldview-2	2.00m	0.50m

Table 1 - Spatial resolution of Quickbird and Worldview-2 sensors.

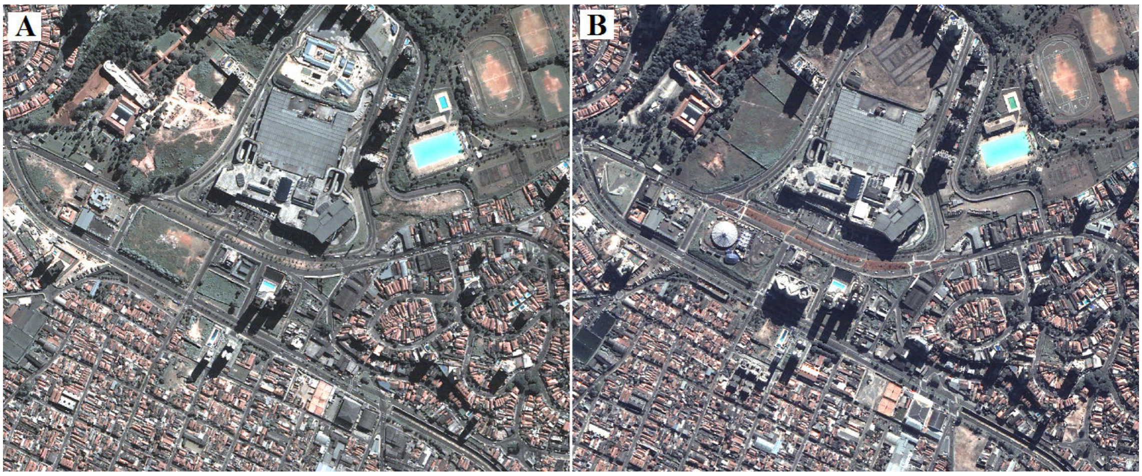

Figure 1 - Original images A. Quickbird (May 2004), B. Worldview-2 (June 2008)

2.1 Image differencing

Direct subtraction of one image from the other, both are spatially registered, will result in a multispectral image(figure 2A), representing the change between the two times in all the bands. The extent of change could be understood by viewing the difference image in a stretched manner rather than RGB color composite. Image difference can be done in single waveband as well. The gray value of each band the resultant image shows the differences in corresponding pixel values. When an appropriate threshold value is applied to this image, an image highlighting the changed and unchanged area could be obtained (figure 2B). Being straight forward, this method is easy to use but for the cost of detailed data. The result is affected by external factors such as sensor orientation, image reflectance difference, atmospheric affects, ground water conditions, day-night difference, weather variations or even color change on roofs of the buildings.

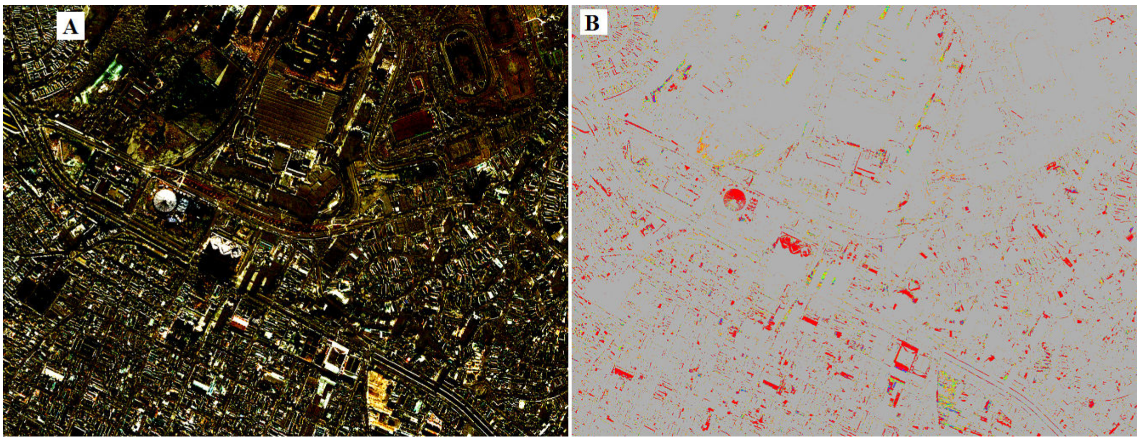

Figure 2 - Difference image and change map after threshold.

2.2 Image ratios

Another widely used method is based on image ratios (can be done in single or multiple wavebands). Some authors suggest image ratio method as a better procedure in urban change detection compared to image differencing or post-classification change detection (Shaoqing and Lu, 2008). If no change has occurred, the pixel value of the corresponding ratio image in corresponding bands will be near unity. Ratio images (figure 3A) were created and applied a suitable threshold value to get a change map (Figure 3B). This method is found to map more urban area change compared to the previous method. It is seen that effects of shadows were removed when image ratios are used. The choice of threshold value will vary with images and what time the images were taken.

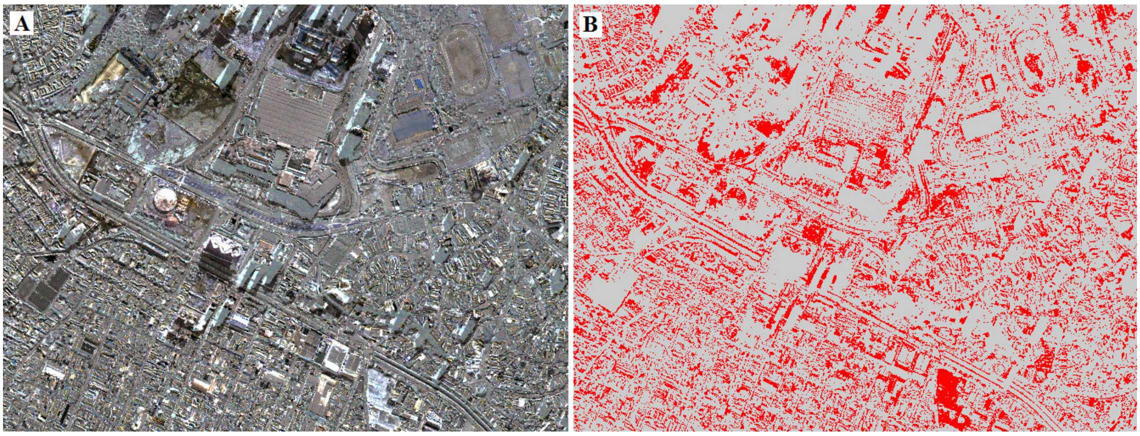

Figure 3 - Ratio image and change map after threshold

2.3 Change detection using NDVI images

NDVI images have been utilized for a long time at its best in vegetation change detection and water body. In this study, NDVI images derived from the before and after images were utilized for mapping urban changes. Direct application of threshold can be done using the NDVI difference images to create change maps (figure 4A). In another method, three difference images using NDVI images, NIR and Red wavebands of the after and before images were created. One of the multispectral image is opened in Erdas Imagine and the NDVI difference, NIR difference and Red difference were displayed in the red, green and blue color guns repetitively. Urbanized areas were shown in bluish color and areas were new vegetation appeared were shown in yellowish color depending on the changes occurred (figure 4B).

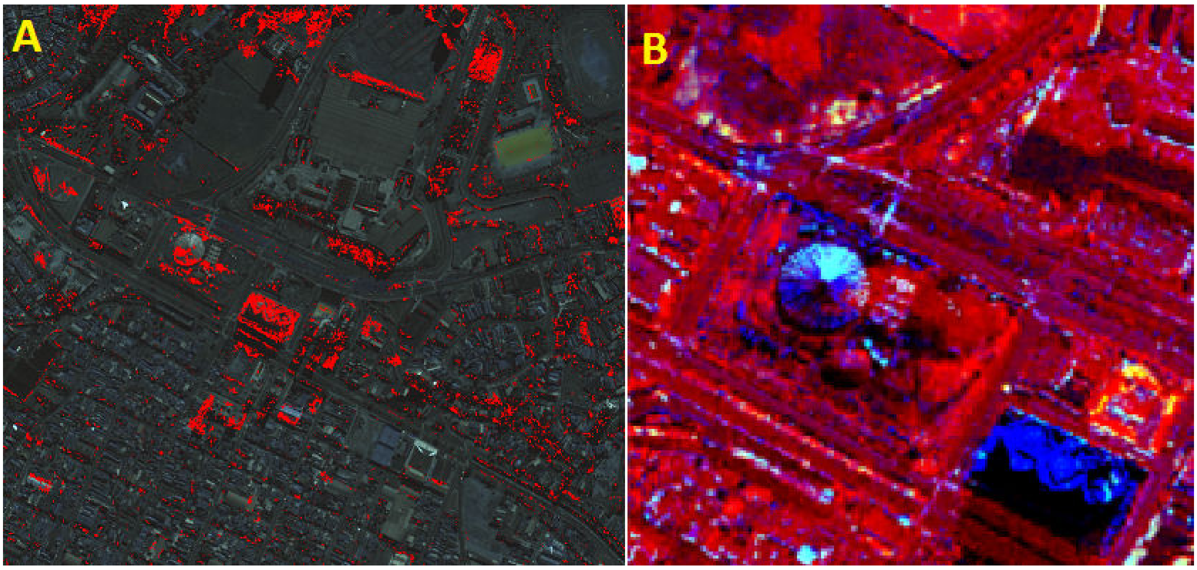

Figure 4 - Change detection methods using NDVI images A. Using NDVI difference, B. Using multiple difference waveband composition

2.4 Statistical change detection methods

Statistical methods were tested during this study. Bhattacharyya distance, which is the distance between profiles in consideration of the standard deviation of front and back time, is found to be a suitable method for urban change detection. In this method, Bhattacharya distance image is calculated and a suitable threshold is applied to separate the changed and unchanged areas (figure 5A). Another statistical method, Euclidian distance, is tested in this study. The same procedure using threshold value is applied here as well (figure 5B).

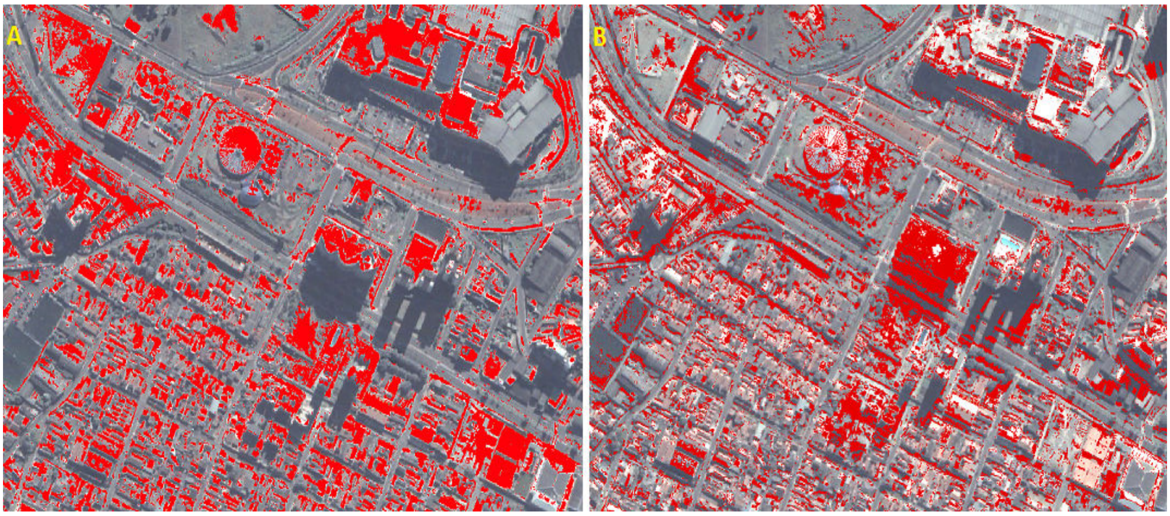

Figure 5 - Statistical methods for change detection. A. Bhattacharyya distance method, B. Euclidian distance method

2.5 Change Vector Analysis (CVA)

Change detection based on change vectors using red and near infrared wavebands were also tested during this study. A spectral change vector describes the direction and magnitude of change from one date to the another. The direction of the change vector corresponds to the type of change and the length of the change vector represents the magnitude of change in the spectral feature space (Nackaerts et al., 2005). Based on the application of different threshold values, we could differentiate the types of changes occurred such as the presence of new buildings, presence of urban vegetation and demolition of buildings. It is seen that the presence of cloud cover interfere with topological changes and it should be made sure that images are having less atmospheric and radiometric errors. Figure 6 shows a change map after the application of a suitable threshold value.

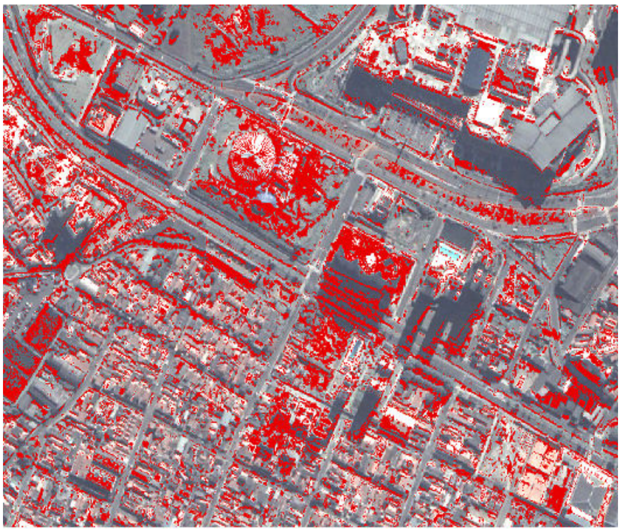

Figure 6 - Change vector method

2.6 Change detection after classification

Post-classification change detection is simple and straight forward. The two steps involved in this method are classification and comparison of the classified image. Images can be classified separately using supervised or unsupervised classification techniques. Unsupervised classification(figures 7A and 7B) is used in this research, which has an advantage that it does not need selection of training samples manually and the cluster analysis is done automatically (Shaoqing and Lu, 2008). Another advantage is less processing time required compared to supervised classification. In the second step, the classified images were compared(figure 7C). The changes in pixel value corresponds to the land cover changes occurred .

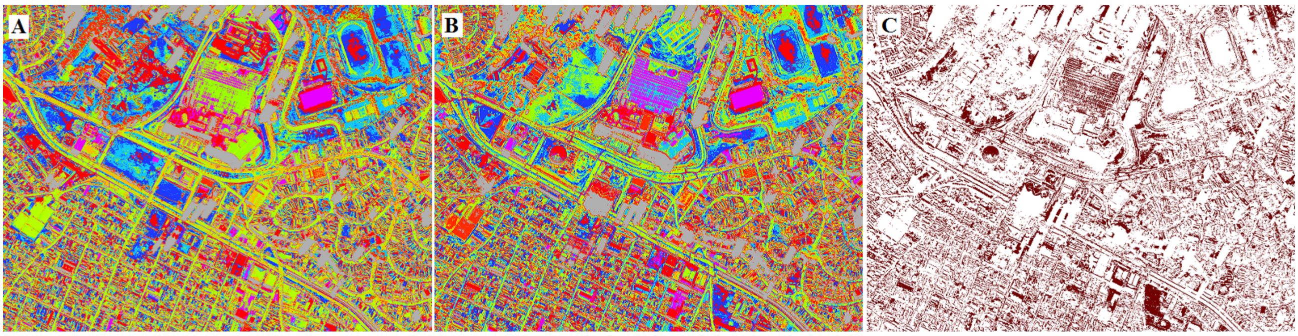

Figure 7 - Post-classification change detection. A. Classified image (2004), B. Classified image (2008), C. Change map

3. CONCLUSIONS

The first method, image differencing, is simple and straight forward. Apart from many disadvantages, it is cheap and time saving. This technique can be applied to a single band (univariate image differencing) or to multiple bands. To reduce the effects of illumination angle, intensity and viewing angle, radiometric standardization should be applied. Dependence on the accuracy of the threshold values is a major drawback, because higher threshold values can cause information and lower threshold value can cause void inspecting (Shaoqing and Lu, 2008). The selection of threshold value is entirely up to the expertise of the researcher. This method just shows whether a change occurred or not and not "what" changed and hence the performance is poor in urban change detection. Some authors suggest this method for change detection of vegetation, especially in temperate regions (Miller et al., 1978; Vogelmann, 1988; Singh, 1989).

Image ratio method is also simple and straight forward. Here also the images should be co-registered. The ratio images can be converted to no change/change or negative change/ positive change images. One of the greatest advantage of the image ratios is the effect of slope, sun angle and shadows were reduced. This method is found to be good for urban change detection. Difficulty in the selection of threshold values and different features of the same slope are easy to confuse and complexity in understanding which feature changed are among the drawbacks of this method (Shaoqing and Lu, 2008).

Change maps produced using NDVI images were found to give good results, especially in highlighting the changed areas. The NDVI difference image, when combined with NIR difference and red difference, it is found to give a better result on urban change. The direct use of NDVI difference by applying threshold values (Hayes and Sader, 2001) failed to detect many settlements. The latter is found to be good in monitoring deforestation, biomass and other vegetation changes (Richardson and Weigand, 1977).

Statistical change detection methods, especially the Bhattacharyya distance method, were found to be a promising methodology in urban change detection (Benedek et al., 2009), and can map even the minute changes in small buildings and residential blocks. Euclidian distance method is found to lose many 'real changed' data and added 'wrong changed' data after the processing, even following the careful selection of threshold values.

Change vector method is found to give results similar to that in Euclidian distance method because the total magnitude per pixel is computed by analyzing the Euclidian distance between end points through space (note that only red and near infrared is used in change vector method whereas in statistical method by Euclidian distance, all the wavebands were used) and is found to be poor in urban change detection. This method is applicable only if the multi-temporal imagery to be analyzed is spectrally normalized and consistent over time and space and if the researcher does not have a good knowledge about the area of study, the decision making can be biased (Nackaerts et al., 2005). Another disadvantage is the requirement of normalization prior to the application of this algorithm.

Post-classification change detection methods seems to be an effective method in studying changes occurred in different classes of objects, especially it showed the presence of new buildings and other man-made objects. Selective elimination of changes occurred in unwanted classes is an advantage. The disadvantages associated with this methods includes the cost and time required for the image classification, which is an independent process compared to change detection. It is seen that the errors occurred in the classification may give rise to a compounding effect(Pilon et al., 1988). A pixel in one date may be classified in one category and the corresponding pixel in another date may fall into another category. In the case of high spatial resolution images such as Quickbird and Worldview-2, where a single pixel covers less ground distance compared to lower resolution images such as Landsat and ASTER, the severity of this kind of error is negligible.

In a nutshell, it is found that three methods are suitable for urban change detection, when using high spatial resolution images - image ratios, Bhattacharyya distance method and post-classification change detection. All other methods except band ratios failed to remove the effects of shadow.

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References from Journals

Blaschike, T., 2010, Object based image analysis for remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing,* 65(1), pp. 2-16.

Dai, X.L.; Khorram, S., 1999, Remotely sensed change detection based on artificial neural networks. *Photogrammetric Engineering and Remote Sensing*. 65(10), pp. 1187-1194.

Elhadi, E.M.; Zomravi, N., 2009, Change detection analysis by using Ikonos and Quickbird imageries. *Nature and Science*, 7(10), pp. 25-31.

Hayes, D.J., Sader, S.A., 2001, Comparison of change-detection techniques for monitoring tropical forest clearing and vegetation regrowth in a time series. *Photogrammetric Engineering and remote sensing,* 67(9), pp. 1067-1075.

Mas, J.F., 1999, Monitoring land-cover changes: a comparison of change detection techniques. *International journal of Remote Sensing*, 20(1), pp. 139-152.

Nackaerts, K., Vaesen, K., Muys, B., Coppin, P., 2005, Comparative performance of a modified change vector analysis in forest change detection. *International Journal of remote Sensing*, 26(5), pp. 839-852.

Pilon, P.G., Howarth, P.J., Bullock, R.A., Adeniyi, P.O., 1988, An enhanced classification approach to change detection in semi-arid environments. *Photogrammetric Engineering and Remote Sensing*, 54 (12), pp. 1709-1716.

Richardson, A.J, Weigand, C.L., 1977, Distinguishing vegetation from soil background information. *Photogrammetric Engineering and Remote Sensing*, 43(12), pp. 1541-1552.

Singh, A., 1989, Digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing*, 10(6), pp. 989-1003.

Vogelmann, J.E., 1988, Detection of forest change in the Green Mountains of Vermont using multispectral scanner data. *International Journal of remote Sensing*, 9(7), pp. 1187-1200.

Yang, L., Xian, G., Klaver, J.M., Deal, B., 2003, Urban Land-cover change detection through sub-pixel imperviousness mapping using remotely sensed data. *Photogrammetric Engineering and Remote Sensing*, 69(9), pp. 1003-1010.

References from Other Literature

Benedek, C., Descombes, X., Zerubia, J., 2009, Building extraction and change detection in multitemporal aerial and satellite images in a joint stochastic approach. Projects ARIANA, Rapport de recherche n° 7143, INRIA, France.

Malpica, J.A., Alonso, M.C., 2008, A method for change detection with multi-temporal satellite images using the RX algorithm. *The international Archives of the Photogrammetry, remote Sensing and Spatial Information Sciences*, V. XXXVII, Part B7. Beijing. pp. 1631-1636.

Miller, L.D., Nualchawee, K., Tom, C., 1978, Analysis of the dynamics of shifting cultivation in the tropic forest of Northern Thailand using landscape modeling and classification of Landsat imagery. NASA Goddard Space Center, Technical Memorandum No. 79545, Greenbelt, Md.

Shaoqing, Z.; Lu, X., 2008, The comparative study of three methods of remote sensing image change detection. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XXXVII, Part B7. Beijing, pp. 1595 - 1598.