PERFORMANCE OF LANDSAT 7 ETM+ IMAGE IN SLC-OFF MODE FOR LAND COVER CLASSIFICATION

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ABSTRACT

Landsat 7 ETM+ was launched in April 15 1999 with more advantaged features than previous satellites of Landsat programme, but after four years on the orbit on May 31, 2003, operation of Landsat 7 had met a great problem that was Scan Line Corrector in the ETM+ instrument permanent failure. At the SLC-off mode, causing lines of no data in zig-zag fashion appeared on images. This report presents a performace of gap-filled image for land cover classification. The method of gap-filling was applied from the approach of USGS-EROS.

There were 12 classes were classified with overall accuracy of 87.44% and Kappa Coefficient is 0.86. This is a good result for an Landsat 7 image SLC-off, had been applied gap-filling by another SLC-off image . The area of study is a part of Hochiminh city and Binh Duong province, belongs to image scene of 125/52, acquised in January 2014.

1. INTRODUCTION

Since May 31, 1999 – failure of Scan Line Corrector (SLC) instrument causing SLC-on turn into permanent SLC-off mode happened to Landsat 7 ETM$^+$ satellite (USGS) just after four years on its orbit acquiring multisectral imagery data. On Imagery of SLC-off, there are nodata gap-lines in pattern of zizag that appear along the the edge of the scene and gradually decrease its size toward the middle of the scene. The width of nodata lines is from 1-2 pixels at the middle to 15 pixel at the edge of the scene. About 22 percent of any scene is lost information and more than 75 percent of the image pixels are still retained radiometric and geometric information as before the malfunction (USGS, 2003). However, although the number of remained pixels is large but these are in zigzag pattern that appears to be an interleave pattern with long strip of data and nodata strip. This makes actual usability of the scene only about 12 percent, which is accounted for around 4,500 sqkm of unaffected area by SLC-off compared to 35,000 sqkm of the whole scene (Figure 1).

Although the data has a great number of nodata pixels, which is still usable for the rest in many appications and in order to keep using this valuable data for Earth observation task, there have been efforts to solve this problem. Soon after that event, there was an approach of using a previous acquired scene at SLC-on for filling the gaps of SLC-off image, both of the same path/row (Scaramuzza, P. *et al*., 2004; Howard, S.M. and J. Lacasse, 2004) then after adopted by NASA (Landsat - USGS) to develop gap-filled product. However, this approach only was applied for a short time because temporal difference between SLC-on and SLC-off images became longer by time and it made products not suitable for monitoring land cover change. Based on this approach, a new algorithm had been developed that uses multi-scenes SLC-off scenes for gap-filling and all select scenes as close in time to the primary scene as possible, known as Phase 2 gap-fill algorithm or Adaptive Window Local Histogram

Matching (USGS-EROS, 2004; Sadiq A. *et. al.*, 2014). This meets requirement of surface change monitoring, for those regions that are relative homogenous and less change over a short time. To apply gap-filled scenes for classification of heterogenous areas, recently an approach of unsupervised land use classification performed on both gap-filled SLC-off data to validate the Phase 2 algorithm mentioned above, of which classification results and accuracies were very comparable (Mohammdy M. *et al*., 2013).

There are many other approaches developed later, such as methods of simple interpolation, spectral interpolation, recovery of the gaps by single or multi other images at the same area, Geosattistical anaysis, etc. (Sadiq A. *et. al*., 2014). Each method has its own advantages and litmitations, use single or multi source images for filling gaps and these have similar problem with heterogeneous land cover. In this research, Phase 2 Methodology of the USGS is applied to consider performance of this approach for image classification in a relative heterogeneous areas regarding land cover. Field survey are implemented to check accuracy of classification.

2. METHOD

2.1 Study area and data

A heterogenerous area with different land cover types are considered to select an area of study (AOS). Urban area of Hochiminh city and its fringe, with type of sprawl area is selected as AOS as it is met this criteria because this area has different land cover types of built-up (with variety in construction types, roads), water, swamps, vegetation (both annual and parennials). Image data of this reasearch is selected based on criteria that close in time between two image acquisition time, no cloud. For this, scene of 125/52 is chosen, covers a part of Hochiminh city, acquisition day of image 1 is 13 January, 2014 and that of image 2 is 29 January, 2014 - time is one cycle (Figure 3 and 4). These images are downloadable from the Earth Explorer website of USGS (USGS-EROS). The AOS is a part of the select scene, sized 1000 x 1000 pixels or 900 sqkm extended within $10^{0}42'$ – $10^{0}58'$ lat N. and $106^{0}29'$ – $106^{0}45'$ long E., and it is near the edge of the scene (Figure 1 and 2). The width of each gap line in this AOS varies from 5 to 10 nodata pixels.

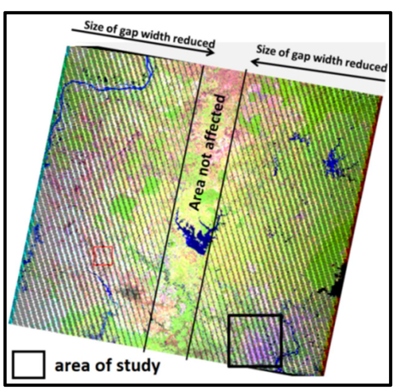

Figure 1. Scene 125/52, square box is AOS Image source: USGS-EROS.

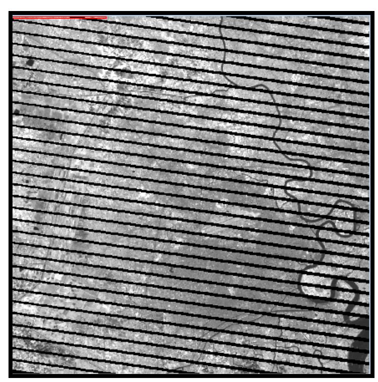

Figure 2. AOS, band 4. Part of Hochiminh city and Binh Duong Province

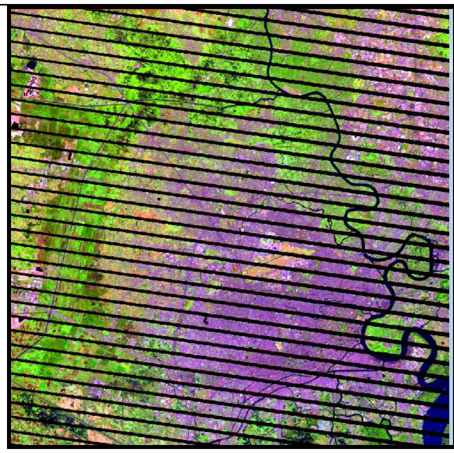

Figure 3: Date 1: 13 January, 2014 in SLC-off mode. Image source: USGS-EROS.

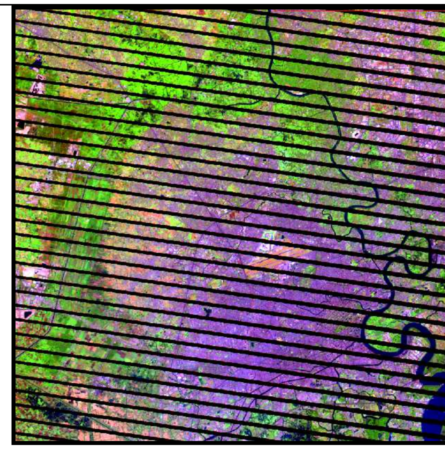

Figure 4: Date 2: 29 January, 2014 in SLC-off mode. Image source: USGS-EROS.

2.2 Method

Gap-fill: This reasearch applied the Phase 2 algorithm mentioned above, which is considered as a simple and effective gap-fill algorithm (Mohammdy M. et al., 2013). To process, this make use the tool Frame and Fill developed by Richard Irish (2009), based on the algorithm and at the present many applications use for filling gaps (Irish R. and Scaramuzza P., 2009; Attarchi S. and Richard G., 2014).

Classification: To classify land cover types as much details as possible, there are 12 classes selected based on reviewing the entire AOS and quality of these images. These classes include Water bodies, Forests, Parennials/ Fruit trees, Annuals (rices), Annuals (crops/ grasses), Buil-up 1, Built-up 2, Built-up 3, Built-up 4 (large streets or large beton surface), Marshes, Bare 1 (prepare for construction), and Bare 2 (crop land no planted). Field survey was carried out to collect samples for traning data, which is used for a supervised classfication, using ENVI and appying Support Vector Machine classifier.

Accuracy assessment: Ground truthing was carried out and Google Earth was made used as a valuable reference source (fortunately, there are new high resolution images of 2014 in this area). Points of groundtruth were designed in a systematic grid, distributed in the extent of AOS, with total points are 225, at each four pixels are selected as a set to check the actual land cover. Error matrix was computated based on statistical model for assessing accuracy (Congalton, 2009).

3. RESULTS

3.1 Gap-filled image

Color composites of bands with differrent image enhancement are visually displayed and without smears on gap-filled image (Figure 5 and 6). The image was converted to reflectant value (percentage) as Top of Atmosphere (TOA) to check any fault on reflectance at lines with data and lines without data that have been filled. Statistcs shows without any abnormal in values for the whole.

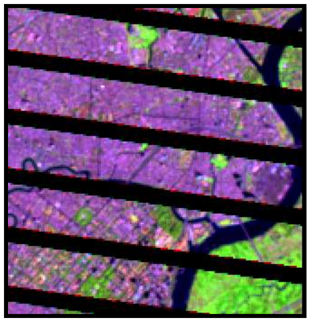

Figure 5: Prior to gap-filled (RGB B.5, B.4, B.2).

Figure 6: After gap-filled (RGB B.5, B.4, B.2).

Spectral profiles were made over areas of three main land covers of water, vegetation (forests) and built-up types. These profiles shows that there are not unusual changes on values across pixels, illustrated as Figure 5.

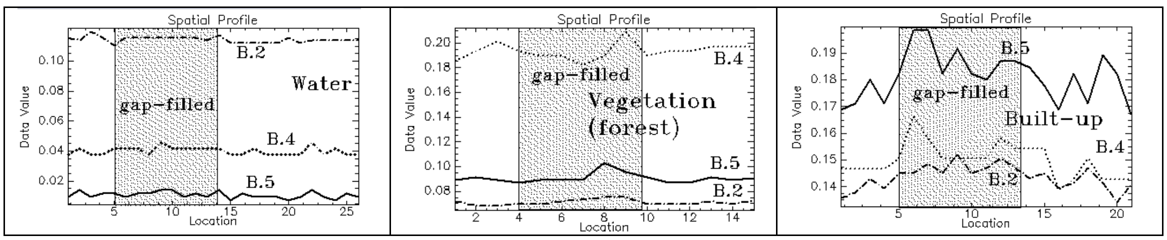

Figure 7. Spectral profile across gap and normal after gap-filled applied. Checking spectral reflectance changes by space for band 2, 4, and 5.

3.2 Classification and accuracy

Twelve clases were classified, in which there are four classes of built-up, large streets are clearly identified diffrence from other built-up types. Parennials and annuals are two different cover types, recognized from the others (Figure 8).

Table 1. Confusion matrix

	Reference/ Ground truth data												
Classified data	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**
1. Water	**23**	0	0	0	0	0	0	0	0	0	1	0	24
2. Fortests	0	**90**	3	1	0	1	0	0	0	0	0	2	97
3. Parennials	0	2	**38**	2	0	0	0	0	0	0	0	1	43
4. Annuals	0	0	2	**58**	0	0	0	0	0	1	0	0	61
5. Built-up 1	0	0	0	0	**126**	2	0	4	2	0	11	0	145
6. Built-up 2	0	1	0	0	0	**125**	0	7	3	1	3	0	140
7. Bare 1	0	0	0	0	0	0	**4**	0	0	0	0	0	4
8. Bare 2	0	1	0	0	2	18	0	**120**	4	1	2	0	148
9. Built-up 3	0	0	0	0	5	0	0	1	**58**	0	2	0	66
10. Annuals/	0	0	0	1	0	1	0	4	0	**20**	0	1	27
11. Buil-up 4	0	0	0	0	7	1	0	0	1	0	**73**	0	82
12. Marshes	1	2	1	2	0	0	0	0	0	5	0	**52**	63
Total	24	96	44	64	140	148	4	136	68	28	92	56	900

Systematic samples for accurcy checking from 225 points, with four pixels at each are calculated following confusion matrix as table 1. It yields an overall accuracy of 87.44% and Kappa coefficient of 0.86. This result is acceptable for Landsat 7 image in SLC-off mode. Image in SLC-off mode, radiometric information are retained and it still valuable for claasifying land cover or mapping. Errors of classification are mostly due to sampling for training data, as seen on commission and omission errors (Table 2).

Table 2. Commission and omission errors

Classes	Commission (%)	Omission (%)
1. Water	4.17	4.17
2. Fortests	7.22	6.25
3. Parennials	11.63	13.64
4. Annuals	4.92	9.38
5. Built-up 1	13.10	10.00
6. Built-up 2	10.71	15.54
7. Bare 1	0.00	0.00
8. Bare 2	18.92	11.76
9. Built-up 3	12.12	14.71
10. Annuals/ Grasses	25.93	28.57
11. Buil-up 4	10.98	20.65
12. Marshes	17.46	7.14

If post-classification applied, such as majority analysis, overall accuracy and Kappa is higher than if that is not applied. In this case, it will result in overall accuracy 90.88% and Kappa of 0.89. This result is appropriate for land cover mapping.

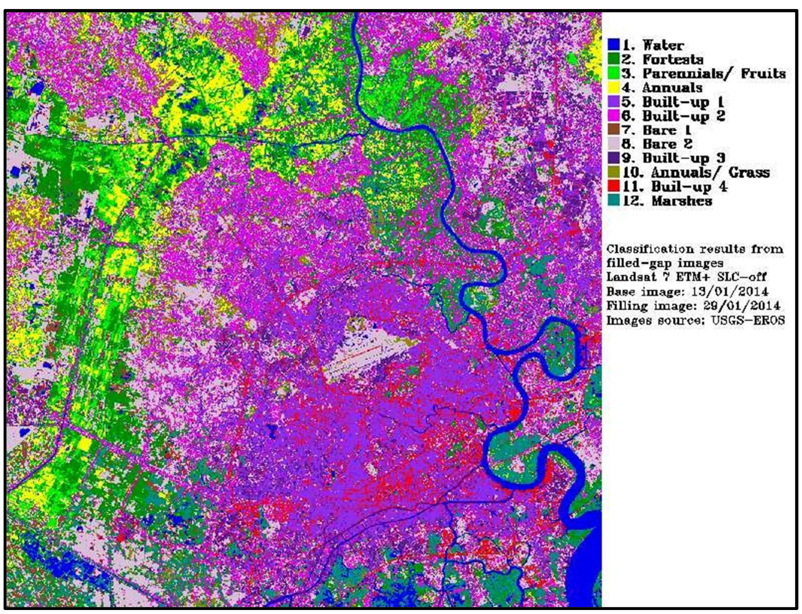

Figure 8. Classification result from gap-filled images.

4. CONCLUSIONS

Landsat 7 ETM+ SLC-off image gap-filled by another at the same scene but different acquisition date yields a satified results for land cover classification for a relative heterogenous area. The two images used must be close in time to avoid changes of incident radiation by time and status of land cover types changes in a short time, e.g. annual/ rices/ grasses growing. The overall accuracy and kappa coefficient are high, with 87.44% and 0.86 respectively. This result is acceptable regarding remote sensing approach for land cover identification. If post classifiction apllied the results will be higher in terms of accuracy.

This result indicates that usability of Landsat 7 SLC-off image is still high. Gap-filled images of Landsat 7 ETM+ SLC-of can be used along with Landsat 8 images to make utilization of Landsat data more efficient because the two satellites make a shorter cycle of the Earth observation, in 8-day instead of 16-day cycle for Landsat program.

5. REFERENCES

Asmaa Sadiq A.J., Ghazali S., Loay Edwar G., 2014. Survey on gap filling algorithms in landsat 7 ETM+ images. *Theorical and applied Informmation Technology*. Vol 63, No.1: 136-146.

Attarchi, S. and Richard G., 2014. Improving the estimation of above ground biomas using dual polarimetric PALSAR and ETM+ data in the Hyrcanian Mountain Forest (Iran). *Remote sensing* 6(5) 3693-3715. (doi:10.3390/rs6053693).

Conalton, Russell G. and Kass G., 2009. *Assessing the accuracy of remotetly sensed data: Principles and Prcatices*. 2nd Edition. Taylor and Frncis Group.

Howard, S.M. and J. Lacasse, 2004. Evaluation of gap-filled Landsat SLC-off imagery for wildland fire burn severity mapping, *Photogrammetric Engineering and Remote Sensing*. 70:877-880.

Irish R. and Scaramuzza P., 2009. *SLC-Off gap filled product generation*. NASA ‘s Goddard Space Flight Center.

Landsat – USGS: http://landsat.usgs.gov/sci_an.php.

Maxwell, S., 2004. Filling Landsat ETM+ SCL-off gaps using a segmentation model approach. *Photogrametric engineering & Remote sensing*: 1109-1111.

Mohammdy M. , Moradi H. R., Zeinivand H.., Temme A. J. A. M., Pourghasemi H. R. & Alizadeh H., 2013. Validating gap-filling of landsat ETM+ satellite images in the Golestan province, Iran. *Arab Journal of Geoscience.*

Richard Irish, 2009. *Frame and Fill*. NASA Goddard Space Flight Center

Scaramuzza, P., Esad M. and Gyanesh C., 2004. *SLC gap-filled products – Phase One Methodology*. (http://landsat.usgs.gov/sci_an.php).

Storey, J., Pasquale S. and Gail S., 2005. Landsat 7 scan line corrector-off gap-filled product development. *Pecora 16 Global priorities in land remote sensing*, 2005, South Dakota – USA.

USGS, 2003. *Preliminary Assessment of the Value of Landsat 7 ETM+ Data following Scan Line Corrector Malfunction*. http://landsat.usgs.gov/products_slcoffusabilityassess.php

USGS : http://landsat.usgs.gov/products_slcoffbackground.php

USGS. 2004. *SLC-off gap-filled products – Gap-fill algorithm methodology – Phase 2 gap-fill algorithm* (http://landsat.usgs.gov/sci_an.php).

USGS-EROS: http:earthexplorer.usgs.gov