VALIDATION OF THE MODIS BURNED-AREA PRODUCTS ACROSS DIFFERENT BIOMES IN SOUTH AFRICA

†Tsela[1] P. L., P. van Helden[1], P. Frost[2] and K. Wessels[2]

[1]Department of Geography, Geoinformatics and Meteorology, University of Pretoria, Pretoria, 0002, South Africa
[2]Remote Sensing Research Unit, Meraka Institute, Council for Scientific and Industrial Research (CSIR), Brummeria, Pretoria, 0001, South Africa

Abstract
The Moderate Resolution Imaging Spectroradiometer (MODIS) time-series data afford the remote sensing community a unique opportunity to investigate the frequency of occurrence and distribution of fires. Previous research on the validation of the MODIS burned area product in South Africa was only limited to two Landsat 7 Enhanced Thematic Mapper plus (ETM+) scenes in savanna vegetation, and therefore not adequate for robust assessment of fire distribution. In the present study, the validation of the MODIS burned area product (MCD45A1) as well as the Backup MODIS Burned Area Product (hereafter BMBAP) is extended over different South African vegetation types by quantifying their burned area detection and estimation accuracy by use of multi-temporal Landsat 5 Thematic Mapper (TM) imagery. Our results reveal that there are subtle differences in the accuracy of the two burned area products. These differences could be influenced for example by the intensity of the fire, vegetation type, the spectral characteristics, the size and spatial distribution of the burned areas. These results have significant implications for fire monitoring in Southern Africa.

Key words: MODIS, Landsat, burned area product, omission and commission errors

1. INTRODUCTION

Satellite remote sensing provides a unique view of the frequency and distribution of fires in South Africa. Recently, regional southern Africa burned-area products have been produced using 500 m Moderate Resolution Imaging Spectroradiometer (MODIS) time-series data which includes the official MODIS burned area product (MCD45A1) [1] as well as the Backup MODIS Burned Area Product (hereafter BMBAP) [2]. Previous research on the validation of the MCD45A1 in South Africa was limited to only two Landsat 7 Enhanced Thematic Mapper plus (ETM+) scenes that covered the Lowveld savanna biome around the southern Kruger National Park [3]. In the present study, the validation work of MCD45A1 reported by [3] is extended across the main fire prone biomes in South Africa by use of similar analysis procedures.

Remote sensing scientists and burned-area product users have encountered three major problems with the MCD45A1 product: a) biased estimation of burned area; b) false detection of unburned area; and c) the omission

† philemon.tsela@up.ac.za

of small and scattered burned areas [4]. The goal of the present work is to validate the moderate resolution burned-area products in order to determine the product accuracy by:

a) quantifying the commission and omission errors in MCD45A1 and BMBAP and;

b) comparing the burned area estimation of MCD45A1 and BMBAP across the main fire prone biomes in South Africa during the dry season of 2007.

2. METHODOLOGY

The June-September season of 2007 (generally a dry season) was considered as representative of recent fire distributions in South Africa. The accumulated active fire product, mean annual temperature and rainfall estimates of 2007 were used to guide the selection of the main fire prone areas that cover the regional climatic variations. Seven validation sites were selected which represent important features that may influence the accuracy of burned area products. These features include, the degree of spectral change from unburned to burned vegetation, the spatial characteristics of the burned areas, and spectrally similar non-fire induced changes [5].

Two 30 m Landsat 5 Thematic Mapper (TM) scenes were obtained for each of the seven sites during June-September 2007. Most of the scenes were cloud-free acquisitions, sensed before and after biomass burning events. These scenes display temporal differences that are less than the persistence time of the burned area spectral signal [6]. To conduct rigorous burned area change detection between the two TM acquisitions for each site, it was necessary to perform image to image registration. A burn-sensitive vegetation index using the TM near-infrared and middle-infrared bands was computed to provide a good burned-unburned discrimination, and to minimize the effects of identical surface changes [7]. Thereafter, a band ratio temporal difference image was computed and the burned areas that appeared to have occurred between the TM acquisitions were enhanced. High resolution burned area maps were derived by visual inspection and on-screen digitizing. However, some non-fire induced spectral changes were evident and required careful interpretation. Only Landsat burned areas with small axis of 4 pixels (240 m) or greater were included in the evaluation process [6].

To allow comparison of the 500 m MODIS burned area products with the 30 m Landsat independent reference data, the spatial properties of the moderate resolution products were transformed to correspond with that of Landsat data to enable direct comparison on a per-pixel basis. The accuracy of the products was summarized through confusion matrices, and the errors of omission and commission were quantified in the burned area products and compared across the main fire prone biomes in South Africa. Unmapped areas which include cloud and cloud shadow interpretation were also reported, in order to limit biasing the summary of the area burned statistics [8]. Further, a linear regression analysis was used to compare estimated area burned by the MODIS products with that of the independently-derived Landsat reference data. Lastly, the burned area proportions within 2.5 km grid cells were computed and compared through regression analysis.

3. RESULTS

The commission errors of the products derived from [1] and [2] over four study sites indicated subtle differences (~ 10%), which have a spatial dependence. From the analysis, it can be concluded that, both products had lower errors of commission. In particular, the BMBAP has the lowest commission error of ~17% (see TABLE 1 and TABLE 2). As a result, the BMBAP has the highest user accuracy overall. The differences in the commission errors could be attributed to differences in the size distribution and the heterogeneity of the burned areas across the selected sites. On the other hand, the MCD45A1 and BMBAP had generally higher errors of omission than commission, and the omission errors did not reveal marked differences except for one scene in the Sabie region. The MCD45A1 demonstrated higher general detection capability with lower errors of omission than the BMBAP in all biomes except in the pine forest. The differences in errors of omission could be as a result of unburned tree canopy, small and/or spatially fragmented burned areas, and the low spectral reflectance caused by low combustion completeness burns.

TABLE 1. GEOSPATIAL ACCURACY ASSESSMENT FOR THE MCD45A1

Biome	Site, Landsat path/row	TM dates	Landsat Burned (%)	MCD45A1 Burned (%)	Correctly Classified (%)	Omission Error (%)	Commission Error (%)
Lowveld Savanna	Southern Kruger 168/077	11 Aug 07 27 Aug 07	3.22	2.8	99.78	40.38	31.35
Highveld Grassland	Middelburg 169/078	18 Aug 07 3 Sep 07	2.63	1.42	97.90	62.87	31.52
Fynbos	Western Cape 175/083	17 Feb 07 6 Apr 07	10.28	2.98	91.42	77.25	21.47
Pine forest	Sabie 169/077	15 Jun 07 18 Aug 07	26.72	13.22	76.21	62.14	23.5

TABLE 2. GEOSPATIAL ACCURACY ASSESSMENT FOR THE BMBAP

Biome	Site, Landsat path/row	TM Dates	Landsat Burned (%)	BMBAP Burned (%)	Correctly Classified (%)	Omission Error (%)	Commission Error (%)
Lowveld Savanna	Southern Kruger 168/077	11 Aug 07 27 Aug 07	3.22	2.33	99.83	40.39	17.68
Highveld Grassland	Middelburg 169/078	18 Aug 07 3 Sep 07	2.63	1.21	97.96	65.79	25.64
Fynbos	Western Cape 175/083	17 Feb 07 6 Apr 07	10.28	2.21	91.12	82.85	18.47
Pine forest	Sabie 169/077	15 Jun 07 18 Aug 07	26.72	36.65	71.81	14.63	37.76

The slope of the regression line was used as a measure of the accuracy of the estimated burned area by MCD45A1 and BMBAP; the results (not shown here) depict a spread in the spatial variance. The variance quantified by the coefficient of determination (r^2) indicated a significant level of agreement between the Landsat independent reference data and the MODIS burned area products. However, the BMBAP revealed a stronger relationship with r^2 values > 0.8 for all validation sites than the MCD45A1 except in the Western Cape region. The regression results showed that the BMBAP has higher accuracy (slope of > 0.8) of the estimated burned area in three out of four sites, but slightly overestimates burned area in the pine forest. The most accurate burned area estimates were obtained for MCD45A1 and BMBAP in the Lowveld savanna and Highveld grassland biomes.

4. CONCLUSION

The MODIS burned area products were validated across savanna, grassland, fynbos and pine forest biomes in South Africa. In areas of low fire intensity, the MCD45A1 revealed high user accuracy relative to the BMBAP. On the other hand, the BMBAP display high user accuracy over areas of high fire intensity as well as reliably detects the burned areas with lower errors of omission relative to the MCD45A1. Generally, the differences in the accuracy of the burned area products depend on the type of vegetation, the spatial pattern, distribution and spectral reflectance of the burned areas. In order to validate these results, more multi-date high-spatial resolution imagery could be needed to assess product accuracy over a longer period.

5. REFERENCES

[1] D. P. Roy, Y. Jin, P. E. Lewis, and C. O. Justice, "Prototyping a global algorithm for systematic fire-affected area mapping using MODIS time series data," *Remote Sens. Environ*., vol. 97, no. 2, pp. 137–162, Jul. 2005.

[2] L. Giglio, T. Loboda, D. P. Roy, B. Quayle, and C. O. Justice, "An active-fire based burned area mapping algorithm for the MODIS sensor," *Remote Sens. Environ*., vol. 113, no. 2, pp. 408–420, Feb. 2009.

[3] D. P. Roy, and L. Boschetti, "Southern Africa Validation of the MODIS, L3JRC and GLOBCARBON Burned Area Products," *IEEE Trans. Geosci. Remote Sens.*, vol. 47, no. 4, pp. 1032 - 1044, Apr. 2009.

[4] S. N. Trigg and D. P. Roy, "A focus group study of factors that promote and constrain the use of satellite derived fire products by resource managers in Southern Africa," *J. Environ.. Manag*., vol. 82, no. 1, pp. 95–110, 2007.

[5] D. P. ROY, J. BORAK, S. DEVADIGA, R. WOLFE, M. ZHENG, and J. DESCLOITRES, "The MODIS land product quality assessment approach," *Remote Sens. Environ.*, vol. 83, no. 1, pp. 62–76, Nov. 2002.

[6] D. P. Roy, P. Frost, C. Justice, T. Landmann, J. Le Roux, K. Gumbo, S. Makungwa, K. Dunham, R. Du Toit, K. Mhwandagara, A. Zacarias, B. Tacheba, O. Dube, J. Pereira, P. Mushove, J. Morisette, S. Santhana Vannan, and D. Davies, "The Southern Africa Fire Network (SAFNet) regional burned-area product-validation protocol," *Int. J. Remote Sens.,* vol. 26, no. 19, pp. 4265–4292, Oct. 2005.

[7] L. Giglio, G.R. van der Werf, J.T. Randerson, G. J. Collatz, and P. Kasibhatla, "Global estimation of burned area using MODIS active fire observations," *Atmos. Chem. Phys.,*vol. 6, no. 4, pp. 957-974, Mar. 2006.

[8] D. P. Roy, L. Boschetti, C. O. Justice, and J. Ju, "The Collection 5 MODIS burned area product—Global evaluation by comparison with the MODIS active fire product," *Remote Sens. Environ.,* vol. 112, no. 9, pp. 3690–3707, Sep. 2008.