

## Second Year Progress Report

**Title:** Burned area mapping in Southern Africa: Case Study Synthesis and Regional Application of MODIS data.

**Principal Investigator:** David Roy  
**Department:** Geography  
**Institution:** University of Maryland, College Park  
**Street:** 1113 Lefrak Hall  
**City:** College Park                      **State:** Maryland  
**Zip:** 20745                                      **Country:** USA  
**E-mail:** [droy@kratmos.gsfc.nasa.gov](mailto:droy@kratmos.gsfc.nasa.gov)  
**Telephone:** (301) 614-5571  
**Fax:** (301) 614 5269

**Co-Investigator Name:** Peter Frost  
**Institution:** Institute of Environmental Studies, University of Zimbabwe  
**Address:** P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe  
**E-mail:** pfrost@science.uz.ac.zw  
**Telephone:** +263-(1)4 30 26 03  
**Fax:** +263-(1)4 33 28 53

**Collaborators** (listed geographically from West to East across Southern Africa): Johan Le Roux (Etosha Ecological Institute, Namibia), Pauline Dube (Department of Environmental Science, University of Botswana, Botswana), Kolthi Gumbo, (Chesa Forest Research Station, Zimbabwe Forestry Commission, Zimbabwe), Raoul du Toit (World Wide Fund for Nature, Southern Africa Regional Programme Office, Zimbabwe), Steve Makungwa (Forest Research Institute of Malawi, Malawi), Tobias Landmann (Council for Scientific and Industrial Research, South Africa & University of Goettingen, Germany), David Woods (Kruger National Park Scientific Services, South Africa), Agostinho Zacarias (FAO, Mozambique).

**Funded:** NASA Land Cover Land Use Change & Applications programs.

**Abstract:** Southern Africa is subjected to some of the most extensive biomass burning in the world. Fires occur due to both natural and anthropogenic causes, primarily lightning and land management. Systematic monitoring of burned areas is needed by the global change research community as an input to biogeochemical models and is required to understand and model how fire regimes are likely to change as a function of climate, population dynamics, and land use change. This three-year project will conduct synthesis research that integrate results from multiple case studies that address the drivers of Land Cover Land Use Change (LCLUC). The research will utilize the improved remote sensing capabilities provided by MODIS and Landsat ETM. The new spectral bands and spatial resolution of the MODIS instrument provide the means for improved study of fire and burned area. MODIS 500m burned area data sets will be made for all of Southern Africa for 2000, 2001 and 2002 using a recently developed algorithm that maps the location and approximate day of burning. An applications component is included and meets an important NASA programmatic need to use MODIS data in the applications domain. The applications component follows a guiding GOFC-GOLD principle that the user community play an active role in defining product requirements and in undertaking product assessment and testing of pre-operational algorithms. The work is being undertaken with collaborators located at eight case study sites throughout Southern Africa. The collaborators are founding members of the Southern African fire network (SAFNet) which is emerging from the Miombo Network, GOLD-Fire, and SAFARI 2000 initiatives. They have existing projects with strong interests for long term fire information to support their research and operational agendas in resource management and environmental assessment. The collaborators will initially evaluate and subsequently utilize satellite data in their decision-making processes for fire management and reporting. Landsat ETM data acquired over the case study sites will be used to validate the regional MODIS burned area product. These data will be used to provide an improved understanding of the relationship between fire timing, occurrence, burn size and spatial distribution, land cover change and land use practice. The collaborators will design the transition of this work from research and validation into operational implementation in the final year of the project. The long term goal is to identify the pathway to transition this work into an operational fire monitoring system for Southern Africa that will meet the fire information needs of policy makers, the scientific community and natural resource managers.

**Research Fields** - Biomass Burning, Change Detection, Product Validation.

**Geographic Area/Biome** - Southern Africa.

**Remote Sensing** - MODIS, Landsat.

**Methods/scales** - Local scale, Regional scale, Time Series Analysis.

## **Project questions, goals, approaches:**

The project is directed at answering

- *what are the changes in land cover and/or land use ?*
- *what are the causes of LCLUC ?*

In addition the project is directed at

- *demonstrating the application of NASA EOS data products* (an applications program objective)

The NASA project themes are GOFC-fire (mapping/monitoring fire) (75%) and applications (25%). The project contains approximately 10% social science.

These goals are being achieved; first, by generating spatially explicit Southern Africa burned area data sets that map the approximate day and 500m location of burning for 2000-2003; second, by collaborator validation of the burned area data sets using multi-temporal Landsat ETM+ at case study sites distributed across the region; third, by collaborator evaluation of the suitability of the Landsat and MODIS burned area data sets in their decision-making processes for fire management and reporting; fourth, by research to relate observed biomass burning spatial and temporal distributions to climate, population and land use.

In year one regional MODIS burned area data sets were produced for 2000 and for 2001 using the available MODIS Collection 1 and Collection 3 data respectively. The initial, Collection 1, MODIS-Terra products generated from data sensed 25 February to 1 November 2000 were of reduced quality because of problems with the instrument configuration and because early algorithm developments were still ongoing. MODIS reprocessing was subsequently undertaken applying the latest available version of the science algorithms to the MODIS instrument data and using the best available calibration and geolocation information.

In year two regional MODIS burned area data sets were produced for 2000 and 2001 using the improved Collection 4 MODIS data. Examples are shown in **Figures 1 and 2**. Regional MODIS burned area data sets were also produced for 2002 using the available Collection 3 MODIS data.

In year one laptop computers bundled with remote sensing software, cables and GPS were sent to the regional collaborators with 28 and 30 Landsat ETM+ 2000 and 2001 scenes respectively. The ETM+ data were used by the collaborators to produce validation burned area data sets following a consensus methodology. The validation data were sent back to the US for quality assessment and harmonization as GIS vector data sets.

In year two a further 27 Landsat ETM+ scenes were sent to the collaborators, and again the collaborator burned area validation data sets were sent back to the US for quality assessment and harmonization. The digital Landsat ETM+ data were made available to SAFARI 2000 and the NASA Tropical Rainforest Information Center (TRFIC).

In year two the MODIS 2000 Collection 4 500m burned area data sets were compared with 1km SPOT Vegetation GBA2000 and 1km ATSR GLOBSCAR burned area data sets (see example in Figure 2). This comparison work is being incorporated into a publication whose main focus will be to present the Collection 4 2000, 2001 and 2002 MODIS burned area validation results. This comparison work has also been incorporated into a southern Africa emissions sensitivity analysis paper.

In year two analysis of the validation results revealed some fundamental issues concerning the ability to precisely define the limits of MODIS burned area detection. Namely, it is unknown to what degree burned areas produced by low combustion completeness fires were mapped using the ETM+ data. Similarly, it is unknown if burned areas produced by surface fires and concealed by unburned overstorey vegetation were mapped. A theoretical, rather than data driven, analysis of this problem resulted in the submission of a paper on this subject, in addition to a paper describing the validation methodology.

In year two the collaborators met under the auspices of the *Third Meeting of the GOF/GOLD Southern Africa Fire Network (SAFNet)*, University of Botswana, Gaborone, Botswana, 29 July - 1 August 2002 (organized by Dube, P. and **Roy D.**). This was a successful meeting and included formal definition of the SAFNet mission statement, and subsequent establishment of the SAFNet web site (<http://safnet.umd.edu/>), and a SAFNet flyer distributed at the United Nations World Summit on Sustainable Development, Johannesburg, 26 August - 4 September, 2002. Results from this project were included in the flyer and on the web site.

At the end of year two a collaborator meeting will be held under the auspices of the *Fourth Meeting of the GOF/GOLD Southern Africa Fire Network (SAFNet)*, Kruger National Park, South Africa, 17-23 August 2003 (organized by Davies, D., **Roy D.**, Govender, N.). The NASA LCLUC and Applications programs are recognized as contributing to the sponsorship of this meeting. See <http://safnet.umd.edu/implementation/events/meetings/> for details.

In year two a number of regional data sets were assembled and projected into registration with the MODIS burned area data sets to begin to relate biomass burning spatial and temporal distributions to climate, population and land use. These data sets include, land cover (White's vegetation map and the MODIS Land Cover Product), MODIS 1km percent tree cover data set, Digital Chart of the World country borders, UNEP Population decadal data, 0.5° mean monthly 2m air temperature climatology data, and 1° Tropical Rainfall Measuring Mission best-estimate precipitation data.

Issues in year two have included:

- Landsat ETM+ failure precluded a third year of validation work. This is not a serious limitation as sufficient Landsat ETM+ (85 scenes 2000-2002) were collected for validation purposes. This limitation does cause some problems in managing African collaborator momentum, as the validation expense money was helpful in this respect.
- A collaborator left their institution for a better position (solution: none as no suitable replacement found)

- The research assistant funded by this project finished his Msc. Spring 2003 and quit working for the project. Solution: currently seeking a suitably qualified replacement.

**New findings:** None at this stage beyond those reported in publications.

**New potential:** Quantitative multi-annual regional and country level estimates of Area Burned.

**New products:**

- 2000 Collection 4 monthly burned area data – made available as **Roy, D.P.**, (2003), *SAFARI 2000 MODIS 500m Burned Area Products, Southern Africa, July & September 2000*, in SAFARI 2000 CD-ROM Series. Volume 3. J. Nickeson, *et al.* eds. CD-ROM. National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, U.S.A. (In prep.)
- 2001 Collection 4 monthly burned area data set
- 2002 Collection 3 monthly burned area data set
- Landsat ETM+ 2000 and 2001 and 2002 burned area validation data sets (GIS vectors)

At the time of writing the Collection 4 2002 data are being reprocessed. In year three Collection 4 2002 and 2003 burned area data sets will be completed. MODIS Aqua data will be combined with MODIS Terra data to make the 2003 burned area data (in the expectation of improved mapping performance). If time permits a 250m burned area data set for select months and locations will be made. All the 2000-2003 burned area data sets and the 2000-2002 Landsat ETM+ derived burned area data (GIS vectors) will be made available publicly in year three.

The next steps are to evaluate the suitability of the Landsat and MODIS burned area data sets for fire management and reporting and to undertake research to relate the observed regional biomass burning to climate, population and land use.

## **Conclusions**

This project is on track for the third year with an emphasis now shifting from generation and validation of MODIS burned area data sets to the applications aspect of the project including designing the pathway to transition this work from research and validation into operational implementation and research to relate the observed regional biomass burning to climate, population and land use.

### Peer reviewed publications

**Roy, D.**, Lewis, P., Justice, C., 2002, Burned area mapping using multi-temporal moderate spatial resolution data - a bi-directional reflectance model-based expectation approach, *Remote Sensing of Environment*, 83:263-286.

Vermote E. and **Roy D.**, 2002, Land surface hot-spot observed by MODIS over Central Africa, *International Journal of Remote Sensing cover and letter*, 23: 2141-2143.

Gumbrecht, T., McCarthy, T.S, McCarthy, J., **Roy D.**, Frost. P.E., Wessels. K., 2002, Remote Sensing to detect sub-surface peat fires and peat fire scars in the Okavango Delta, Botswana, *South African Journal of Science*, 98, 351-360.

Swap, R.J., Annegarn, H.J., Suttles, J.T., Haywood, J., Helmlinger, M.C., Hely, C., Hobbs, P.V., Holben, B. N., Ji, J., King, M., Landmann, T., Maenhaut, W., Otter, L., Pak, B., Piketh, S.J., Platnick, S., Privette, J., **Roy, D.**, Thompson, A.M., Ward, D., Yokelson, R., 2002, The Southern African Regional Science Initiative (SAFARI 2000): overview of the dry-season field campaign, *South African Journal of Science*, 98, 125-130.

Justice, C., Giglio, L., Korontzi, S., Owens, J., Morisette, J., **Roy, D.**, Descloitres, J., Alleaume, S., Petitcolin, F., Kaufman, Y., 2002, The MODIS fire products, *Remote Sensing of Environment*, 83: 244-262.

### Submitted publications

**Roy, D.P** and Landmann, T., Characterizing the surface heterogeneity of fire effects using multi-temporal reflective wavelength data, *International Journal of Remote Sensing*, Accepted 2003.

**Roy, D.**, Frost, P., Justice, C., Landmann, T., Le Roux, J., Gumbo, K., Makungwa, S., Dunham, K., Du Toit, R., Mhwandagara, K., Zacarias, A, Tacheba, B., Dube, O., Pereira, J., Mushove, P., Morisette, J., Santhana Vannan, S., Davies, D., The Southern Africa Fire Network (SAFNet) regional burned area product validation protocol, *International Journal of Remote Sensing*, Submitted 2003.

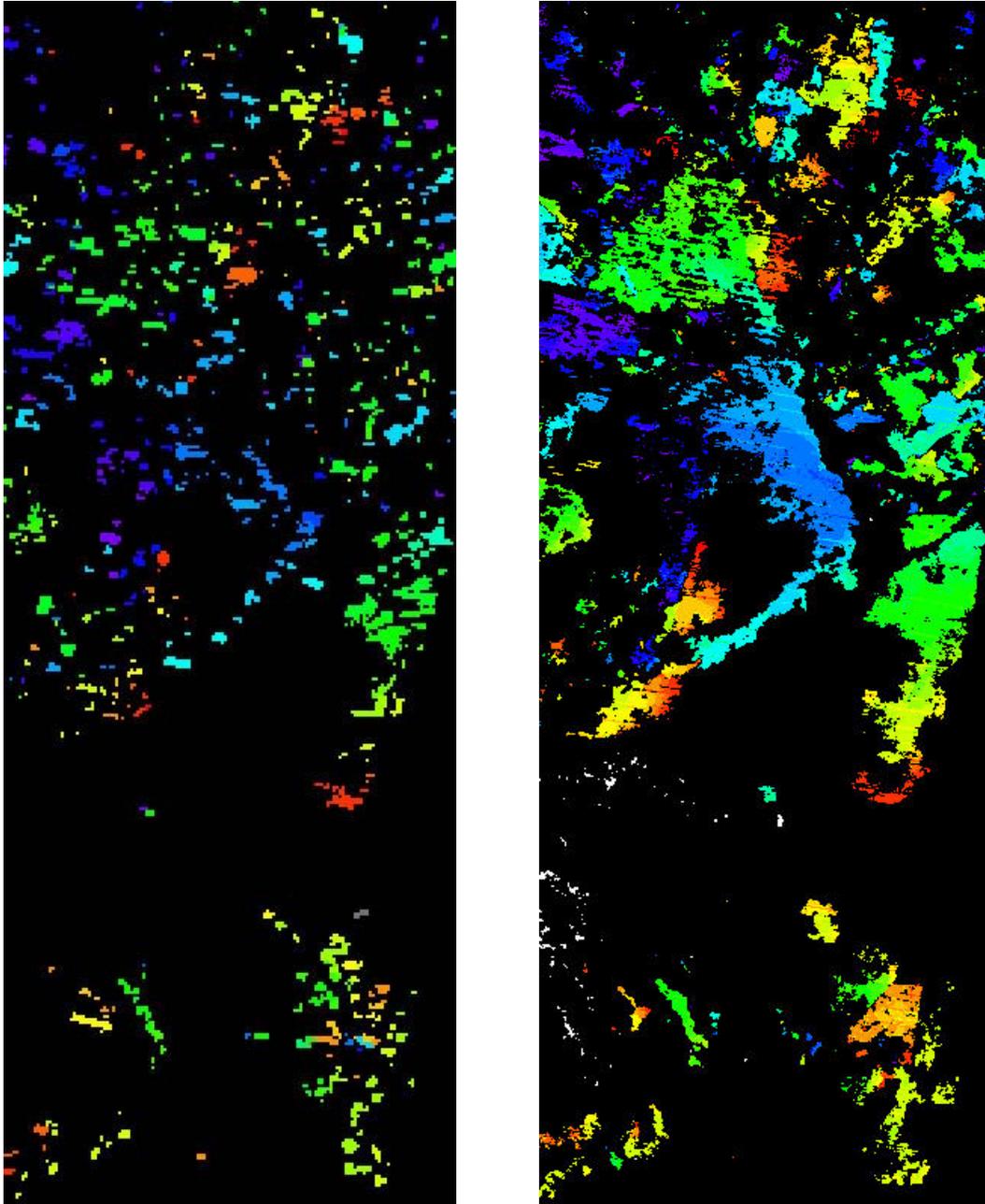
**Roy, D.P** and Justice, C.O., Book chapter “A burning question – the changing role of fire on Earth” in *Our Changing Planet: A View From Space*, Cambridge University Press, Submitted 2003.

Korontzi, S., **Roy, D.P.**, Justice,C.O., Yokelson,R.J., Ward, D.E., Hobbs, P.V., Regional dynamic modeling and sensitivity analysis of southern African fire emissions, *Remote Sensing of Environment*, Submitted 2003.

Csiszar, I., Justice, C.O., Mcguire, A.D., Cochrane, M.A., **Roy, D.P.**, Brown, F., Conard, S.G., Frost, P.G.H., Giglio, L., Elvidge, C., Flannigan, M.D., Kasischke, E., Mccrae, D.J., Rupp, T.S., Stocks, B.J., Verbyla, D.L., Book chapter “Land Use and Fires” in

*Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface*, Kluwer Academic Publishers, Submitted 2003.

**Figure 1** Temporal composite of the 1km MODIS Terra day and night active fire detections (left) and 500m MODIS burned areas (right) for **August 27 to October 26 2000** (61 days). These data are the recently reprocessed Collection 4 products. A rainbow color scale is use to show the temporal progression of burning. In the right image gray colors denote pixels where there were insufficient cloud-free observations to detected burned areas. A 150\*400km region encompassing parts of Botswana, Namibia and Angolan is shown.



**Figure 2:** Inter comparison of southern Africa September 2000 burned area data sets produced using MODIS data (Roy et al. 2002) and using SPOT Vegetation data (GBA2000). Red shows MODIS-SPOT agreement, blue shows MODIS only, yellow shows SPOT only. White shows regions not mapped by MODIS due to missing and/or persistently cloudy data.

