FIRE TRENDS FOR BELIZE (2003-07): DATA FROM SATELLITE-BASED MONITORING

EMIL A. CHERRINGTON

Water Center for the Humid Tropics of Latin America & the Caribbean (CATHALAC), 801 City of Knowledge, Panama City, Panama · TEL: (507) 317-3200 · emil.cherrington@cathalac.org

Revised April 2008

Mesoamerica is crucial to efforts at global biodiversity conservation; while the isthmus represents less than a percent of the globe's landmass, by stark contrast, 7% of the world's terrestrial species are found there (Barry 2003). Nevertheless, the region's globally significant biological diversity is vulnerable to climatic events. Year after year, hurricanes, tropical storms, floods, fires and drought ravage the region.

Recognizing that satellite-based technologies can play a significant role in the monitoring of environmental phenomena and response to natural disasters, Central America's governments requested the development of the *Regional Visualization & Monitoring System (SERVIR).* SERVIR is implemented by NASA, the Water Center for the Humid Tropics of Latin America & the Caribbean (CATHALAC), the Central American Commission for the Environment & Development (CCAD), the U.S. Agency for International Development (USAID), the World Bank, and other partners. SERVIR constitutes a platform for the observation, forecasting and modeling of environmental processes in Mesoamerica and provides information freely to the region's decision-makers and scientists via the Internet (*see* www.servir.net).

Particularly important to regional environmental monitoring efforts is the influence of fire, which constitutes an especially significant threat to Mesoamerica's biodiversity. In the context of fire monitoring, SERVIR makes much use of the *Rapid Response System* developed for the *Moderate Resolution Imaging Spectroradiometer* (MODIS), and the University of Maryland's associated *Fire Information for Management System* (FIRMS). Flying approximately 705km above the earth on NASA's Terra and Aqua satellite platforms, MODIS can detect fires and other thermal anomalies[1] such as gas flares and volcanic eruptions (Lillesand et al 2004, UMD 2007). MODIS takes snapshots of Mesoamerica about four times daily, allowing for detection of fires occurring at set intervals, when these fires are not obscured by cloud cover or by thick smoke (UMD 2007). **This paper is a brief review of the past five years' worth of satellite-based data on fires in the Central American nation of Belize**.

DATA PRE-PROCESSING

Fire data from MODIS were obtained for Belize through the University of Maryland's *Fire Information for Resource Management System* (FIRMS). Prior to analysis, however, careful filtering of the data was necessary. While MODIS-Terra has effectively been collecting data since 2000, it was preferable to restrict the study period to the period in which the dual platform Aqua / Terra system was operational. The period of January 1, 2003 through to December 31, 2007 was thus selected. Additionally, the current data archive is a mix of data derived from two

---

[1] For this reason, many times these are referred to "hotspots" in place of "fires" although the University of Maryland's standard term is "active fire detections."

differing processing algorithms; these sets of data are referred to as MODIS Collections 4 and 5 (UMD 2007). To negate the likely errors of commission resultant from Collection 4, and to ensure a suitable degree of compatibility between data derived from the two algorithms, only data with high estimated confidence values (at or exceeding 70%) have been selected for this analysis.

Through spatial analysis in powerful geographic information systems (GIS) applications, fire detections can be combined with other data to trace detections, for instance, to which types of vegetative cover were burning. Whether such detections were occurring within national parks and other protected areas can also be assessed. Important caveats to recall are that (i) fires detected by MODIS on any given day are mere subsets of the total fires occurring, representing only 'snapshots' of fires occurring throughout the day, and (ii) clouds or thick smoke occlude fire detections (UMD 2007).

RESULTS

In the five years between 2003 and 2007, the MODIS sensors have detected over 2,000 fires across Belize (NASA / UMD 2008). For the sake of differentiating the various land cover / vegetation types upon which such fires occur, these are broken out by land cover type in **Table 1** below.[2] The data indicate that over time, the incidence of forest fires is increasing, even as the overall incidence of detected fires is fluctuating. The year 2003 seems to have had the worst fire season, with an estimated 850 fires detected, compared to 2007, which had an estimated 473 fires. The data indicate, in fact, that 2007 had the most forest fires (44.2% of all fire detections), though overall, fires on agricultural lands – likely due to land clearing – represents over a third of total fires detected between 2003 and 2007. While not representing substantial losses of biomass, fires in scrublands and savannas also represent on average a quarter of all detected fires. Some wetland clearings have also been detected, although these represent a very small proportion of detected fires. The MODIS sensor has even detected a number of fires in human settlements.

Table 1: Detected Fires by Land Cover Type[3]

Year	Land Cover Types										Total
	Agricultural		Forest		Scrubland		Wetlands		Settlements		
	N	%	n	%	n	%	n	%	n	%	
2003	361	42.5	254	29.9	204	24.0	28	3.3	3	0.4	**850**
2004	81	42.6	49	25.8	47	24.7	12	6.3	1	0.5	**190**
2005	133	31.1	148	34.6	131	30.6	15	3.5	1	0.2	**428**
2006	47	33.8	53	38.1	35	25.2	3	2.2	1	0.7	**139**
2007	123	26.0	209	44.2	132	27.9	8	1.7	1	0.2	**473**

[2] Agricultural lands refer to both cultivated lands and to pastures. Forests include lands with high tree cover of the broadleaf, needle-leaf or mixed varieties. Scrublands include areas with short / sparse vegetation, including savannas and early forest regrowth. The category of wetlands also includes mangrove forests. These classes were aggregated from Belize's 2004 ecosystem map from Meerman (Meerman 2005).

[3] All the fire data presented in the tables were extracted from the MODIS Collection 4 / 5 data obtained from the University of Maryland / FIRMS. Data were filtered in a GIS environment, as described above.

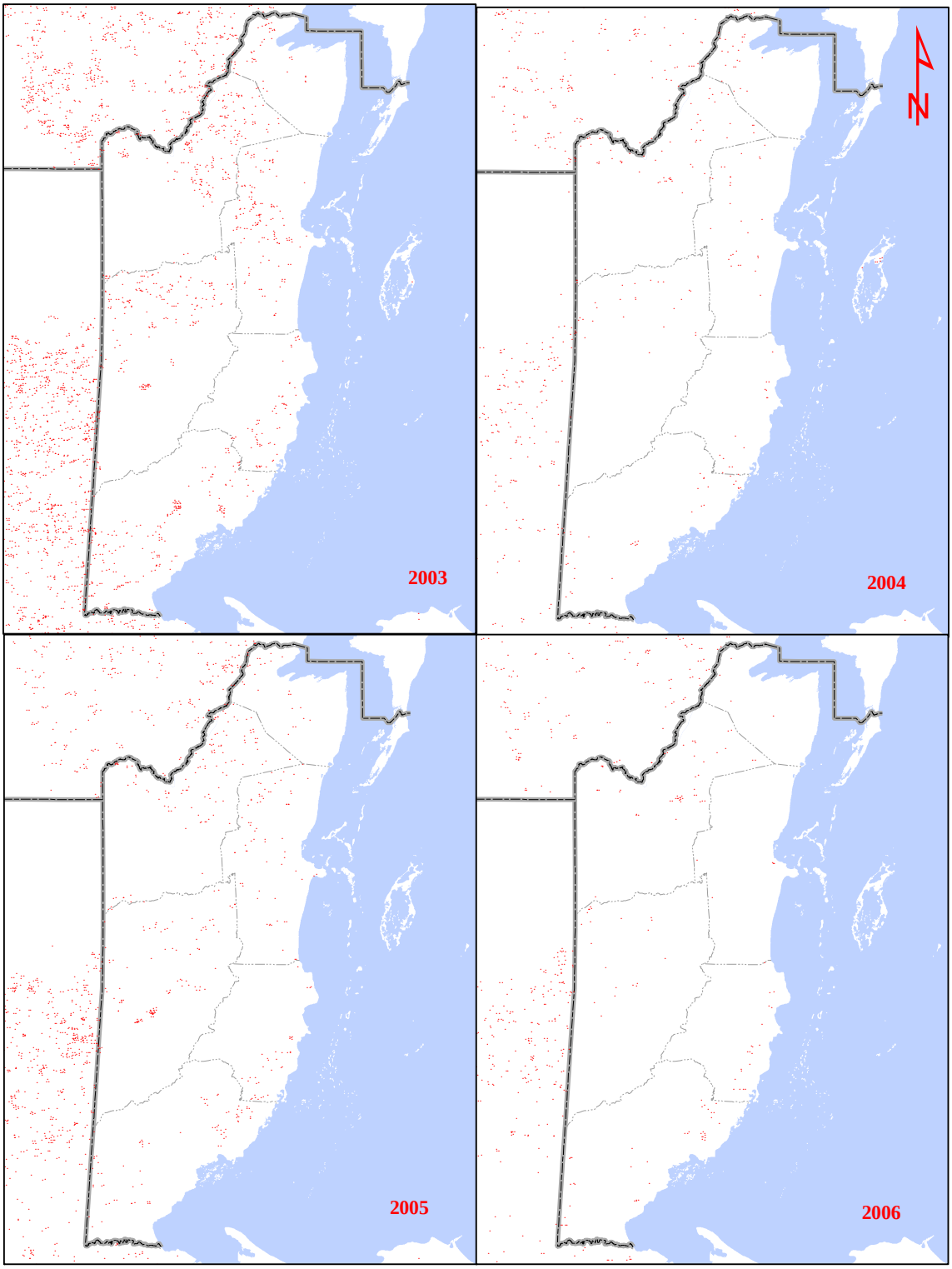

Figure 1: Geographic Distributions of the Fires across Belize, 2003-06

Table 2 and **Figure 1** illustrate that fire incidence varies geographically in any given year, although in any given year – *with the exception of 2007* – the number of fires occurring annually

in the Orange Walk district represent the majority of fires occurring (between 25% and 34%, excluding 2007). Fires in Cayo, however, represented a quarter of all fires in the five year period. In any given year, the fires in the Orange Walk, Cayo, Toledo and Belize districts represent some 80% of all fires, with the Corozal and Stann Creek districts and the offshore cayes accounting for less than 20% of fires nationally. The fires in Orange Walk were largely agricultural fires (e.g. burning of agricultural fields) while those in the Cayo district likely represented the clearing of land for agricultural development. From late April to late May 2007, massive fires likewise burned tens of thousands of acres of forest the Mountain Pine Ridge in the Cayo district (CATHALAC / NASA 2007).

Nevertheless, the fires detected have not been confined to activities occurring on the mainland. In early 2004, in particular, a small but nonetheless alarming number of fires were detected on the Turneffe Atoll. Anecdotal information later suggested that the fires on Turneffe were caused by clearing of mangroves on the Atoll. This therefore illustrates the ability of the technology to serve as an 'eye in the sky' detecting phenomena that might otherwise go unnoticed.

Table 2: Detected Fires by District

Year	Region														Total
	Corozal		Orange Walk		Belize		Cayo		Stann Creek		Toledo		Cayes		
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
2003	44	5.2	217	25.5	143	16.8	182	21.4	59	6.9	204	24.0	1	0.1	**850**
2004	21	11.1	61	32.1	30	15.8	25	13.2	14	7.4	34	17.9	5	2.6	**190**
2005	24	5.6	115	26.9	67	15.7	110	25.7	36	8.4	76	17.8	0	0.0	**428**
2006	4	2.9	48	34.5	6	4.3	22	15.8	18	12.9	41	29.5	0	0.0	**139**
2007	18	3.8	72	15.2	47	9.9	208	44.0	38	8.0	89	18.8	0	0.0	**473**

In fact, a distinct pattern can be seen with regard to the temporal distribution of fires. The majority of fires occur between March and May of any given year, pertaining to the height and close of the dry season in Belize – both when conditions are most dry and wildfires are likely to break out, and when farmers are likely to be preparing their fields for the onset of the rain. Nevertheless, it bears noting too that a number of fires have been detected outside of the dry season per se, perhaps pointing to the incidence of specific development-related activities.

Table 3: Distribution of Detected Fires by Months

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
2003	0	2	201	251	377	15	0	0	3	0	0	1	**850**
2004	1	4	20	72	44	7	6	35	2	0	0	1	**192**
2005	3	21	112	198	76	15	4	1	0	0	0	0	**430**
2006	0	2	12	53	70	1	0	2	0	0	0	0	**140**
2007	1	5	26	109	308	14	4	2	2	0	1	1	**473**

In addition to noting types of vegetation affected by fires and the geographic areas in which such fires occur, other trends that can be examined from the MODIS fire data are the threats to protected areas (particularly terrestrial protected areas). The April-May 2007 fires noted previously affected significant portions of the Mountain Pine Ridge Forest Reserve, as illustrated in **Figure 2** below.

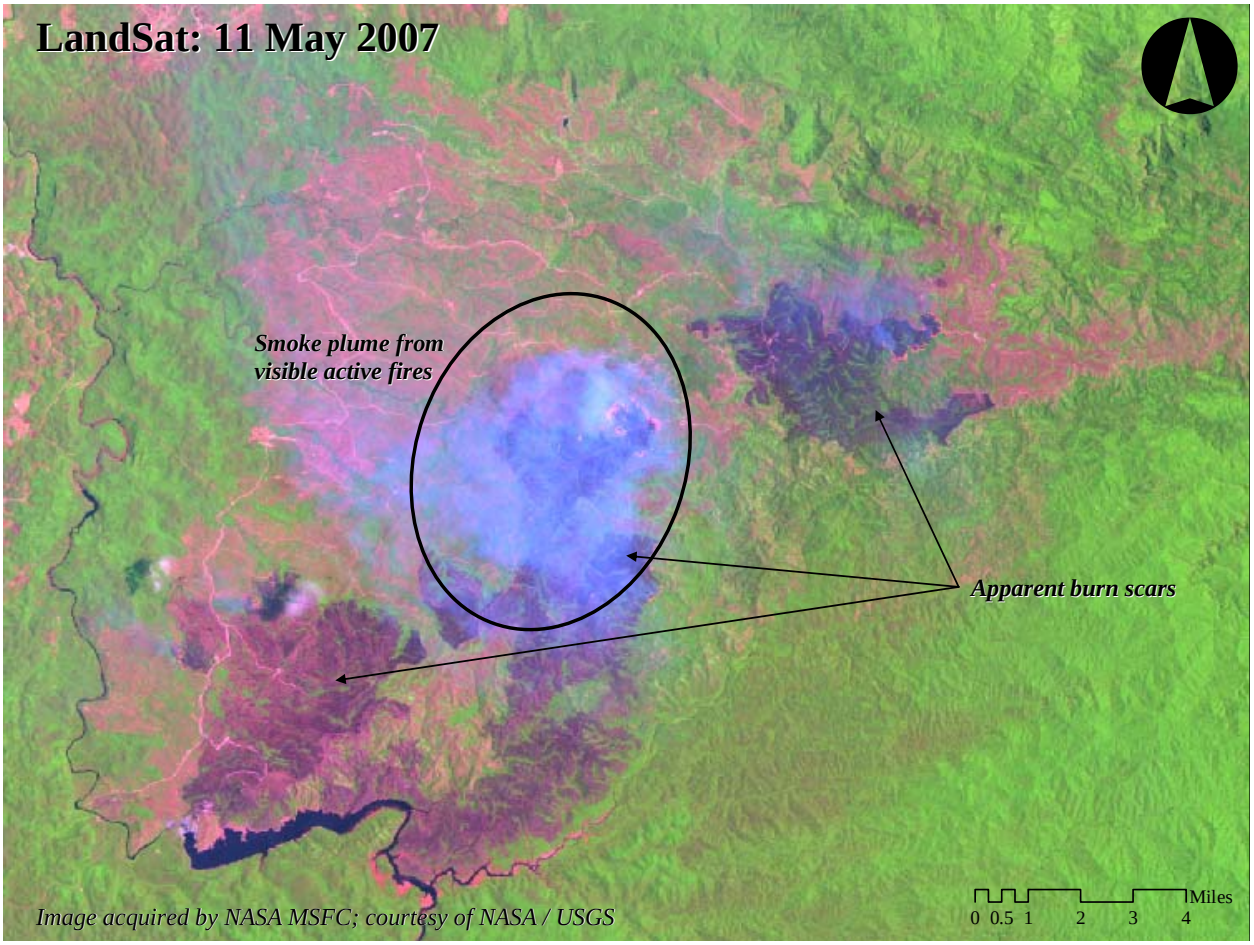

Figure 2: Extent of the Mountain Pine Ridge Fires[4] (*source: CATHALAC / NASA 2007*)

Looking at the data holistically – as presented in **Table 4** – it is, however, noted that overall fires detected in protected areas account, on average, for about a fifth of all fires. MODIS cannot, nevertheless, point out whether those fires are anthropogenic or natural in nature. The year 2005, with its intense drought, saw almost a third of detected fires occurring in protected areas, while 2007 saw almost two fifths of all fires occurring within the bounds of protected areas.

[4] According to the satellite data, the Mountain Pine Ridge fires lasted from April 28 through May 25, 2007 (UMD 2008). **Figure 2** therefore shows the extent of the fires approximately mid-way through the event's duration, and shows the fires actively burning on the morning of May 11, 2007, as well as the smoke produced by the fire. According to the assessment conducted by CATHALAC and NASA (2007) for the Belize Forest Department, some 33,000 acres of the Mountain Pine Ridge Forest Reserve possibly burned.

Table 4: Proportion of Detected Fires within Protected Areas

Year	Fires in Protected Areas	% of Fires in Protected Areas	Total Fires
2003	117	13.8%	**850**
2004	19	10.0%	**190**
2005	126	29.4%	**428**
2006	32	23.0%	**139**
2007	188	39.7%	**473**

Similarly, examination of data also reveals those protected areas which have experienced fires in recent years. Of the nearly one hundred terrestrial protected areas on Belize's mainland, within the past four and a half years, fires have been detected in almost a third of them (twenty-seven individual protected areas), as illustrated in **Table 5**. Over the rough four and a half year period, there are protected areas (particularly forest reserves) which undergo burning on an annual and near-annual basis. These might indicate incursions into protected areas (e.g. land clearing for farming), or perhaps fires which have escaped from nearby agricultural lands, as noted in Meerman & Sabido (2001)'s review of the role of fire on Belize's ecosystems.

In terms of the frequency of fires in protected areas, fires have been detected in five consecutive years in the Deep River Forest Reserve, the two Mango Creek Forest Reserves, Payne's Creek National Park, the Swasey-Bladen Forest Reserve and even the Rio Bravo Conservation & Management Area. In the case of the Rio Bravo, it is not possible at present to determine whether the fires were, for instance, the result of controlled burning. Nevertheless, it should also be of concern that there are other protected areas such as the Chiquibul Forest Reserve, the Columbia River Forest Reserve, Crooked Tree Wildlife Sanctuary, Manatee Forest Reserve, Mountain Pine Ridge Forest Reserve, and the Vaca Forest Reserve in whose bounds fires have been detected roughly every other year. Because each MODIS fire detection may represent sizable fires (up to 100 hectares / 247 acres per detection), these data in the least indicate substantial pressures on the nation's protected areas.

Table 5: Protected Areas within which Fires were detected

Protected Area Name / Type		2003	2004	2005	2006	2007
Aguacaliente	Wildlife Sanctuary	■				
Aguas Turbias	National Park		■			
Caracol	Archaeological Reserve	■		■		■
Chiquibul	Forest Reserve	■		■		■
Chiquibul	National Park	■				■
Columbia River	Forest Reserve	■		■	■	
Community Baboon Sanctuary	Private Reserve	■		■		
Crooked Tree	Wildlife Sanctuary	■	■	■		
Deep River	Forest Reserve	■	■	■	■	■
Fresh Water Creek	Forest Reserve			■		
Grants Works	Forest Reserve	■				
Hidden Valley	Private Reserve					
Manatee	Forest Reserve	■		■		■
Mango Creek (1)	Forest Reserve	■	■	■	■	■
Mango Creek (4)	Forest Reserve	■	■	■	■	■
Maya Mountain	Forest Reserve			■		
Mountain Pine Ridge	Forest Reserve	■		■	■	■
Payne's Creek	National Park	■	■	■	■	■
Pine Hill	Private Reserve				■	
Rio Bravo CMA	Private Reserve	■	■	■	■	■
Runaway Creek	Private Reserve	■				
Sarstoon-Temash	National Park	■				
Sibun	Forest Reserve			■		
Swasey-Bladen	Forest Reserve	■	■	■	■	■
Thousand Foot Falls	Natural Monument					
Vaca	Forest Reserve	■		■	■	■
Total Protected Areas on Fire in Given Year		**19**	**8**	**17**	**10**	**12**

CONCLUSION

In summary, the MODIS-based fire detection data indicate that in recent years, the incidence of fires in Belize has varied from year to year, with over 2,000 fires detected in the past five years. Nevertheless, for a country the size of Belize and with significant forest resources and associated biodiversity, the high proportion of forest fires and fires within specially protected zones should be of concern. Fires have been detected in recent years in nearly a third of Belize's protected areas, and this should be a cause of concern for land managers.

It is nonetheless promising that there exist platforms for the remote monitoring of forest fires and other types of environmental disasters. These include the collaborations between FIRMS, the MODIS Rapid Response System and SERVIR. Belize's Ministry of Natural Resources and the Environment is an important stakeholder in the implementation of SERVIR. In its role as a regional resource, SERVIR was able to provide support to that Ministry in the damage assessment of the huge fires which occurred in Belize's Mountain Pine Ridge area in May 2007.

It is therefore hoped that institutions in Belize will further take advantage of the simple and user-friendly satellite-based tools that are now available for monitoring of the environment – tools which were unavailable only a few years ago prior to the establishment of the Regional Visualization & Monitoring System, SERVIR.[5] These tools provide the perspective of an 'eye in the sky' on the environment that would otherwise be unavailable.

ACKNOWLEDGEMENTS

This report was supported by the U.S. Agency for International Development through Cooperative Agreement No. 596-A-00-06-00099-00. In particular, Mr. Orlando Altamirano and Ms. Carrie Stokes of USAID must be acknowledged. Ms. Diane Davies, the Principal Investigator of FIRMS at the University of Maryland and Ms. Minnie Wong of the University of Maryland must be acknowledged for providing the archived fire detection data utilized in this study. Mr. Jan Meerman, Director of Belize Tropical Forest Studies, provided the land cover data utilized in this assessment. Mr. Edgar Ek of the Land Information Center, Mr. Percival Cho of the Forest Department, and Mr. Ismael Fabro of the Department of the Environment of Belize's Ministry of Natural Resources and the Environment must be acknowledged for their role in supporting the earlier assessment of the impacts of the Mountain Pine Ridge fires. Dr. Melanie McField, Senior Fellow of the World Wildlife Fund, Mrs. Janet Gibson of the Wildlife Conservation Society and Ms. Marydelene Vasquez of the Mesoamerican Barrier Reef Systems Project must also be acknowledged for their input regarding the offshore fires. Mrs. Diane Wade-Moore, Environmental Programme Officer of the United Nations Development Programme's Belize office also provided input. CATHALAC Director Mr. Emilio Sempris, Mr. Francisco Delgado, Ms. Africa Flores and Mr. Eric Anderson of CATHALAC must also be acknowledged for their input. NASA Ecological Forecasting Program Manager Mr. Woody Turner, NASA SERVIR Project Director Mr. Daniel Irwin, Ms. Gwendolyn Artis, Mr. Burgess Howell and Mr. Jason Arnold, all of NASA must also be acknowledged for their support. Mr. Victor Hugo Ramos of Guatemala's CONAP must likewise be acknowledged for his comprehensive fire assessments of the Petén which inspired the present report. A provisional version of this report had originally been developed in June 2007 for Dr. Elma Kay of the University of Belize in support of the national assessment being developed under the framework of the United Nations Environment Programme's Global Environment Assessment, 'GEO: Belize.'

[5] For more information on SERVIR, please visit www.servir.net or contact servir@cathalac.org.

REFERENCES

Barry, P.L. 2003. "Mesoamerica Burning." Science@NASA. National Aeronautics and Space Administration. Washington, DC. Available online: http://science.nasa.gov/headlines/y2003/16may_biocorridors.htm

Centro del Agua del Trópico Húmedo para America Latina y el Caribe (CATHALAC) and National Aeronautics & Space Administration (NASA). 2007. "Preliminary Damage Assessment of the May 2007 Fires in the Mountain Pine Ridge Area, Belize." Assessment developed for the Forest Department of the Ministry of Natural Resources and the Environment of the Government of Belize. 39 pp. Available online: www.servir.net

Lillesand, T.M., Kiefer, R.W., and J.W. Chipman. 2004. Remote Sensing & Image Interpretation. Fifth Edition. Wiley & Sons. 763 pp.

Meerman, J.C. & W. Sabido. 2001. "Central American Ecosystems Map: Belize." Volumes I. Programme for Belize. Belize City, Belize. 28 pp.

Meerman, J.C. 2005. "Belize Ecosystems Map: 2004 update." Data set. National Protected Areas Policy & Systems Plan. Available online: www.biodiversity.bz

National Aeronautics & Space Administration / University of Maryland. 2008. MODIS Hotspot / Active Fire Detections. Data set. MODIS Rapid Response Project, NASA/GSFC [producer], University of Maryland, Fire Information for Resource Management System [distributors]. Available online: http://maps.geog.umd.edu

University of Maryland (UMD). 2007. "Fire Information for Resource Management System: Frequently Asked Questions." Department of Geography, University of Maryland, College Park, Maryland. Available online: http://maps.geog.umd.edu/firms/faq.asp