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# Forest Fires in the Insular Caribbean

This paper presents a summary of the forest fire reports in the insular Caribbean derived from both management reports and an analysis of publicly available Moderate Resolution Imaging Spectrodiometer (MODIS) satellite active fire products from the region. A vast difference between the amount of fires reported by land managers and fire points in the MODIS Fire Information for Resource Management System data can be observed. Future research is recommended to better understand the nature of these differences. While there is a general lack of available statistical data on forest fires in the Caribbean, a few general observations can be made: Forest fires occur mainly in dry forest types (500 to 1000 mm of mean annual rainfall). These are also the areas where most human settlements are located. Lowland high forests and montane forests with higher rainfall (1000 and more mm $y^{-1}$) are less susceptible to forest fire, but they can burn in exceptionally dry years. Most of the dry forest ecosystems in the Caribbean can be considered to be fire-sensitive ecosystems, while the pine forests in the Caribbean (Cuba, Dominican Republic, and the Bahamas) are maintained by wildfires. In fire-sensitive ecosystems, uncontrolled burning often encourages the spread of alien invasive species. A Caribbean Fire Management Cooperation Strategy was developed between 2005 and 2006 under auspices of the Food and Agriculture Organization of the United Nations. This regional strategy aims to strengthen Caribbean fire management networking by encouraging closer collaboration among countries with similar ecological conditions. The strategy for the Caribbean identifies a number of research, training, and management activities to improve wildfire management capacity in the Caribbean.

## INTRODUCTION

Global estimates of active vegetation fires indicate that over 70% of these occur in the tropics (1, 2). Unintended fires are a major cause of deforestation. Anthropogenic activities are creating new fire-prone ecosystems in the tropics through the alteration of vegetation cover by logging, burning, and development (3–5). These new ecosystems can potentially differ substantially in carbon budgets (6, 7), nutrient cycling (4, 8), and fuel and habitat characteristics (5, 9, 10). Within the context of this report, the Caribbean is understood to be the islands of the Caribbean, including the Bahamas and excluding the coastal areas of South and Central America. The Caribbean region lags behind other areas in the United States in terms of fire prediction, monitoring, education, prevention, and analysis of the effects of fire on ecosystems and society. In the case of Puerto Rico, historical and paleoecological evidence suggests that not only is fire frequency increasing, but fires are beginning to occur in areas of humid forests never known to have burned before (11). Slight climatic warming and drying has the potential to increase fire frequency and fire-related economic and ecological effects in the Caribbean. Additionally, the rapid pace of development tends to create more wildland-urban interfaces, increasing the costs of fire control and management, and increasing fire-related damages (12). Management and research efforts are needed to keep pace with these changes in order to provide sound information for land management decisions.

This review analyzes the information on wildfire occurrence, causes, and effects in the insular Caribbean. The data were gathered from the available reports prepared by governmental agencies and individual researchers, and from publicly available global satellite data being regularly acquired and analyzed on fire occurrences. Most of the country reports were presented at the 12th Caribbean Foresters Meeting, held on June 2004 at the International Institute of Tropical Forestry (IITF), San Juan, Puerto Rico (13–15). The management reports are difficult to analyze because, in most instances, they were written by forest managers and practitioners with limited experience in forest fire ecology. In many cases, the reports document how the fire problem is perceived, but they do not necessarily reflect the fire ecology of the forest areas.

Reports about wildland and forest fires are not consistently available for all island states in the Caribbean. These reports do not correlate with information derived from satellite analysis. However, while there appears to be a general lack of consistent statistical data on forest fires in the Caribbean, a few general observations can be made. We also present a summary of causes for wildfires in the region as they are understood and perceived by the forest managers. Two tables are presented: fire occurrences for the insular Caribbean from recent management reports and global Moderate Resolution Imaging Spectroradiometer (MODIS) active fire products.

## STUDY AREA

The insular Caribbean region includes some 22 island states ranging in size from 110 $km^2$ to 110 000 $km^2$ (Fig. 1). Although mostly small in comparison with Mesoamerican mainland states, their forest resources play an important role in their economies, and the effect of fires can be significant. In common with the mainland, island climate is determined by the movement of the Intertropical Convergence Zone, prevailing trade winds, and topography. Most islands tend to have drier western areas under the rain shadow of a central land mass. Mountainous areas are wetter than lowlands due to orographic effects. As rainfall diminishes, the dry season becomes more severe, and fire hazards increase. In the event of a hurricane, the fire hazard increases even further due to the windblown trees and branches that build up as fuel load.

The insular Caribbean contains approximately 11 424 544 ha of forested lands, which can be subdivided into 5 328 085 ha (47%) of dry forest, 3 593 830 ha (32%) of moist forest, 1 417 606 ha (12%) of pine forest, 730 356 ha (6%) of wet forest, and 354 665 ha (3%) of shrubland (16). Forest fires occur mainly in dry forest types (500–1000 mm mean annual rainfall), where most human settlements are located, and in the dry seasons (typically January to June, but with variation often bimodal) (17–22). Fire-maintained pine forests have recurring fires defined by specific fire regimes (characteristics that define fire behavior in an ecosystem, e.g., intensity, frequency, burn severity, seasonality, and pattern of burning) that help to maintain the forest structure and species composition (23, 24). Lowland moist forests and montane forests with higher rainfall (1000 and more mm $y^{-1}$) are less susceptible to fires, but they can burn in exceptionally dry years.

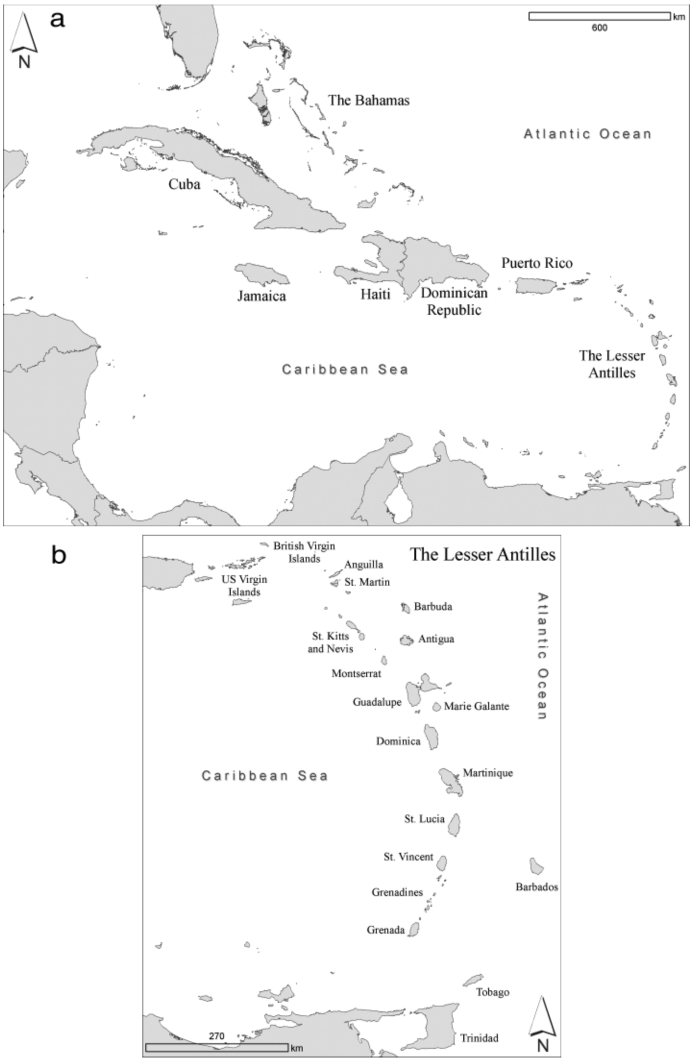


**Figure 1. Map of the insular Caribbean.**

Vegetation types in the islands respond differently to wildfires. Following the classification as presented by Myers (23), the Caribbean shows examples of four basic categories:

*i)* Fire-dependent vegetation types: pine forests, palm forests and savannas, and coastal and freshwater marshlands.
*ii)* Fire-independent vegetation types: undisturbed montane forests, humid montane forests at higher elevations, and mangrove forests in tidal zones.
*iii)* Vegetation sensitive to wildfires and prone to fire damage: lowland evergreen and semi-evergreen forests, especially when they are fragmented and altered through logging and other forest uses, dry evergreen coppice forests in the Bahamas, flooded forests in Guadeloupe under exceptional dry weather conditions, dry deciduous forests, mangrove forests in transition to inland forest, and disturbed montane forests.
*iv)* Fire-influenced vegetation: non-native grasslands and bamboo forests (mainly on the Lesser Antilles), and forest plantations of introduced species, such as Caribbean pine and teak.

Based on these categories and the narrative description provided in the management reports, the greatest proportion of land cover in the Caribbean appears to belong to fire-sensitive ecosystems, and the most prevalent fire-dependent ecosystems are the pine forests.

## FIRE OCCURRENCES

We used two distinct data sets to compile information on fire occurrences: management reports and research publications, wherever they were available; and publicly available MODIS active fire products. The information from management reports is fairly straightforward, though often anecdotal, or compiled from accounts by land managers or fire-control agencies. The MODIS information is quite a bit more technical, and some detail is presented here regarding its acquisition and interpretation.

### Management Reports

Only a few countries are in a position to present reliable forest fire statistics indicating the number of forest fires or the area affected (Table 1). Six countries have published statistics for any year, and the majority of these were reported at the 12th Caribbean Foresters Meeting, held at the IITF in 2004. There is also information for one of the countries in an unpublished report with data obtained from a local fire service internal report (30), which demonstrates that while some governments are recording wildland fire incidences in conjunction with structural fires, the data are not being published or are not easily accessible.

### MODIS Active Fire Products

*Aqua* and *Terra* MODIS active fire products provide a resourceful tool for identifying global wildland fires (31). These fire products recognize active fires and other thermal anomalies, such as lava from volcanoes and gas flares, by identifying bright or saturated pixels, on MODIS satellite images, where these anomalies are occurring.

MODIS is an optical sensor onboard the *Terra* and *Aqua* satellites. The satellites were launched on 18 December 1999 and 4 May 2002, respectively. *Terra* travels from north to south, crossing the equator in the morning, while *Aqua* travels from south to north, crossing the equator in the afternoon. This allows for the collection of the entire surface of Earth every 1 to 2 d (32). The MODIS sensor collects data in 36 spectral bands with a swath of 2330 km (across track) by 10 km (along track) and has a spatial resolution from 250 m to 1000 m (1 km) dependent on the band. Bands 1 and 2 (red and infrared) offer a spatial resolution of 250 m, bands 3 to 7 offer a spatial resolution of 500 m, and the remaining bands 8–36 collect imagery at 1 km spatial resolution.

The MODIS active fire products were developed using active fire detection algorithms based on heritage algorithms previously developed for Advanced Very High-Resolution Radiometer and Tropical Rainfall Measuring Mission–Visible and Infrared Scanner (33). The algorithm is constantly being improved to account for limitations of the current one. Each new version is called a collection.

The algorithm identifies anomalously bright pixels to create an active fire mask. To avoid false positives, the algorithm identifies and eliminates pixels that are naturally saturated, such as highly reflective surfaces, or pixels that are located along land-cover boundaries, which can cause sharp radiometric transitions (33). The algorithm also uses the surrounding pixels of a bright pixel to determine a thermal background that accounts for variability of surface temperature and reflection by sunlight (34).

One condition that tends to create false positive fire pixels is the coastal false alarm rejection. The difference in temperature between water pixels and land pixels causes a sharp radiometric transition that can confuse the algorithm. To prevent this problem, a water mask is used to remove water pixels from the

**Table 1. Land area of countries and available data on wildfire occurrence.**

| Country/territory | Land area ($km^2$) | Number of wildfires average for period, or for specified year | Total area affected (ha $y^{-1}$) | Source |
|---|---|---|---|---|
| Antigua and Barbuda | 440 | No data | No data | |
| Bahamas | 10 010 | No data | No data | |
| Barbados* | 430 | 1338 (2003) | No data | 17 |
| British Virgin Islands | 150 | No data | No data | |
| Cayman Islands | 260 | No data | No data | |
| Cuba | 109 820 | 325 $yr^{-1}$ (1984–1998) | 4878 | 25, 26 |
| | | 373 $yr^{-1}$ (2000–2003) | 12 964 | |
| Dominica | 750 | 50 (1986) to 222 (2001) | No data | 27 |
| Dominican Republic | 48 380 | 141 $yr^{-1}$ (2000–2003) | 4660 | 28 |
| Grenada | 340 | 100 $yr^{-1}$ | No data | 18 |
| Guadeloupe | 1690 | No data | No data | |
| Haiti | 27 560 | No data | No data | |
| Jamaica | 10 830 | No data | No data | |
| Martinique | 1070 | No data | No data | |
| Montserrat | 110 | No data | No data | |
| Netherlands Antilles | 800 | No data | No data | |
| Puerto Rico | 8870 | 2975 (1999) | No data | 25 |
| St. Kitts and Nevis | 360 | No data | No data | |
| St. Lucia | 610 | 22 (2004) to 200 (2001) | No data | 21 |
| St. Vincent and The Grenadines | 390 | No data | No data | |
| Trinidad and Tobago | 5130 | 315 $yr^{-1}$ (1987–2003) | 4082 | 29 |
| Total area | 228 000 | | | |

* Data presented for Barbados appear to be questionable—the number presented seems to reflect more the total number of fire incidences than the number of wildland fires.

image before it is analyzed. However, the land/sea mask for collections 3 and 4 contains significant errors (33). The coastal false alarm rejection is a problem that could affect the insular Caribbean region and should be taken into account by fire managers when using the MODIS active fire products. Another consideration for forest managers in the region is the cloud cover. As a tropical region, cloud cover in the Caribbean is a serious problem when doing remote-sensing analysis with optical satellite imagery (35–37). Cloud cover and cloud shadow need to be masked (removed) from the satellite images prior to processing. This means that a portion of land is not visible in the image and cannot be used, which increases the possibility of wildland fires that remain unmapped. Also, short-duration fires that occur in between satellite passes will go undetected.

The MODIS fire products are provided at 1 $km^2$ spatial resolution; an active fire can be located anywhere within that pixel. Giglio et al. (33) documented previous accuracy assessments for the algorithm. In one of the performance tests, collection 4 data show that for all biomes, under ideal atmospheric conditions, relatively homogeneous terrain, and with images taken at or near nadir, there is a 50% chance of detecting flaming fires as small as 100 $m^2$. For smoldering fires, the area needs to be from 10 to 20 times larger for a 50% probability of detection. Earlier versions of the algorithm need much larger areas to successfully detect fires. Given the small size of some of the islands in the Caribbean region, it is important to take into consideration the possibility that most small fires will not be detected, even with the best available version of the algorithm.

Given these uncertainties, confidence values from zero to 100 are assigned to each fire pixel to compensate for the complexity of the process and limitations of the algorithm. The confidence values are based on various factors, including brightness, pixel values based on operational experience, and proximity to cloud and water pixels, which increase the likelihood of false positives (33).

To get a general idea of fire activity as detected by the MODIS fire algorithm in the insular Caribbean region, archived data from 2000 to mid-December 2007 were obtained from the Fire Information for Resource Management System (FIRMS) run by the University of Maryland (38). The archived data presently available were processed using versions 3 and 4 of the algorithm. The data were downloadable as a geographic information system (GIS) vector point layer, where each point represents the middle of an active fire pixel. Since the orbit of the *Terra* and *Aqua* satellites takes them around the planet every 1 to 2 d, it is possible that multiple fire points are associated with a fire that has been burning over a long period of time. This would only be the case with this type of data set where individual observations have been joined together.

A simplified version (Fig. 2) of the terrestrial targets map prepared by The Nature Conservancy (16) was used to analyze the FIRMS data in relation to forest type. The original map, developed as part of the Caribbean Decision Support System, classifies the insular Caribbean landscape into 55 biodiversity elements. These elements, also called targets, were produced by combining geospatial information on climate, geology, and land cover. The map was simplified in the GIS and Remote Sensing Laboratory of the IITF into six basic forest types: dry forest, moist forest, pine forest, wet forest, shrubland, and nonforest.

Table 2 shows the total fire points with a confidence level of 50 or more by basic forest types and yearly average per country in the insular Caribbean. Most fire points were detected on the biggest islands (Cuba and Hispaniola), and most detected fires occurred in nonforest cover types, most likely grassland and agricultural lands.

When comparing the two tables, the available management statistics and the MODIS FIRMS active fire data, a few observations can be made:

*i)* MODIS fire points with a confidence level of 50 or more diverge widely from the amount of fires reported in management reports.
*ii)* In larger islands such as Cuba and the Dominican Republic, there are excessively more fire points observed within the MODIS fire data than fires in the management reports.
*iii)* The opposite is true of smaller islands, where MODIS observation points are extremely low in comparison with the amount of fires in the management reports.

This over- and underestimation of fires by the FIRMS satellite observations could be explained by the fire size. If the fires cover a wider ground extent on bigger islands, more pixels

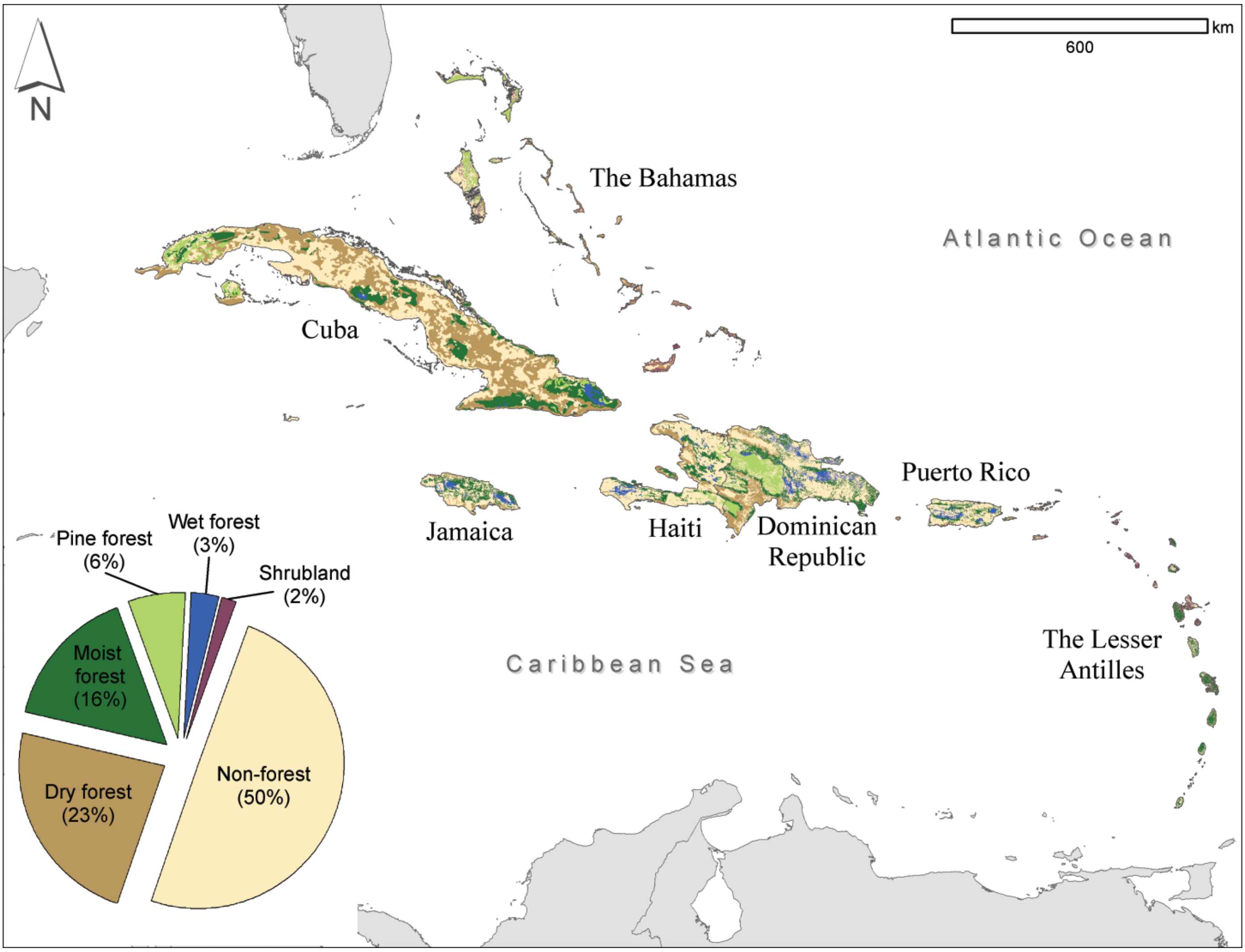


**Figure 2. Simplified vegetation map of the insular Caribbean. Spatial data were modified from Huggins et al. (16).**

would be detected as part of one fire. Given that the data set obtained identifies the amount of bright pixels and not individual fires, these larger fires would appear here as multiple fire points. Smaller islands fires would presumably cover less terrain, and therefore many of the smaller fires in the country would go undetected by the satellite products. However, there might be other factors (i.e., confidence level, accuracy of management reports, limitations of the FIRMS algorithm)

**Table 2. MODIS active fire points for the insular Caribbean region from 2000 to mid-December 2007 (33) giving total fire observations with a confidence value of 50 or more by forest type. Although some data are missing for some years, an average per year was calculated to facilitate comparison with the management report data that are available.**

| Country | Nonforest | Dry forest | Moist forest | Pine forest | Wet forest | Shrubland | Average per year |
|---|---|---|---|---|---|---|---|
| Antigua and Barbuda | 5 | | 3 | | | | 1 |
| Bahamas | 130 | 60 | | 739 | | 55 | 141 |
| Barbados | 13 | | 2 | | | 22 | 5.3 |
| British Virgin Islands | | | | | | | 0 |
| Cayman Islands | 1 | | | | | | <1 |
| Cuba | 15 502 | 9200 | 1319 | 468 | 10 | | 3786 |
| Dominica | | | | | | | 0 |
| Dominican Republic | 2023 | 376 | 2372 | 1052 | 127 | | 850 |
| Grenada | | | 1 | | | | <1 |
| Guadeloupe | 12 | | | | | 3 | 2 |
| Haiti | 359 | 182 | 223 | 59 | 33 | | 122 |
| Jamaica | 488 | 40 | 26 | | 1 | | 79 |
| Martinique | 1 | | 2 | | | | <1 |
| Montserrat | 705 | | | | | 11 | 102 |
| Netherlands Antilles | 78 | | | | | | 11 |
| Puerto Rico | 193 | 9 | 9 | | 1 | | 30 |
| St. Kitts and Nevis | 4 | | | | | 4 | 1 |
| St. Lucia | 2 | 5 | 1 | | | | 1 |
| St. Vincent and The Grenadines | | | | | | | 0 |
| Trinidad and Tobago | 355 | | | | | | 51 |
| Total | 19 879 | 9875 | 3958 | 2318 | 172 | 95 | 5185 |

affecting the results, and more research is needed to clearly state and explain the differences between these two data sets and develop steps that will allow both data sets to be compared and integrated in order to help managers.

The individual fire masks are also available from FIRMS and the National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) Data Gateway. The fire masks are raster images showing the pixels from the satellite imagery that were identified by the algorithm as active fires. These masks contain a single satellite observation and could be useful to study the behavior of fires over a few satellite observations or to validate the MODIS active fire products in the region (39, 40).

## CAUSES AND EFFECTS OF WILDFIRE IN THE CARIBBEAN

### Causes

For areas where we have information, wildfires are nearly all associated with human activity (30) and occur mainly in dry forest and grassland types during the dry seasons (17). The risk of fire increases with logging since reduction of the upper canopy triggers development of scrub and brush undergrowth, which dries more quickly and is easier to ignite than the original understory (41).

Increasing population pressure in the Caribbean has led to a reduction of forested areas where fire is used as a tool to aid the clearance of land (23). In addition, fragmentation, disturbance, agricultural abandonment, and forest regeneration promote grass and shrubland communities that are more susceptible to fire. Almost all fires in broadleaf forests seem to be man-made. Natural causes such as lightning appear to be most common in areas with native pine forests. Spontaneous combustion sources, for example, glass bottles that can act like a magnifying glass to ignite vegetation and discarded cigarettes thrown from passing car, were mentioned as possible ignition sources, although there was little confirmation through direct observation.

The following main causes are summarized from the country reports (13):

*i)* In rural areas, fires are used to clear land for agriculture, to improve pasture for livestock grazing, for settlement, and to facilitate hunting by clearing the area and driving out animals. When such fires get out of control, adjacent forest is burned. There is less motivation to control the spreading of fires if neighboring lands are state-owned or the land ownership is uncertain.

*ii)* In areas close to urban settlements, most community members mention campfires and playing children as common causes.

*iii)* Many reports mention the use of fire as a common form of protest against individuals or the government.

*iv)* Volcanic action is being reported as a rare but catastrophic cause of fires, and it may result in complete incineration of large areas.

*v)* In addition to these, many reports mention fire out of malicious intent. Without being able to determine rational reasons, those who prepared the reports believed that the fires were started as a form of entertainment or unspecific protest. In most cases, it appears to affect forests located on public land and often out of sight from the eyes of society. These fires are often described as malicious acts or antisocial behavior, but they appear to have a cultural or social dimension that merits some in-depth research. For example, the island of Guadeloupe reported only two to three forest fires per decade, while other Caribbean islands with similar vegetation types and population densities reported hundreds of forest fire incidents per year.

### Effects

Forest fires have many effects, both at social and ecological levels. They can be beneficial for fire-dependent species in forests where fire occurs naturally (23, 24), and for invasive grasses that serve as grazing lands for cattle (42–44); they can also be highly damaging to the forest structure and composition in forests where fires are naturally rare (23), and in fire-dependent forests where the fire regime has been altered to have more intense and/or frequent fires than the native vegetation is accustomed to (24, 42, 43, 45).

One particular effect that is important to managers in the insular Caribbean is the spreading of alien and invasive grasses because of uncontrolled wildfire. An example of this is the proliferation of Lemon grass (*Cymbopogon citrates*), introduced to Antigua in the 1940s for soil conservation purposes. The grass is set afire almost every year in the dry season, most likely by landless cattle farmers (46). The younger sprouts of the grass provide a better food for the roaming cattle and small ruminants than the dry grass. The grass survives the fire and is very well-adapted to frequent burning. As the fire burns toward the adjacent dry and low scrub forest, it kills trees approximately 10 to 20 m along the edge between bush and pasture. This belt is subsequently invaded by Lemon grass. By this slow succession, approximately 1200 ha of the island are now covered with a thick carpet of Lemon grass.

In Trinidad and the leeward side of other southern Caribbean islands, the African Guinea Elephant grass (*Pennisetum purpureum*) is altering the fire regime of pine forests. As in Antigua, the grass was introduced for soil conservation purposes and thrives on burned sites. The grass tends to invade pine plantations, and after every burn, it appears to regrow more vigorously, accumulating more fuel and burning hotter in the following year. Caribbean pine, although a fire-dependant species, becomes increasingly affected, dies back, and the forest floor receives more light, which further encourages the development of the grass and fires. The high frequency and intensity of the fires due to the amount of fuels on the ground kill the pine saplings, disrupting the regeneration process (40). The result of this succession is an extended carpet of tall grass expanding from year to year.

The causes and frequency of forest fires are closely related to human livelihood. In rural communities, escaped agricultural burnings are the main reason for forest fires. Generally, intentional bush fires are more likely to go undetected if neighboring lands are either state-owned or the land ownership is uncertain. In urban and more affluent regions, wildland fires due to "malicious acts" are mentioned more frequently by land managers as the cause for fires.

### Management

*Prevention and Extinction.* The smaller islands rely on basic methods of prevention, detection, and control. Unless the fire threatens human settlements, it is often left to burn out. On the larger islands (Cuba, Jamaica, and Hispaniola), techniques are being developed to increase awareness, enforce legislation, and improve techniques in control of existing fire. Most countries have ground patrols, and some have a system of watchtowers. Fires are mainly extinguished directly by hand, aided with indirect techniques such as backfiring and the use of fire traces. The use of wildland fire tenders is limited to accessible areas close to residential areas.

*Institutions, Responsibilities, and Roles*. The responsibilities for wildfire management in the Caribbean countries are shared by several institutions. A national fire service is typically responsible for controlling fires that pose a hazard to people, with priority given to urban areas. A forestry authority is typically responsible for fire control in forested areas under its jurisdiction. Additionally, environmental and/or conservation agencies may be responsible for fire control at special reserves or parks; the national defense force may also be concerned with providing support where the capacity of the other institutions is limited.

*Recommendations for National Fire Management Programs*. From the countries' reports, and the summary of the working group presentations at the 12th Caribbean Foresters Meeting in 2004 in Puerto Rico, documented in the proceedings (13), the following recommendations for the preparation of a national wildland fire strategy can be summarized:

*i)* Increase public awareness about fire ecology and potential damages of uncontrolled forest fires. Depending on the ecological environment, there is a need to distinguish between good and damaging fires.
*ii)* Increase participation of stakeholders in the prevention and management of wildland fires.
*iii)* Improve documentation and recording of fire events to improve the understanding of forest fire and to research strategies for fire management.
*iv)* Increase law enforcement. Many countries have legislation that governs the use of fire, mainly for agriculture. The laws define techniques for fire prevention, institutional arrangements to obtain fire permits, as well as penalties, but the level of enforcement is generally low, and the implementation of some laws is controversial.
*v)* Revise legislation. Most of the fire-related legislation was written to regulate slash and burn agriculture, and new aspects of forest fire management need to be included.
*vi)* Encourage interagency collaboration. Increased collaboration among responsible authorities would increase the effectiveness of fire control and prevention. In order to facilitate the cooperation, standardized protocols and operational procedures should be developed.
*vii)* Establish clear and transparent institutional responsibilities for government agencies to define who is responsible for fire prevention, monitoring, and suppression.

*Wildfire Management and Cooperation Strategy for the Caribbean*. Under the framework of the Latin American and Caribbean Forestry Commission and in connection with the 23rd Session of the Regional Forestry Commission, the Food and Agriculture Organization of the United Nations (FAO) organized the first Pan-American Conference on Wildland Fire, held in Costa Rica in October 2004. As a follow up to this conference, FAO supported a Technical Cooperation Project (TCP/RLA/3010) to develop a cooperation strategy for fire management. The general objective of the project was to facilitate closer collaboration among the member countries of the Forestry Commission.

The Caribbean Fire Management Cooperation Strategy is part of the regional strategy, but it is more specifically geared toward the Caribbean subgroup of the Commission. The Caribbean subgroup embraces all the Caribbean Island states plus Belize, Guyana, and Suriname. The Caribbean subgroup of the Latin American and Caribbean Forestry Commission is the body responsible for the implementation of the strategy with secretarial support from FAO.

The Caribbean Fire Management Cooperation Strategy identified a number of program areas to facilitate cooperation among participating countries. These are: *i)* harmonization of wildfire-related terminology; *ii)* development of national forest fire management strategies; *iii)* standardization of a forest fire record system; *iv)* development of early warning systems; *v)* promotion of an exchange of experts in fire control and suppression; *vi)* training, including a general course in fire management and suppression, introduction to wildland fire ecology with different approaches to fire management, community-based forest fire management, preparation and implementation of controlled burning, and preparation of a basic health and safety training module for fire fighters; and *vii)* research, including research into the social dimension of forest fires and exploration of possibilities for partnerships to facilitate intraregional research cooperation.

In the Caribbean subgroup of the Latin American and Caribbean Forestry Commission, the countries are represented by their respective directors of the national forest authorities. As such, the Caribbean subgroup does not have the capacity to conduct research. However, the subgroup provides a forum to organize political support, to develop a research agenda, and to implement research recommendations to improve forest fire management in the Caribbean.

## CONCLUSIONS

Regardless of the type of vegetation in a given forest, be it fire sensitive, fire dependent, or any of the others, the reality is that the natural fire regime of every forest is being altered by anthropogenic activity through the introduction of more resilient alien species or the vast array of fire practices that are being used around and within our grasslands and forests. Wildland fires need to be managed, and each manager needs to take into account the specific needs of their region. In order to create a comprehensive management plan at a regional and local level, a thorough understanding of fire behavior in the Caribbean is needed, and for this, consistent and comprehensive wildland fire statistics are important.

Currently, only a few countries are in the position to present reliable wildland fire statistics indicating the number of forest fires or the area affected, and the ones that do are not consistent with each other. The lack of availability and uniformity of fire data limits our understanding of the importance of wildland fires across the Caribbean. The issue of standardized wildland fire reporting should be addressed at the national and regional level. An appropriate forum to facilitate the standardization of reporting procedures is the Caribbean subgroup of the Latin American and Caribbean Forestry Commission facilitated by FAO.

There is no mention of the MODIS active fire products in management reports for the insular Caribbean, which gives the impression that the data are currently not being used. The MODIS active fire products provide fire managers and fire ecologists with tools to observe, detect, and quantify large fires across the globe. Although there are some current limitations with the MODIS active fire products, new technologies such as MODIS could be a cost-effective way of improving fire management, especially in the larger islands of the insular Caribbean, by adding, for example, another method of mapping large wildland fires and detecting spatial patterns. Additional setbacks exist with the multidate archived data because they do not account for multiple observations of the same fire. However, the individual fire masks are also available through NASA EOS Data Gateway and the University of Maryland, which can be used for future smaller-scale studies. Also, a new version of the algorithm has already been developed that will hopefully address some of the limitations of earlier versions. Further research is needed to validate the data in this region and explain the apparent over- and underestimation of fire observations documented here.

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