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THE GLOBAL FIRE INITIATIVE

Fire Management Assessment of the

Highland Ecosystems of the Dominican Republic

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Cover Photo: View of Hispaniolan pine forest in Juan B. Pérez Rancier National Park, Dominican Republic.

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1 introduction

Purpose

During 7–14 July 2003, a team of fire management and fire ecology experts visited Madre de las Aguas Conservation Area (Ebano Verde Scientific Reserve, Juan B. Pérez Rancier National Park) and Sierra de Bahoruco National Park to assess the fire issues facing the Hispaniolan pine forest ecosystem, and associated savannas and cloud forests, in the Dominican Republic. The objectives for the assessment were:

(1) Gather information on the fire management needs and issues facing the ecosystems of the central highlands and Sierra de Bahoruco of the Dominican Republic.

(2) Assess current fire regimes and evaluate evidence of fire effects. Discuss whether the fire regimes are significantly altered from what is believed to be appropriate to maintain the ecological integrity and dynamics of these ecosystems.

(3) Develop a list of research needs and information gaps.

(4) Evaluate fire management planning and training needs.

(5) Identify other threats related to fire, e.g., invasive species and land use issues.

Team Members

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- Dr. David Mehlman, TNC Director of Migratory Bird Program, New Mexico, USA
- Dr. Ronald Myers, TNC Senior Fire Ecologist, Florida, USA
- Dr. Joseph O'Brien, USDA Forest Service, Research Ecologist, Georgia, USA

The team was accompanied by

- Andrés Ferrer, TNC Dominican Republic Country Program Director
- Carlos Garcia, Executive Director, Fundación Moscoso Puello (FMP)
- Elvis Cuevas, Ornithologist, FMP
- Pedro Rodríguez, Bird Conservation Program Director, FMP
- Eladio Fernandez, President, Hispanola Ornithological Society
- Alberto Sánchez, United Nations Development Programmes, Santo Domingo
- Williams Hernandez Regalado, Agroforestry Engineer, Secretary of the Environment & Natural Resources
- Rafael David Espinal Montero, Agroforestry Engineer, Secretary of the Environment & Natural Resources

The Team also met with Odalis Perez (USAID Environmental Officer), Ing. Roberto Sanchez (Director of Protected Areas), and Ing. Maximo Aquino (Undersecretary of Forest Resources).

(6) Identify projects and programs that could be developed and implemented by The Nature Conservancy, its NGO and bilateral partners, and the Dominican government to reduce the threat of altered fire regimes in the Central Highlands.

(7) Identify land management staff who could participate in training courses, exchanges, and mentoring programs.

(8) Provide fire managers and conservation specialists in the Dominican Republic with recommendations on strategy and actions to reduce the threat of altered fire regimes.

(9) Propose and discuss the possibility of holding a Fire Learning Network workshop in the Dominican Republic on fire in highland pine and savanna ecosystems in the Latin America.

This assessment was conducted as part of the Latin American & Caribbean Fire Learning Network (LACFLN) funded through The Nature Conservancy by the USDA Forest Service International Programs.

Focus & Constraints

Information in this report is based on observations by, and discussion between, the Assessment Team and its Dominican hosts during four days in the field and two days of meetings with TNC staff and their NGO and government partners. The Team's observations in Madre de las Aguas (Cordillera Central) were limited to sites (1) along the main road through Juan B. Pérez Rancier National Park (also known as Valle Nuevo) from El Convento to San José de Ocoa, (2) in the Cañada de La Zanja near the Dr. Rafael Moscoso Puello Research Station, and (3) along the road to the top of Alto Bandera.

In Bahoruco National Park, the Team observed sites (1) along the road from Puerto Escondido to El Aguacate, then (2) south along the International Highway (on the Haitian border), followed by (3) stops along the Alcoa Road ending at the visitor center at Hoyo de Pelempito.

This itinerary provided broad transects through:
(1) the Hispaniolan pine forests and savannas in the Cordillera Central,
(2) cloud forests at the Ebano Verde Scientific Reserve and at a site in Valle Nuevo called Jurassic Park, and
(3) pine forests and hardwood forests on limestone substrates in the Sierra de Bahoruco.

These areas by no means afforded the Team the opportunity to observe the full range of forest conditions nor the effects of all the recent fires in the Hispaniolan pine forests and related ecosystems. The Team was also limited in its observations of the forest/agricultural interface where many fires that affect the forests originate, although they were able to get good views of the differences and effects along the border with Haiti and Sierra de Bahoruco National Park. We were also unable to observe and evaluate some key vegetation types such as the Manaclares—a wet tropical forest with abundant palm, *Prestoea montana*.

Furthermore, the interpretations presented in this report are largely inferences based on the Team's keen observations, professional expertise and experience, and drawn from scientific studies in similar ecosystems elsewhere in the world. The validity of these interpretations will have to await more detailed scientific studies and management experience.

There is a research team from the University of Tennessee currently working on post-fire vegetation dynamics, dendrochronology, vegetation history, and fire history in the Hispaniolan pine forests of the Cordillera

Central. There is another research team from Cornell University looking at vegetation-environmental relationships, including fire, in the distribution and structure of montane types in the Cordillera Central. The Cornell project is funded by The Nature Conservancy through the Mellon Foundation. The references from these projects, Horn et al. (2000), Horn et al. (2001), and Sherman et al. (2003), provided the Team with research results and background information in the Cordillera Central. Background on the floristics of the pinelands of the Sierra de Bahoruco is found in Fisher-Meerow & Judd (1989). Latta et al. (2000) discuss fire issues in the Sierra de Bahoruco.

2 fire & vegetation

There are three main vegetation types within the Juan B. Pérez Rancier National Park and in Sierra de Bahoruco National Park that are affected by fire: (1) Hispaniolan pine forests, woodlands and savannas, (2) mixed pine-broadleaved forests, and (3) cloud forests. The pine forests are dependent on fire; the mixed pine-broadleaved forest is an artifact of a changing fire regime; the cloud forest is fire-sensitive (Figure 1).

Pinus occidentalis Forest, Woodland & Savanna Ecosystems

Pinus occidentalis, known as Hispaniolan pine or West Indian pine, is considered endemic to the island of Hispaniola. It once covered an estimated 3 million ha, but has been depleted to perhaps less than five percent of that area (Darrow & Zanoni, 1990). Virtually all of the remaining forests are in the Dominican Republic. The species occurs at elevations of 200–3000 m in the Cordillera Central and in the Sierra de Bahoruco. The more extensive and pure stands occur at 900–2700 m. The soils in the Cordillera Central are nutrient-poor, shallow acidic clays mixed with igneous rock; in the Sierra de Bahoruco the soils are derived from limestone. Rainfall ranges from 1200–2300 mm, with a three- to five-month dry season during the winter when there are occasional frosts above 1600 m.

Because of the lack of marked seasonality in the tropics, high-altitude environments have

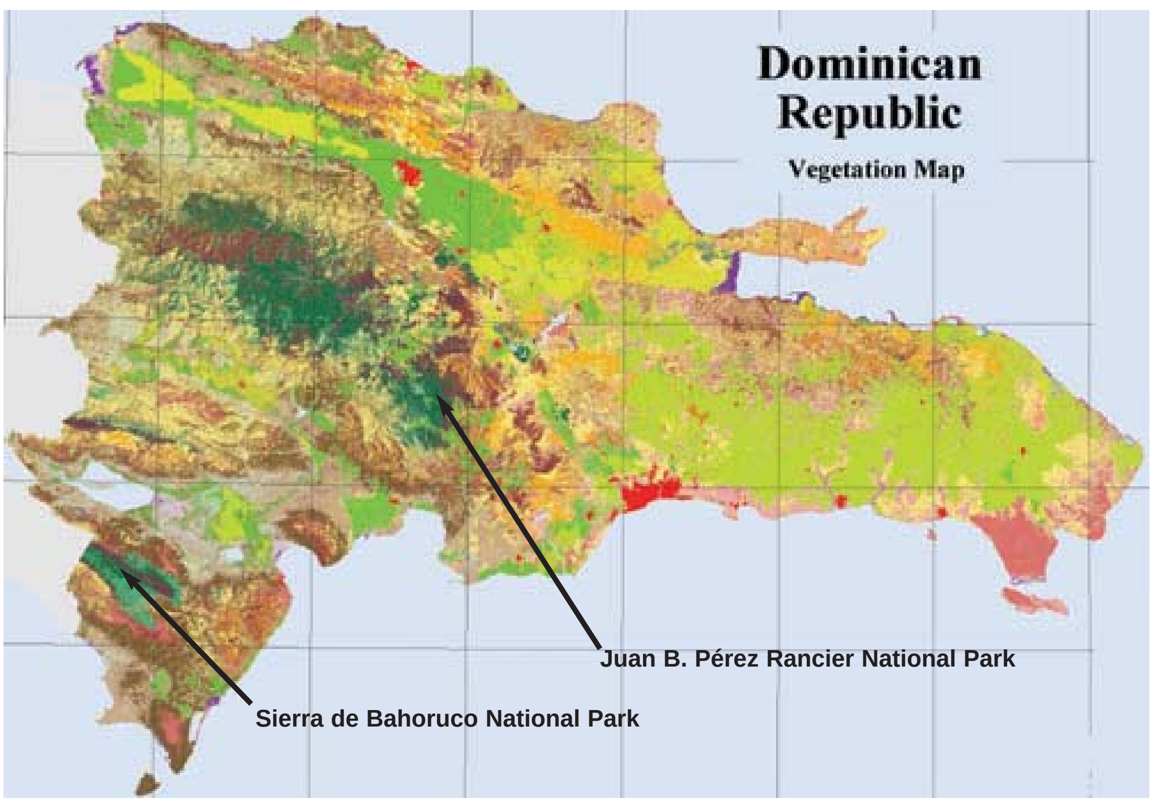

Figure 1. Locations of Juan B. Pérez Rancier and Sierra de Bahoruco national parks and pine forests. Dark green = Montane Pine Forest & Mixed Pine-Broadleaved Forest. Aqua green = Pine Woodland. Purple = Montane Rainforest & Cloud Forest.

relatively cold nighttime temperatures year-round. This contrasts with highland environments at higher latitudes where there is marked seasonality. The cold environment limits growth rates in these pineland ecosystems compared to pinelands at the same latitude but at lower elevation. Thus, growth rates, fuel accumulation and decomposition are relatively slow compared to lowland tropical environments.

Where the pines still occur in Haiti, the invasive alien shrub *Syzgium jambos* forms dense thickets beneath the pines, which purportedly exclude fire (Darrow & Zanoni, 1990). The most serious invasive species problem we observed was the spread of non-native Caribbean pine (*Pinus caribea*) from inappropriate reforestation efforts near Valle Nuevo in the Cordillera Central and along the Alcoa Road in Sierra de Bahoruco National Park.

The affinity of *Pinus occidentalis* to several endemic pine species in Cuba is not clear. Several authors report it on both islands, the Cuban variety being *Pinus occidentalis* var. *cubensis*. There is apparently considerable variation among pine populations in eastern Cuba and the possibility of hybrids of *Pinus cubensis* and *Pinus occidentalis* has been noted. Borhidi (1996) states that these morphologically diverse populations in Cuba are united under the name *Pinus maestrensis*. Farjon & Styles (1997) maintain that reports of *P. occidentalis* from eastern Cuba are probably erroneous and likely pertain to *Pinus cubensis*. *P. occidentalis* has three to four predominantly five-needled fascicles, while both *P. cubensis* and *P. maestrensis* have fascicles of two to three needles (Bisse, 1981). The pine in the Sierra de Bahoruco has been described as *P. occidentalis* var. *baorucoensis*, although this variety is not generally recognized (Farjon & Styles, 1997).

Figure 2. ***Danthonia domingensis*** **tussocks in a savanna in Valle Nuevo that was burned in 2001. Note limited amount of fuel accumulation and lack of fuel continuity between tussocks two years post-burn. This illustrates that in this cold highland environment fuel accumulation is relatively slow. (Photo: R. Myers)**

Its morphological characteristic may be an expression of it growing on calcareous soils.

The IUCN Species Survival Commission (1994) lists *Pinus occidentalis* as vulnerable and in need of conservation and management measures.

Due to the marked substrate/soil differences, the floral species composition is quite distinct between the forests and savannas in the Cordillera Central and those of Sierra de Bahoruco. This differentiation may have also been influenced by the fact that Sierra de Bahoruco once formed a separate island and was isolated from the Cordillera Central. The acid soils of the Cordillera Central support shrub species such as *Lyonia heptamera, Myrica picardae, Myrsine coriacea, Ilex tuerkheimii, Garrya fadyenii,* and *Baccharis myrsinites*. The tussock-forming grass *Danthonia domingensis* dominates grasslands and savannas, and is even common in relatively dense forests (Figure 2).

In contrast to the Cordillera Central, the understory and ground cover vegetation in the pine forests of Sierra de Bahoruco are reminiscent of species found on calcareous rocklands, e.g., the palm *Coccothrinax scoparia*, the agave *Agave antillana*, and shrubs such as *Cestrum brevifolium, Chamaescrista glandulosa, Lyonia truncata, Myrica picardae, Senecio picardae, Hypericum hypericoides*, and *Coreopsis buchii*. Grasses are abundant, but *Danthonia domingensis* is not one of them (Figure 3).

Cloud Forest

Mountains at tropical/subtropical latitudes frequently reach the height of, or pierce, the trade wind inversion which, at the latitude of the Dominican Republic, is strongest and lowest

Figure 3. Pineland ground cover on limestone substrate in Sierra de Bahoruco National Park. Pine needle litter forms a continuous fuel and is the primary carrier of fire. (Photo: R. Myers)

during late winter and spring, and again in the fall. Below the trade wind inversion, there is predictably a band of clouds on the windward side to the mountains produced by orographic lifting of the trade wind airflow. This band of persistent clouds shifts slightly up- or down-slope as the tilt of the earth changes with seasons. The high humidity associated with this band of clouds produces conditions for broadleaved evergreen forests with characteristics unique to these conditions, e.g., elfin or dwarf stature due to limited transpiration; and abundant epiphytic flowering plants, bryophtes, and ferns. Fires in these cloud forests are rare events and can be very destructive when they do occur. May (1997) documented the effects and response of the cloud forest at the Ebano Verde Scientific Reserve to a fire in 1992 and found that although some species had the ability to resprout after fire, the ecosystem as a whole is poorly adapted to fire. Besides fire, these ecosystems are susceptible to wind damage and soil slumping or landslides. As in other types of tropical broadleaved forests, a single fire in a cloud forest changes the fuel characteristics, making it more susceptible to future fires (Figure 4).

Figure 4. Former cloud forest vegetation that has been subjected to repeated fire, near Ebano Verde Scientific Reserve. The most recent fire occurred in July 2003. This photo was taken approximately one week post-burn. What had once been relatively fire-resistant broadleaved cloud forest is now dominated by flammable ferns, graminoids, and vines. (Photo: R. Myers)

In the Dominican Republic, cloud forests are wedged between pine forests both above and below them. Frequent fires in the pine forests limit the altitudinal expansion of the cloud forest vegetation either up- or down-slope. If fires are excluded at the transition of pine and cloud forest, cloud forest species will move into those fire-free areas at the expense of pine. Conversely, severe fires in the cloud forest may create conditions for pine to become established post-burn. With repeated burning the pines would persist and expand at the expense of cloud forest species. Sherman et al. (2003) describe two types of pine forests where cloud forest tree and shrub species are common in the understory, and epiphytes occur on the pines. Such sites could likely support either pine or cloud forest depending on the fire regime.

The most abundant tree species in the cloud forests are *Didymopanax tremulus, Magnolia pallescens, Clusia clusiodides*, and *Podocarpus aristulatus*. As is common with fire-influenced ecosystems, fire affects the presence and relative abundance of species. Guerrero et al. (2002) describe a number of instances where fire may have influenced the species composition of cloud forest.

Mixed Pine-Broadleaved Forest

Mixed pine-broadleaved forests exist at low elevation where the pine intergrades with tropical moist forest, as riparian forest along river courses and drainages at all elevations, and at higher elevation where pine intergrades

Figure 5. Marked contrast between former pine & broadleaved forest in Haiti now in agriculture and the pine forests of Bahoruco National Park in the Dominican Republic. (Photo: R. Myers)

with cloud forest vegetation. Where pines occur within broadleaved forest, it most likely represents a former pineland where fire has been excluded allowing broadleaved species to expand into the former pineland, or where fire entered and damaged a broadleaved forest and created conditions conducive to pine establishment. In either case, the state is not stable and will not persist. In the continued absence of fire the pines will die out; with repeated fire the pine forest or pine woodland would develop and persist.

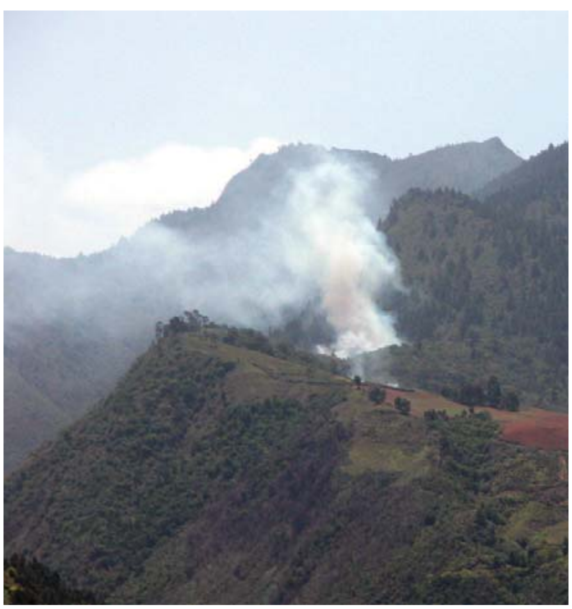

Figure 6. Escaped agricultural burn just below the pine forests of Juan B. Pérez Rancier National Park. (Photo: R. Myers)

Lower elevations, i.e. below the pine and pine-broadleaved forest zone, were once subtropical mixed broadleaf moist or dry forest. Now agriculture is prevalent in this zone, and most of the forest is gone (Figure 5). Fallow agricultural land is frequently burned when it rotates back into cultivation, and a number of these fires escape and burn into higher vegetation zones (Figure 6).

3 observations & interpretations

Fire Ecology & Fire Regimes

The historical distribution of Hispaniolan pine is largely an artifact of fire, i.e. these forests are fire-maintained. Holdridge (1949) was probably the first to note the ecological role of fire in maintaining the pine forests on Hispaniola. The long history of fire in these pine and savanna ecosystems has been documented by Horn et al. (2000) and Clark et al. (1997). These studies dated charcoal from soil and sediments from the late Pleistocene (42,000 yrs BP) and throughout the Holocene (last 10,000 years). The incidence of fire pre-dates the arrival of humans (6000–7000 yrs BP). Pollen analyses suggest, but do not confirm, that human activities may have resulted in the expansion of pine down-slope. The overall findings, however, indicate that the fire regime has not changed significantly over the past 5000 years, and that recent human activities have not necessarily favored pines and savanna vegetation over broadleaved forests in the Cordillera Central, as is sometimes suggested. Frequent fires do limit the areal extent and distribution of broadleaved cloud forest vegetation, and the boundary between this forest type and pine or savanna may wax and wane in any given area depending on the incidence of fire.

Today, many fires are probably of human origin, but because few records have been kept, the incidence of lightning-ignited fires and the relative role of human versus lightning fires is not known. The human sources of ignition are escaped fires from around homes and from agricultural burning, fires set by hunters, accidental ignitions by local residents and visitors to the region's national parks, and revenge or protest burning against individuals or the government. Guerrero & McPherson (2002) describe the recent history of fire in Juan B. Pérez Rancier National Park (Valle Nuevo). McPherson et al. (2002) interviewed local communities regarding their use and attitudes toward fire and found that escaped agricultural fires, though important, have probably been less of a factor affecting the pine ecosystems than fires set as a form of protest or revenge related to socio-political issues. The *Integrated Ecological Evaluation of Juan B. Pérez Rancier National Park,* which contains these two cited papers, presents a map of large fires documented between 1983 and 1998. There were seven registered fires; the largest, in 1983, covered 51,200 ha.

Fire has been an important influence affecting the current distribution and structure of the pine forest and savanna ecosystems. Many pine forests, woodlands, savannas, and open grasslands throughout the world depend on specific fire regimes for their persistence and characteristics. Without fire they will change to something else, with the loss of not only the pines but also many of the plant and animal species that are specific to those habitats. The Hispaniolan pine ecosystems are no exception. The fire regime that maintains viable Hispaniolan pine ecosystems is probably best described as "mixed," i.e. a combination of frequent, low-intensity fires restricted to the fuels on the forest floor (e.g., grasses, pine needle cast, small shrubs), and high-intensity stand-replacing/crown fires that kill many of the pines in their path. The high-intensity component is mediated by the interaction of winds, humidity, slope, fuel accumulation, and stand density. These types of fires are more likely to occur during very dry conditions, on steep slopes, with up-slope winds, and over expanses that have accumulated fuels during extended fire-free periods.

The size of the area affected by these high-intensity fires may be limited to small stands or may involve multiple slopes and ridges across the landscape. Conversely, low-intensity surface fires would be common under moderate burning conditions and/or low fuel loads, on relatively flat ground, in areas burning with fires backing down or flanking across slopes, and with fires backing into the wind. Under moderate to mild burning conditions, fires in open stands and in long-unburned savannas may be of higher intensity than in adjacent dense pine stands because of differences in the surface fuel structure (i.e. upright grasses versus compact, horizontal, pine needle litter), and because pine stand density affects wind speed, fuel moisture, and fuel temperature (through shading) as long as conditions are not conducive to crowning (Figure 7).

The Hispaniolan pine has specific adaptations that allow it to survive and/or respond favorably to fire. As seedlings, the pine does not have any adaptations to survive fire. This indicates that the mean fire return interval would have to be long enough to allow some of the trees in a stand to become large enough to survive fire. There is a relationship between survival size and fire intensity. Some smaller trees will survive low-intensity fires while none may

Figure 7. Fire effects resulting from a heading fire burning from an open savanna into a closed pine forest. Note greater mortality of small trees and the height of dead branches at the forest edge. As the fire entered the forest, its behavior moderated considerably, greatly reducing the effects on the pines. The burn occurred in 2001. This is probably a normal dynamic at the savanna-forest edge where the pines encroach on the savanna during fire-free intervals, and then are killed back when a fire occurs. (Photo: R. Myers)

Figure 8. Eleven-year-old pine regeneration in savanna fuels after a fire in 1992, Valle Nuevo. It appears that a heading fire killed scattered large trees that were in the savanna and damaged trees at the edge of the forest. The fire then moved through the forest as a lower-intensity surface fire and had no impact on the trees in the dense stand. Given the current fuel conditions, a heading fire in the regeneration would likely kill most individuals, but it would still have little impact on the mature forest because of the low amount of fuel and shaded conditions. Under severe burning conditions, the dense forest would be prone to crowning fire resulting in the loss of most of the trees. (Photo: R. Myers)

survive a high-intensity fire. Larger individuals have two adaptations that increase their probability of surviving fire: (1) thick bark that protects the cambium from heat, and (2) a natural pruning of lower branches that keeps growing buds high above the lethal heat of a surface fire (fire may also be a pruning agent). Horn et al. (2001) found that pine mortality in fires is strongly correlated to stem diameter. Trees with diameters over 10 cm survive fires more frequently than smaller-diameter trees.

Irrespective of pine survival or mortality, fire prepares a mineral soil seed bed, makes nutrients available to facilitate growth, and reduces shade and other competition from other species, facilitating regeneration and growth of pine. Fire also may thin dense stands of pine, leading to more vigorous growth, and more fire-tolerant, open stands.

What is not known is the minimum fire return interval that will allow the persistence of pine on a particular site. Survival will be partly a function of site productivity, i.e. how fast the young trees grow, and fuel conditions: type of fuel, amount of fuel and fuel moisture, all of which contribute to fire intensity. Figure 8 shows size of pine regeneration after a fire in 1992 in savanna grass fuels in the Cordillera Central. A fire burning with the wind (heading fire) under these fuel conditions will likely kill the regeneration shown in this picture. A lower intensity fire, backing into or moving

Figure 9. Pine stand in Sierra de Bahoruco National Park that burned within the past year. The fire had no impact on the overstory pines. It may have killed pine regeneration, but the stand was already fully stocked. Most of the agave survived the fire, suggesting a very low-intensity burn. Understory shrubs are resprouting. A thin layer of pine needles covers the ground surface, which could potentially burn again. (Photo: R. Myers)

perpendicular to the wind (flanking fire), may allow considerable survival of trees this size. This suggests that the minimum fire return interval for pine survival in grass fuels is 10 to 12 years. This minimum may be considerably different in woodland fuels or the pine litter/sparse grass fuels found in Sierra de Bahoruco, or elsewhere in the Cordillera Central.

Fires in more mature stands can be considerably more frequent than 10 to 12 years. The return interval would be limited by fuel accumulation, and could be as frequent as two to five years. Frequent fires would afford stands of larger trees protection from wildfires under extreme conditions because fuels would rarely accumulate to support destructive fires (Figures 9 & 10).

The shrub layer also responds to fire. Horn et al. (2001) documented high (95–100%) basal resprouts of most understory shrubs two years post-fire in an area burned in Alto de la Primera Cañada in Juan B. Pérez Rancier National Park. This, coupled with survival of larger trees and recruitment of pine seedlings and the persistence of tussock grasses point to an ecosystem that is adapted to fire, and dependent on periodic fire.

Role & Impact of Forest Exploitation

The current structure and dynamics of the Hispaniolan pine forests and their relationship to adjacent cloud forest and broadleaved forest has been strongly influenced by previous logging events. Commercial logging of the pines in the Cordillera Central began in the early

Figure 10. Frequently burned pine forest on left contrasts with a long-unburned pine forest on the right. Pines cannot regenerate under the long-unburned conditions and many ground cover species are being shaded out. In the continued absence of fire, pines will disappear from the site. In the meantime pine needle litter and shrub fuels are accumulating making the site susceptible to a stand-destroying fire. Prescribed burning could maintain the condition on the left and restore the forest on the right to a more healthy state. (Photo: R. Myers)

1900's. The intensity of extraction increased after World War II, and reached its peak in the final decade of the Trujillo regime when the road through Valle Nuevo was completed in 1952. Between 1943 and 1959 there were 19 sawmills inside what is now Juan B. Pérez Rancier National Park. Although we have no specific information, we assume that the pine forests of Sierra de Bahoruco where exploited at about the same time and at the same intensity.

Besides changing the structure of the pine forests, deforestation associated with logging led to the migration of people who converted once forested areas to agriculture. See references in Guerrero & McPherson (2002) for more information on forest exploitation and land use in the Cordillera Central.

The pine forests observed during this fire assessment exhibited a structure strongly influenced by past logging and subsequent fire events. All of the forests observed in both the Cordillera Central and in Sierra de Bahoruco were second growth. In places, there were isolated large pines with flat-topped crowns characteristic of old-growth trees that probably escaped logging. Several different forest structures were evident that are probably the result of specific fire histories after the areas were logged. They are:

(1) Dense even-aged stands of pole-sized trees with occasional emergent seed trees (Figure 11). These stands likely developed after the area was logged. The emergent old growth trees had fire scars and may have been left for that reason. These areas have either not burned for many years (possibly since the 1950's), or they have burned with very low-intensity understory fires burning through the litter/grass fuels that had little impact on the pines. In places, there was a deep (>10 cm) layer of duff. Under extreme burning conditions, these stands would be susceptible to stand-replacing fires. In areas with considerable duff accumulation, even low-intensity surface fires under extremely dry conditions could be lethal to the pines by killing feeder roots in the duff and by the heat from smoldering combustion killing the cambium at the base of the tree. These conditions notwithstanding, fuels could be easily reduced in these stands with appropriately applied prescribed burns.

(2) A mosaic of: dense saplings and no large trees, open stands of large trees with grasses and no reproduction, and scattered large trees with dense reproduction underneath (Figure 12). These patches reflect where: (a) overstory trees may have been killed by fire and have reseeded from adjacent seed trees; (b) overstory trees were removed during logging and regeneration is periodically killed back before the trees reach a likely survival size; (c) frequent surface fires have prevented or killed regeneration but spared the large fire-resistant trees; and (d) fire may have killed a generation of reproduction, but has been fire-free long enough to support vigorous reproduction under large fire-resistant trees. In the continued absence of fire, each of these would develop the dense structure shown in Figure 11.

Figure 11. Densely stocked stand of second-growth pine in Valle Nuevo that may have become established after logging or a severe, stand-replacing fire. These types of stands are susceptible to stand-replacing fires. Fuels and stand density could be reduced with appropriately applied prescribed fire. Under moist conditions these well-shaded forests would likely stop fires burning in adjacent savanna. (Photo: R. Myers)

Figure 12. A mosaic of stand structures created by past fire events illustrating regeneration in patches in where large trees were killed by a fire, and regeneration under large trees that survived the fire. At this stage another fire could (1) kill all the regeneration but spare the large trees, or (2) kill only the smallest of the regeneration leading to an open stand of pines of mixed ages. (Photo: R. Myers)

(3) Even-aged or uneven-aged stands of pines with clumps of reproduction in small openings (Figure 13). This structure likely develops when surface fires leave most large trees unaffected, but light gaps in the canopy are created when several large trees are killed by a fire, lightning, windthrow, or other factors such as disease. The burning of surface fuels and vegetation coupled with the increased light intensity create conditions conducive to the establishment of a clump of reproduction in the gaps. This reproduction may be (a) killed by the next fire, recreating the gap, (b) thinned by repeated fires, or (c) thinned through competition.

Figure 13. Stand of mature pine with considerable pine regeneration in Sierra de Bahoruco. Light gaps in the canopy will favor the growth of pines in patches. Seedlings under pine trees are likely to be killed in the next fire, while larger saplings in gaps are more likely to survive because of their larger size. Fire is an important thinning agent where there is dense reproduction under pines. (Photo: R. Myers)

(4) Stands where non-native Caribbean pine (*Pinus caribea*), planted as part of reforestation projects, dominates former Hispaniolan pine sites (Figure 14). This structure dominated the landscape along the Alcoa Road and

around the Hoya del Pelempito visitor center in Sierra de Bahoruco National Park. Although the displays at the visitor center highlight the endemic Hispaniolan pine of the Dominican Republic, most of the trees in the area are Caribbean pine, and perhaps other introduced species. The elevation and soils of this area are very suitable for Caribbean pine, and it appears to be a very aggressive invader favored by the frequent fires. In contrast, Caribbean pine has also been introduced at higher elevations in the Cordillera Central, and it is clearly not adapted to these conditions. The small stunted trees could easily be eliminated in a fire.

Figure 14. Aggressive Caribbean pine regeneration along the Alcoa Road in Sierra de Bahoruco National Park. This is an unfortunate non-native introduction to an island ecosystem that has an endemic pine species that would normally occupy this site. Consideration should be given to removing these trees and replanting or reseeding with *Pinus occidentalis.* (Photo: R. Myers)

4 conclusions & recommendations

Key Ecological Attributes Related to Fire

(1) The Dominican Republic has some of the best examples of intact subtropical montane ecosystems in the Americas, consisting of an endemic pine forest ecosystem (*Pinus occidentalis*), montane grasslands, elfin (dwarf) cloud forest, and lower montane broadleaved forests.

(2) The landscape encompassing these ecosystems represents a classic example of the dynamic relationship between fire-maintained/fire-dependent pine forests, woodlands, and savannas and fire-sensitive cloud forests and lower-elevation tropical broadleaved forests.

(3) The long-term history and role of fire in this landscape is not in doubt. Studies by researchers at the University of Tennessee have documented a long history of fire in the pine and savanna ecosystems.

(4) The importance of fire in maintaining the pine and savanna ecosystems can be inferred from (a) this history coupled with the life history characteristics and adaptations of the pine and other key species, (b) the structure of existing forests, and (c) the effects of recent fires.

(5) Fires originating in the pine and savanna ecosystems are important in determining the distribution and extent of cloud forest and tropical broadleaved forest vegetation, i.e. fire plays a role in these ecosystems and may be important in creating certain habitats and determining the relative abundance of species.

(6) A general synopsis of these natural landscape dynamics and species characteristics are:

a. Fire generally originates in the highly-ignitable and flammable pine and grassland fuels; i.e. the primary fuels of most fires are grasses and pine needle litter.

b. The pines, dominant grasses, forbs, and many of the shrubs have developed adaptations to respond positively to fire, e.g., large pines with thick protective bark and high open branches readily survive low-intensity surface fires. Pine seedlings and many (but not all) saplings may be killed in these fires, but the fires remove grasses and shrubs that compete with pines and release nutrients from the ash creating a favorable seedbed for pine regeneration. The Hispaniolan pine appears to be a prolific producer of seed, so burned areas are readily reforested from surviving trees or from trees in nearby unburned areas.

c. The dominant grasses are clump-forming, i.e. they are bunch or tussock grasses typical of fire-maintained ecosystems. They produce a fuel arrangement that is easily ignited and readily carries fire even when green and/or under relatively moist conditions. The fuel is fine, very loose, and well aerated; the dead blades are held for a long time within the clump; and the blades possibly have chemical compounds that make them highly flammable.

d. The grasses, many of the forbs, and the shrub species have the ability to resprout after fire, i.e. the ground cover recovers rapidly after fire. Although erosion after fires is widespread, particularly on steep slopes, the root stocks of shrubs and grasses are not killed so they continue to hold soil and limit its loss from slopes.

e. Fire in the pine forest and savanna is not an ecological succession-initiating process. What burns simply recovers.

f. Fires originating in the savanna and pine forest frequently go out when they reach the cloud forest or tropical broadleaved forest. The latter two forest types produce less flammable fuels, which are more compact and less aerated, retain moisture, and are shaded. In the case of the cloud forest, it is located in a moisture belt, i.e. a generally wetter environment than found in most of the pinelands. Other tropical broadleaved forests are frequently located in moist ravines and drainages. These differences in environment, fuels, and fire behavior interact to produce the abrupt boundary that is often seen between fire-maintained and fire-sensitive ecosystems.

g. Fire is an important disturbance process in cloud forests and tropical broadleaved forests, but because it does not re-occur as a predictable event, many species in these two vegetation types do not have adaptations to respond to it. That notwithstanding, occasional small fires may be important in creating unique habitats for certain species, and for determining the dominance of certain species.

h. During the dry season, and particularly during protracted droughts, fires originating in the pine forest and savanna can broach the ecosystem boundary with cloud and tropical broadleaved forests. Such fires may be very damaging, and may, if repeated frequently, cause a shift in the boundary.

i. Fire damage in cloud forest and other broadleaved forests opens the canopy and creates huge quantities of fuel from dead trees. The open canopy allows more rapid drying of these fuels, making them more susceptible to repeated burning and loss of the forest.

j. After an initial fire in cloud forest, flammable vegetation, e.g., ferns, can invade and potentially initiate more frequent fires.

k. During extended fire-free periods, the cloud forest and broadleaved forests will encroach upon the savanna and pine forests. The mixed-pine/broadleaved forests described in the Cordillera Central and Sierra de Bahoruco may be the result of these shifts.

l. Fire interacts with hurricanes. Hurricane damage may produce huge fuel loads that may allow fire to affect large areas in all of the highland ecosystems, both fire-prone and fire-sensitive.

m. Key to the integrity of all of these ecosystems is fire frequency. Fires need to be frequent enough to maintain varied examples of pine forest and savanna, but not so frequent that they limit pine regeneration over large areas. Conversely, they need to be infrequent and small in scale in the cloud forest and broadleaved forest. Keep fire out of the savannas and they will first become pine forests. Keep fire out of the pines and (1) fuels will accumulate, (2) which may lead to destructive fires that (3) kill large pines and degrade watersheds. Long-term absence of fire will prevent regeneration of the pine and lead to the gradual change to either cloud forest vegetation or broadleaved hardwood forest depending on the environment. If fires are too frequent in the cloud or broadleaved forest, they will change to pineland, savanna or shrubland, and be susceptible to the invasion of non-native species from agricultural lands and pastures. If fires are too frequent in the pine forest, the forest will change to savanna or grassland.

(7) It does not matter if fires are natural or human-caused. One is not better or worse than the other. The ignition source is not important, rather it is the characteristics of the fire regime. If the fire regime changes or is altered from what is needed to maintain a particular ecosystem, it will change to something else.

(8) It is unknown at this time to what degree human-ignited fires escaping from agricultural clearings that surround, or are imbedded in, the natural areas, or those that are purposely set, are posing a significant threat to any or all of the ecosystem types within the Cordillera Central and Sierra de Bahoruco. The incidence of fires and their effects need to be monitored in greater detail and to a greater extent.

(9) It appears that frequent fire may be killing back pine regeneration in many areas of the Cordillera Central, preventing the development of more mature forests. Likewise, fire in portions of the Sierra de Bahoruco may be maintaining shrubland without pine.

(10) Fire has been excluded from some pine stands, either by happenstance or through suppression efforts. These stands should have been thinned by fire. Current fuel loads and stand density make them susceptible to large crown fires that will kill trees and adversely impact watersheds.

(11) It is likely that escaped agricultural fires and accidental or provoked fires are converting broadleaved forests to non-native flammable grasslands or shrublands, and in the pine forests are preventing the regeneration of pine. This process creates a positive feedback loop where fires enter the forest and create more flammable conditions, which leads to more frequent fires and enhanced expansion of non-native grasses at the expense of forests.

(12) Although much needs to be learned about the details of the fire regimes that maintain pine forests and savannas and influence cloud forests and broadleaved forests, it appears that the fire regime in the pine/savanna ecosystems can be described as "mixed," e.g., a combination of low-intensity, non-lethal surface fires and high-intensity lethal fires (lethal to the pines). This mix is mediated by time since last fire (fuel accumulation); burn conditions (e.g., dryness, humidity, temperature), stand density, slope, and wind speed. Under natural conditions, such a fire regime would create a diverse array of habitats, stand densities, and stand ages.

(13) Past logging (everywhere) and fire suppression in accessible areas has altered the natural stand structure of the pine forests and made them more susceptible to fire damage. The reported high level of stand replacing fires in Sierra de Bahoruco (Latta et al., 2000) is likely an artifact of the interaction of relatively young dense stands that developed after logging and frequent human-caused ignitions. Dense, young stands, not subjected to low-intensity understory burns, are more susceptible to crown fires and pine mortality, than forests in a landscape of larger, more widely spaced trees, mixed with smaller patches of reproduction. A goal should be to gradually shift the structure of the forest towards stands of larger, more widely spaced trees.

Recommended Fire Management Strategies

(1) The Dominican Republic has a highly professional and effective fire suppression organization. Fire suppression and fire prevention are important strategies, but applied effectively would be detrimental to the pine and savanna ecosystems. Effective fire exclusion would ultimately produce conditions for larger, more destructive fires and/or the loss of the pine and savanna ecosystems due to the loss of fire as a key ecosystem maintenance factor.

(2) Although fire suppression and prevention are needed to prevent and reduce damage from unwanted fires, the important role of fire in pine and savanna ecosystems needs to be recognized, and an integrated approach to fire management developed.

(3) What is Integrated Fire Management? Integrated Fire Management is an approach to addressing the problems and issues posed by both unwanted and desirable fires within the context of the natural environments and socioeconomic systems in which they occur, by evaluating and balancing the relative risks posed by fire with the beneficial role that it may play in a given conservation area, landscape or region. It looks for cost-effective approaches to preventing unwanted fires while responding appropriately to those fires when they occur. It recognizes both the important ecological role that fire plays in many ecosystems and the socioeconomic necessity and value of using fire for traditional and economic purposes.

(4) Develop integrated fire management plans for key conservation areas that include:

a. **Analysis of the Problem:** What are the underlying causes of unwanted fires? Where do they occur? Why do they occur? What areas are at risk? What areas have high resource or biodiversity values that may either be benefited by fire or adversely affected by it? Where is fire needed? What is the justification for managing fires in different ways?

b. **Prevention:** Regulate fire use, educate fire users, enforcement, community education programs. **Impact mitigation:** fuel reduction, vegetation management.

c. **Fire Use:** Prescribed burning—where and when is it needed? Where and under what conditions can fires be allowed to run their course or be constrained rather than suppressed? Develop policies that allow appropriate use of fire in natural areas.

d. **Preparedness:** Early warning and predictive systems, detection and response systems, trained fire staff.

e. **Response:** Level and degree of response for given fire situations, and potential threats and benefits.

f. **Ecosystem Restoration and Maintenance:** Environmental repair and restoration; maintenance of desired ecosystem structure and function; community welfare assistance.

(5) Reduce the incidence of unwanted ignitions by:

a. Working with local agricultural communities to contain agricultural fires. This may involve developing and disseminating educational materials on controlled burning, and providing training and burn assistance.

b. Educate local communities so they understand fire's role, including benefits and harm.

c. Form volunteer brigades to help suppress unwanted fires.

(6) Restore forest structure: Gradually change the pine forests in Madre de las Aguas and Sierra de Bahoruco toward a structure with larger trees, a ground cover conducive to relatively low-intensity surface fires, and changes in the proportion of area burned by crowning fire to area burned by surface fire. A diversity of stand ages and structure may be needed for a variety of species. For example, the white-winged crossbill requires a habitat with mature large pines along with other forest structures (Latta et al. 2000).

(7) Develop prescribed fire capability and following a fire management plan introduce low-intensity prescribed fire at appropriate intervals initially in accessible areas to thin and protect dense stands and allow for survival of trees from sapling size through pole size to mature trees.

(8) Develop a management staff (both at the reserve level and at national administrative levels) that is skilled in understanding fire behavior and making fuels assessments, using fire prediction tools, and interpreting fire effects, so they can better assess which fires need to be suppressed and which are providing ecosystem benefits, and how best to respond.

(9) Develop a management staff skilled in fire suppression and fire use, e.g., prescribed burning. Ensure that they are appropriately equipped, including transportation.

(10) Where appropriate, use ecological forestry methods (in conjunction with fire) to restore a forest structure less susceptible to damaging fire, e.g., thinning, harvesting, and planting of only native species.

(11) Harvest, cut or kill with prescribed burns all Caribbean pine that was planted and has spread in Madre de las Aguas and Sierra de Bahoruco. Replant or reseed only with Hispaniolan pine that is from the same ecological area being restored. Dobler (1999) proposes a general provenance zone map for *Pinus occidentales*.

(12) Aggressive reforestation efforts should not be undertaken after most, if any fires. These efforts are expensive, have been using inappropriate species, and are frequently unsuccessful. The Hispaniolan pine has a high regenerative capacity if seed trees are in the vicinity. Ground cover vegetation has the capacity to resprout. Pine reseeding and watershed protection may be necessary when dense stands are destroyed in crowning fires and little ground cover vegetation was there prior to the fire because of shading.

5 suggested next steps

Dominican Republic natural resource managers are currently participating in the Latin America & Caribbean Fire Learning Network, which is coordinated by TNC's Global Fire Initiative with funding from the USDA Forest Service. A small team of Dominicans has been trained in ecological fire effects in pineland ecosystems and in fire behavior. Continue and expand this participation by:

(1) Hosting a Network workshop on fire ecology and fire management in tropical highland ecosystems. This would be an international workshop highlighting the Dominican Republic, and would have participants from the Dominican Republic, Cuba, Mexico, Central America, the Andean countries, and the USA. It would be in Spanish. Funding is already available for this workshop. It would be jointly hosted by FMP, the Secretaria de Estado de Medio Ambiente y Recursos Naturales, and TNC. The workshop would bring together scientists and managers working in the Dominican Republic and similar ecosystems elsewhere to share information, strategies, techniques, and problems and solutions. The workshop would be limited to about 40 participants.

(2) Conduct a prescribed fire training course and a workshop on fire management planning in the Dominican Republic. Funds will likely be available for this in mid-2004.

(3) With TNC's Global Fire Initiative, TNC DR Country Program, and FMP develop a fire management strategy for the two organizations for the country.

(4) As part of the strategy, work with FMP and other partners to develop and implement a model community-based integrated fire management project. This would include involving government agencies in training farmers in techniques to contain agricultural fires; education and prevention programs including the preparation of literature, posters, etc; and organizing and training local volunteer fire brigades.

(5) Develop a system to better document the occurrence of fire, area burned, impacts, or significant effects.

(6) Develop a fire danger index and reporting system for communities near park boundaries.

(7) Develop an integrated fire management plan for a key conservation area (possibly Juan B. Pérez Rancier National Park) to serve as a model for plans elsewhere. The plan should include or identify:

a. Ecological fire management objectives;

b. A justification for fire management;

c. Desired future conditions;

d. Conceptual models showing the relationship of fire regimes to vegetation;

e. Areas of high fire danger, e.g., where fires are likely to be severe;

f. Areas of high fire risk, e.g., where fires are likely to occur or escape control;

g. Areas of high value that could be impacted by, or benefit from, fire;

h. A fire detection and reporting process;

i. A fire response plan;

j. A fire monitoring and mapping plan;

k. A fire use plan, e.g., prescribed fire and let burn protocol; and

l. An ecosystem restoration and maintenance plan.

(8) Identify key individuals and opportunities for training, exchanges and mentoring. The Latin America & Caribbean Fire Learning Network along with the USDA Forest Service can facilitate training and mentoring opportunities.

(9) Develop a cadre of fire management instructors in the Dominican Republic. Initial focus of training and mentoring should be to develop this instructor cadre, which can then develop appropriate training courses within the Dominican Republic.

(10) Identify a TNC or FMP staff person to coordinate activities and actions with the Global Fire Initiative.

(11) Develop and/or promote a research program to address the many questions related to fire effects, fire regimes, fuels, and fire behavior. Important research questions include:

a. What effect does season of burn have on pine forest and savanna response? Natural lightning fires would have been common during wetter periods. Human-caused fires tend to occur earlier in the year when conditions are drier and effects may be markedly different.

b. What are fuel accumulation rates and what is the minimum fire return interval for maintaining different vegetation structures?

c. How does fire affect specific endemic or rare species?

d. What are the survival characteristics of pines under different types of fire?

e. What effect do different season, frequency and intensity of burn have on ground cover and understory structure and diversity?

f. Given the remnant nature of the pine forests, woodlands, and savannas, what are desirable options for applying fire over the landscape to create or maintain a pattern of vegetation and habitats best suited to maintaining the biodiversity of the area?

(12) Pursue funding to develop and implement fire projects.

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