GUANACASTE NATIONAL PARK:

TROPICAL ECOLOGICAL AND CULTURAL RESTORATION

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COVER

CENTER. Eastern and southern half of Guanacaste National Park (GNP), as viewed from about 1200 meters elevation over the Pacific Ocean. The lower two-thirds of the photograph is primarily Santa Rosa National Park. This Park is the primary source of the dry forest habitats and organisms that will reoccupy much of the land to be incorporated in GNP.

In the foreground lies Playa Naranjo (Naranjo Beach). In the lower left is a southern corner of the severely deforested Santa Elena Peninsula, which extends to the left and rear of this photograph. Moving inland,sthere are two large seasonal river drainages (center-left, Río Nisperal; center, Río Calera). The Santa Rosa plateau is covered with a mosaic of various ages of deciduous forest and abandoned jaragua pasture (yellow). The escarpment running to the left from the center of the photograph is closely paralleled by the Park entrance road. Further inland lie ranches outside of Santa Rosa. The upper part of the plateau was previously covered with oak forest and joins with the bases of Volcán Orosí (left) and Volcán Cacao (right). Old but active pastures are visible as yellow patches cut out of the evergreen pristine forest on the sides of the volcanos. The clouds are the moisture that generates the headwaters of the Río Tempisque, which flows out through the upper right-hand corner of the photograph.

UPPER LEFT. Ten-day-old seedlings of the guanacaste tree *(Enterolobium cyclocarpum)* that are germinating from seeds occurring naturally in cattle dung. Cattle eat the large fruits of this large tree and are major dispersal agents for the seeds; because of this, these large mammals are important in the early stages of forest invasion of large expanses of dry forest pasture that are to be restored to forest. Santa Rosa National Park.

UPPER RIGHT. Red color morph of an adult tettigoniid grasshopper (katydid). The most common morph of this common species is brilliant leaf green. Santa Rosa National Park.

LOWER RIGHT. Adult female agouti *(Dasyprocta punctata),* a 3 kilogram prominent forest rodent that is a major dispersal agent of large seeds in the dry forest. There is an acorn *(Quercus oleoides)* in her mouth. Dispersal of seeds by agoutis is critical the movement of large pristine forest trees into the early stages of forest reinvasion in dry forest. Photo W. Hallwachs. Santa Rosa National Park.

LOWER LEFT. Full-size caterpillar of the saturniid moth *Schausiella santarosensis.* This large moth is found only within the area of Guanacaste National Park, yet feeds only on the leaves of guapinol *(Hymenaea courbaril)* which is a large legume tree that ranges from Mexico to South America. Santa Rosa National Park.

SUMMARY

Dry forest is the most endangered of the once widespread habitat types in Mesoamerica; today only 0.08 percent of the original 550,000 km^2 is in preserves. This document describes and discusses an $11.8 million project in northwestern Costa Rica that will allow the dry forest organisms in Santa Rosa National Park and on the evergreen-forested slopes of two nearby volcanos to reoccupy the adjacent low-quality agricultural and pasture land. Simultaneously this project in tropical restoration ecology will have a management focus designed to integrate the park itself, Guanacaste National Park, into Costa Rican local and national society as a major new cultural resource in an area that is agriculturally rich but culturally deprived. The 700 km^2 park will be large enough to maintain healthy populations of all animals, plants and habitats that are known to have originally occupied the site, and to contain enough habitat replication to allow intensive use of some areas by visitors and researchers. The biological technology for restoring a large area of species-rich and habitat-rich tropical dry forest is primarily fire control by managers, grass control by cattle, and tree seed dispersal by wild and domestic animals (and as budgets permit, intensive reforestation programs with native trees); this restoration biology is already relatively well understood or currently being subjected to field experiments. The sociological technology for integration of the park into Costa Rican society is straightforward education of students and teachers at all ages and levels in the society, and research on the biology of the park to obtain more information to feed that education process. In addition to being a major cultural resource, the park will have a variety of economic values such as gene and seed banks for dry forest plants and animals, watershed protection, reforestation examples and technology, ecotourism, and conventional tourism. The land to be incorporated in Guanacaste National Park is almost entirely owned as investment property by people willing to sell it for a fair market price; $8.8 million is needed for this purpose ($200 per ha, $81 per acre). A park that will survive into perpetuity and display its cultural potential must have a substantial endowment for technical and cultural management; a minimum endowment of $3 million is needed for this purpose (an operating budget of $300 000 per year). The entire project must be in place by 1990, and about $1 million is needed immediately to secure the habitats that are in danger of inmediate destruction.

INTRODUCTION

When the Spaniards arrived, there were 550 000 km² of dry forest on the Pacific side of lowland tropical Mesoamerica *(Figure 1)*. Equal to about five Guatemalas in area, this dry forest occupied as much or more of the Mesoamerican lowlands as did rainforest. Today, less than 2% of this dry forest exists as relatively undisturbed wildlands, and only 0.08% of it lies within national parks or other kinds of conserved areas (Appendix 1). In contrast to today's conservation battle for the tropical rainforest, the dry forest conservation battle would have had to have been fought a hundred or more years ago. To save what dry forest we still have, we are going to have to give some land back to it. Habitat restoration is essential before natural and anthropogenic fluctuations and perturbations extinguish many of the small populations and habitat remnants that have survived to this date.

Likewise, when the Spaniards arrived the dry forest habitat was occupied by peoples with an intimate, if pragmatic, factual knowledge and cultural understanding of the biology of dry forest. Today, virtually all of the present-day occupants of the western Mesoamerican pastures, fields and degraded forests are deaf, blind and mute to the fragments of the rich biological and cultural heritage that still occupies the shelves of the unused and unappreciated library in which they reside. The schoolchildren of a Mesoamerican town have neither their predecessors' contact with the natural world nor the human cultural offerings of the large cities that are supported by their parents' agricultural activities. What gives the greater return - build a cultural center in the fields cut from the forest or lead the audience to the cultural center that already exists in the forest? We must lead the audience to the forest, or all the well-meaning conservation efforts in the tropical world will disappear down humanity's throat.

Simultaneously, those tropical peoples that destroy their last fragments of tropical forest close the door to one of humanity's most ancient and complex opportunities for cultural enlightenment.

Guanacaste National Park *(Center Cover and Figure 2-4)* has three functions:

1° *Use existing dry forest fragments as seed to restore about 700 km² of topographically diverse land to a dry forest* that is sufficiently large and diverse to maintain into perpetuity all ani-

mal and plant species, and their habitats, known to originally occupy the site. It also must be large enough to contain some habitat replicates that can absorb intense visitation and research use. It will be the only such dry forest wildland area on the Pacific side of Mesoamerica and is the only large area with sufficient biological and social traits to become this. We have the seed and the biological expertise; we lack control of the terrain.

2° *Restore and maintain a tropical wildland so as to offer a menu of material goods* such as plant and animal gene banks and stocking material, reforestation examples with native trees, watershed protection, manipulation of vegetation by livestock, recreation sites, tourism profits, wildlife management examples, agroforestry research data, educational programs (from elementary levels to international symposia), and basic wildland biology data (which will in turn be part of the cultural offering of Guanacaste National Park). We have the knowledge and the interest, but we lack the arena and funds to develop it.

3° *Use a tropical wildland as the stimulus and factual base for a reawakening to the intellectual and cultural offerings of the natural world;* the audience will be local, national and international and the philosophy will be "user-friendly". We have the audience, and we know what to start telling them, but again, we lack the arena and the funds to develop it.

This document outlines and discusses the plan to achieve the above three goals with Guanacaste National Park (GNP) as a new national park in northwestern Costa Rica. The area contains 230 km² of established national parks and 470 km² of private land *(Figure 3-4, Appendix 4),* and is about 1% of the area of Costa Rica. One of the national parks (Santa Rosa) contains quite enough habitats and populations to serve as the seed; they will be supplemented by the population remnants throughout GNP and the pristine forest remaining on the nearby volcanic slopes.

GNP is new in area and in concept from traditional Netropical national parks. It is also old in area and concept in that it a) will contain the well-established Santa Rosa National Park *(Center Cover)* and Murcielago National Park *(Figure 3-4),* b) is foreshadowed by 5-plus-year-old pilot studies in restoration ecology in Santa Rosa, and c) is embedded in Costa Rican culture, a society that has long held education and cultural development to be noble and legitimate human activities. In this society, disagreement traditionally leads to debate rather than to physical attack.

The start-up and endowment cost is going to be $11.8 million (US). This is the price tag on about 600 new Toyota jeeps in Costa Rica or the cost of one medium-sized new biology building on a US university campus. It is $4.72 per person for each Costa Rica citizen.

The GNP plan is extremely site- and culture-specific. It is designed to function in the exact context of the sparsely occupied and low-quality pastures and degraded forests of a small part of north-central Guanacaste Province, which is otherwise a rich agricultural province. It must be evaluated in this context, and not in the context of its appropriateness to other parts of the tropical world; on the other hand, major fragments of the philosophy and technol-

ogy underlying the plan are relevant to agroecosystem design throughout the tropics, and much of the plan's design was stimulated by first-hand observation of the interaction of wildlands with their societies throughout the tropics. The trials and examples of GNP will be both training ground and models for the consolidation and development of the other portions of the Costa Rican national park system, and vice versa. The early stages of planning have been developed in consultation with many persons and agencies inside and outside of Costa Rica. Subsequent detailed planning of guidelines and their implementation will be conducted by committees of interested persons and organizations primarily or entirely of Costa Rican origin.

Within the next 5-10 years the wildland component of Costa Rican society will be forever fixed in place; even worse, it is clear that the Pacific coastal dry forest was destroyed faster and more thoroughly than was the Atlantic rainforests *(e.g., Figure 5)*. What Costa Rican habitat is not in preserves will be dead, and the next stage (which we have already entered) is that of improving the quality of both wildland preserves and agriculture in the agroecosystem. The preserves that do not become adequately integrated into Costa Rican society will die as well. Small parts of the GNP plan are of crisis urgency, and if the entire plan is not in place and functioning by 1990 there will be no choice but to retreat to the 108 km^2 of Santa Rosa National Park and apply the GNP plan on a scale that is biologically and socially much inferior. If the terrain for GNP cannot be purchased or otherwise frozen in its currently mildly damaged and relatively unoccupied state within the next 1-3 years, likewise the plan will have to be abandoned for GNP and applied to Santa Rosa alone.

This urgency comes about because the social and economic stasis that has characterised the GNP area for the past 400 years is at this moment coming to an abrupt end as a consequence of the serendipitous coincidence of a) the obliteration of almost all pioneer agriculture in Costa Rica, b) the recent influx of outside influence from central Mesoamerica, c) the liquidation of family-land holdings as owners pass retirement age, d) the corporatization of the high quality farmland in the remainder of the province, and e) the realization by large land owners that only a tiny fraction of the GNP terrain is of agricultural use and that this use can only be realized through labor-intensive farming by what amounts to human draught animals. There is substantial risk that the current owners will subdivide their large properties and sell the valuable parts as luxury investment property and the other parts to gullible or desperate subsistence farmers. At the present time, the entire 470 km^2 of GNP that is privately owned is supporting approximately 1200 head of cattle (though it could support perhaps five times as many with intensive management) and a few ha of corn and sorghum. Removing it from "production" will have no significant negative impact on either the local or national economy.

The GNP plan outlined below follows the somewhat traditional format for conservation and land development plans. However, throughout there is the underlying philosophy that tropical conservation has unwittingly used an incomplete recipe in its adoption of national park and other conservation systems from extra-tropical regions. It is traditional in, for example, the US and

now in Costa Rica, to identify biologically important habitats, obtain title to them, fence and patrol them, and view the task as largely complete. Such an act is functional *if* society at large is pre-programmed to recognize the jewel thus bestowed upon it as of worth. If not, and this is the general case in tropical conservation, the story is only half-way through the first chapter of a long book. The traditions of tropical conservation in general, and certainly Costa Rica specifically, have to evolve with urgent haste to a mode where the integration of the park into the social consciousness is dominant and central to the entire plan. Those areas we view today as endangered are probably already extinct and those areas we view today as securely preserved are at best on the endangered list; they will remain there until they are viewed in the same breath as schools, churches, libraries and democratic government.

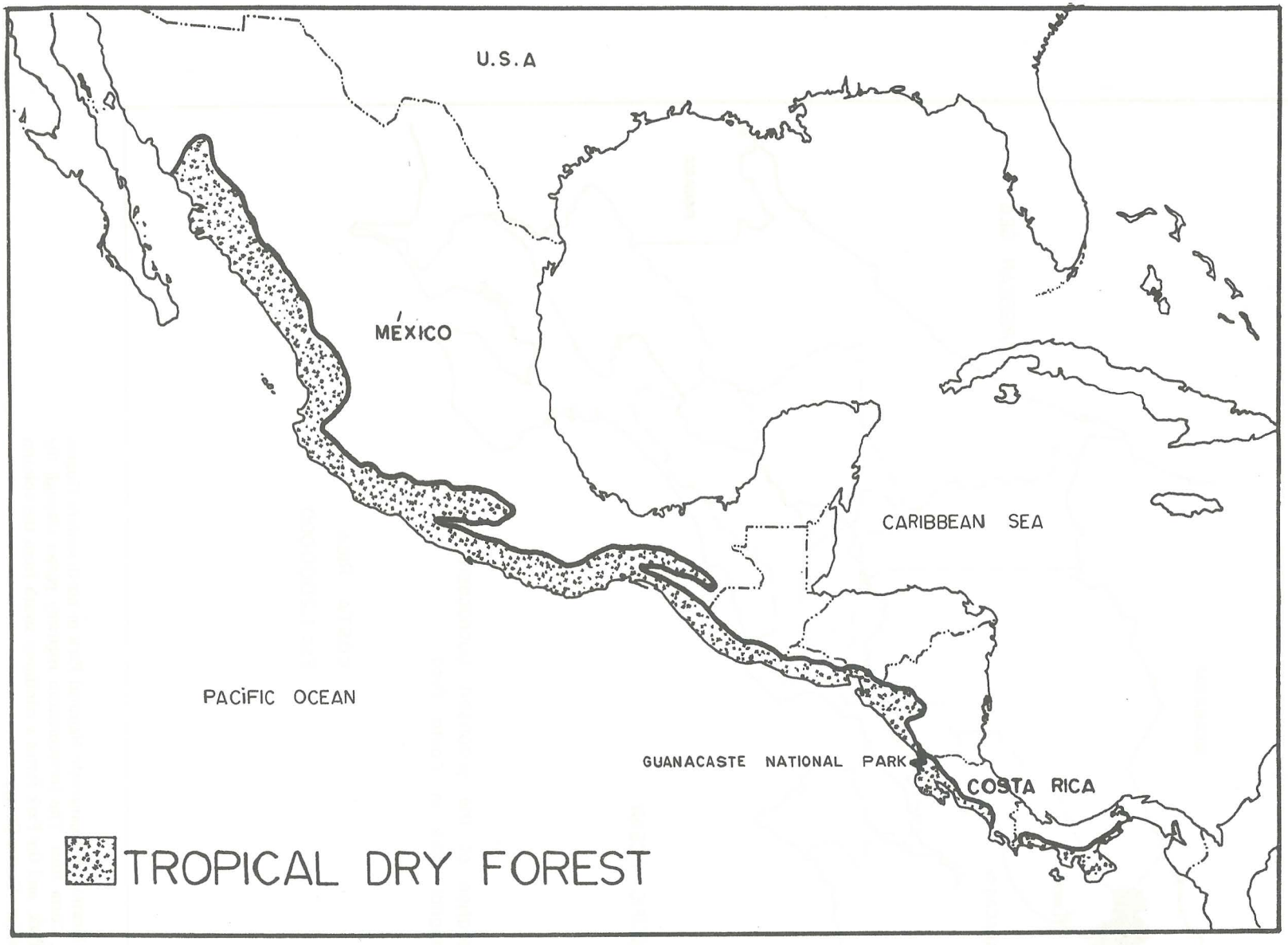

Figure 1. The distribution of Mesoamerican Pacific dry forest (stippled) at the time of the arrival of the Spanish conquistadores. Guanacaste National Park is indicated in black in northwestern Costa Rica; the other preserved areas (see Appendix) are too small to be readily visible at this scale.

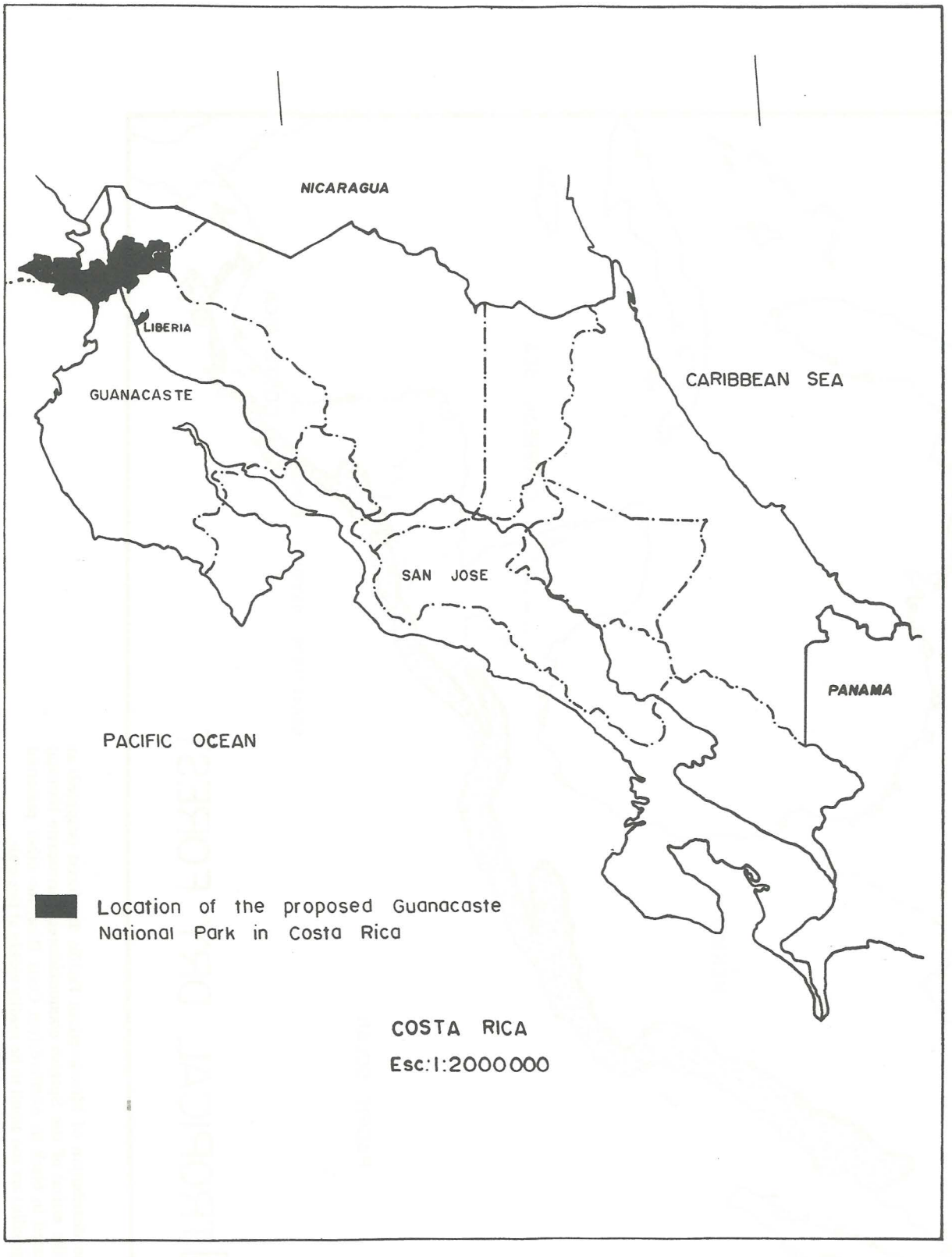

Figure 2. The location of Guanacaste National Park in northwestern Guanacaste Province, Costa Rica. The Interamerican Highway passes through the center of the Park, and the Park forms a continous swath from the volcano tops to the coast (see Center Cover).

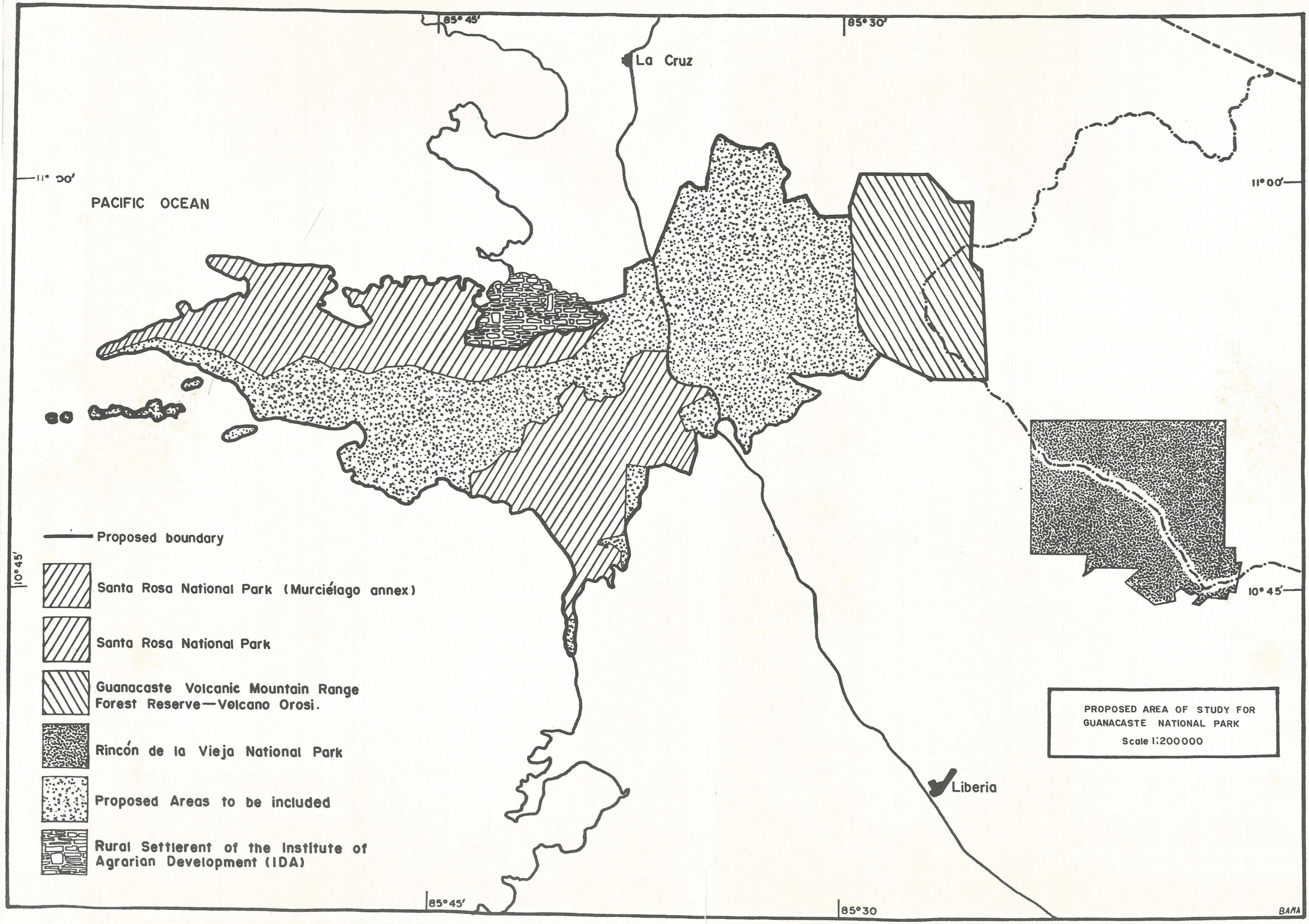

Figure 3. The new area to be added to Santa Rosa National Park and Murciélago National Park to form Guanacaste National Park (see also Appendix 4).

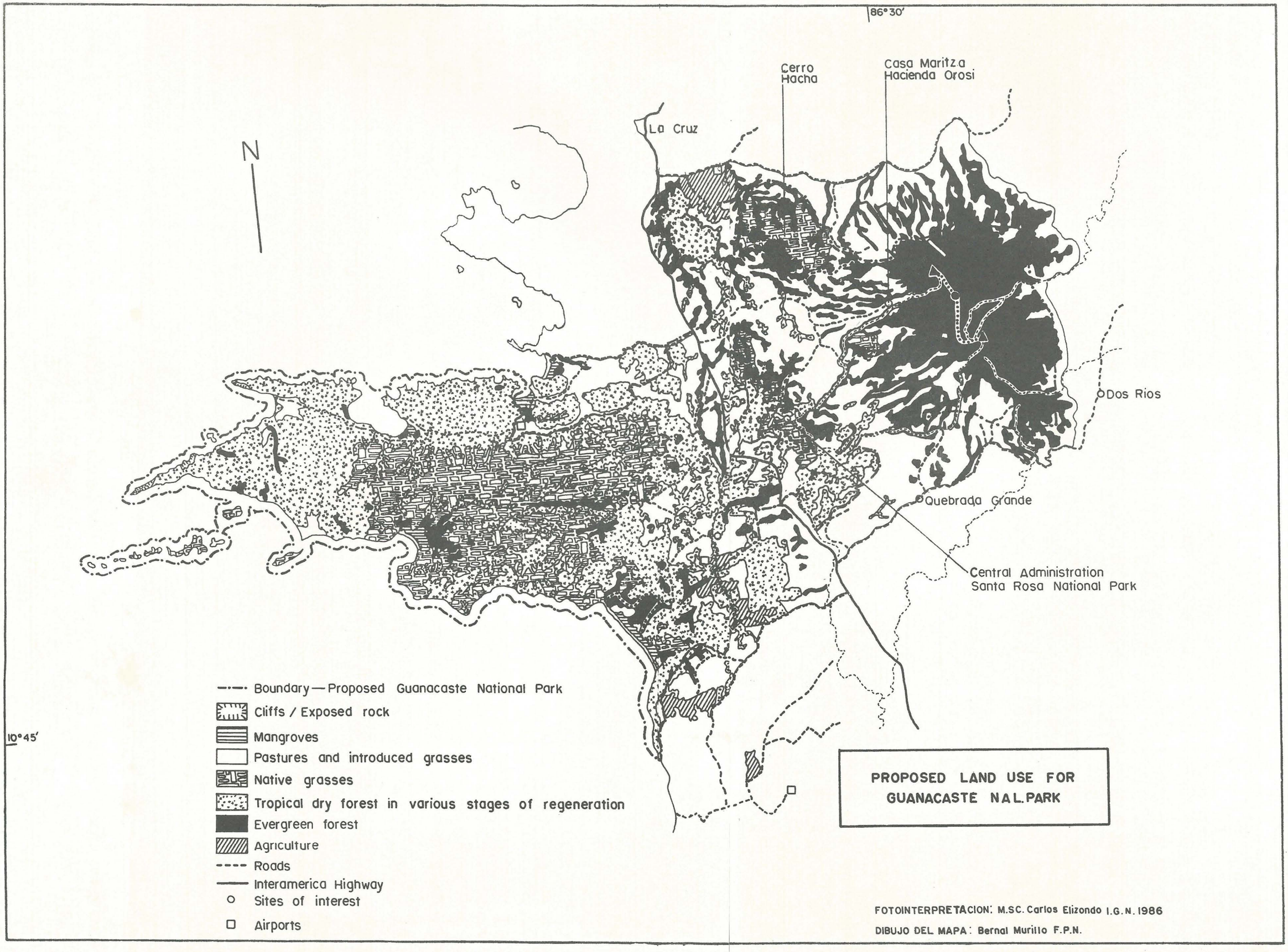

Figure 4. Approximate location of the individual properties that are collectively referred to in the text as Guanacaste National Park.

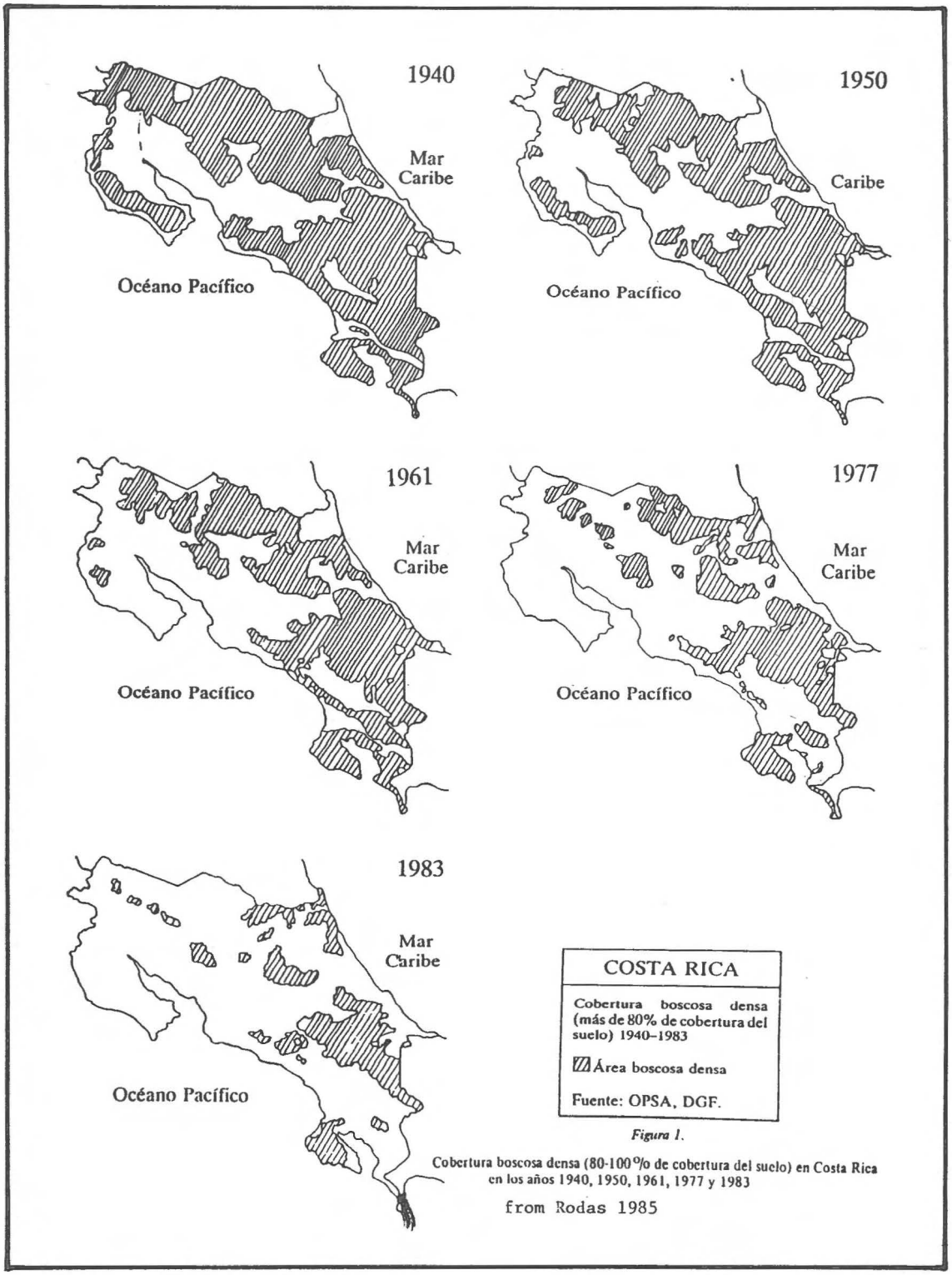

Figura 1.

Cobertura boscosa densa (80-100 % de cobertura del suelo) en Costa Rica en los años 1940, 1950, 1961, 1977 y 1983

from Rodas 1985

Figure 5. The shrinkage in distribution of closed canopy forest in Costa Rica from 1940 to the present. Only the volcano slopes within the area of Guanacaste National Park (northwestern Costa Rica) contained enough pristine forest to be recorded in this map in 1983 (Rodas 1985). Note that the relative rate and thoroughness of forest removal has been substantially greater in the dry western habitats than in the mountainous rainforest habitats.

THE REGION

IN GENERAL

Guanacaste National Park sweeps from the 1500 m peaks of Volcán Orosí and Volcán Cacao down to the Pacific Ocean, including the Santa Elena Peninsula *(Center Cover, Figure 2-3).* It is thus a wide band across the north central portion of Guanacaste Province and straddles the Interamerican Highway. The southern boundary of GNP lies 30 km north of the Guanacaste provincial capital, Liberia (the population of Guanacaste Province is 200,000); the northern boundary lies 30 km south of the Nicaraguan border at Peñas Blancas. The small fishing and farming village of Cuajiniquil is only a few kilometers north of the northern boundary of GNP, and a land colonization site of the Institute of Agrarian Development also lies on the north central GNP boundary. The northern Guanacaste regional center of La Cruz lies 15 km north of the northern boundary of GNP on the Interamerican Highway. The town of Quebrada Grande and the growing villages of Potrerillos and Los Angeles lie a short distance from the southern boundaries. All of these communities are based on agricultural land of much greater value than that in GNP.

When the first conquistadores traveled from the present-day area of Managua south-east to the Indian city of Nicoya (in the upper central Nicoya Peninsula) in the mid-1520's, they passed within a few kilometers of the eastern edge of Santa Rosa National Park, at the center of GNP. In the late 1500's, Hacienda Santa Rosa was established as a 700 km^2 beef-, hide- and mule-producing ranch; GNP resides almost entirely within the boundaries of that original hacienda, which was one of the very first to be established on land that is today Costa Rica. During the following 400 years, Hacienda Santa Rosa was variously subdivided into large pieces and sold to various owners, with numerous changes of hand. The current pieces will be discussed in detail in a later section.

ECOLOGICAL PLACEMENT

GNP lies in the nearly continuous belt of what was once dry tropical lowland forest from north of Mazatlán, Mexico to approximately the Panama Canal in Panama (*Figure* 1). Pacific Mesoamerican dry forest *(e.g., Figure 6-8)* is characterised by receiving 900 to 2400 mm of annual rainfall during 5-7 months of the year (April-May to October-December) and no rain during the 5-7 month dry season *(e.g., Appendix 3).* The upper end of this rainfall regime generates rainforest in certain other parts of the tropics (e.g., Nigeria), but these other areas are not subjected to the strong winds that blow during the first half of the dry season at GNP and are characteristic of much

of western Mesoamericana. Southern Mesoamerican dry forests also have a 0-6 week short day season in the middle (July-August) of the rainy season; in GNP, the timing and intensity of this dry season is extremely variable *(Appendix 3).* While average values can be derived from weather data for the GNP area, it is critical to recognize that the dry side of Mesoamerica is characterised by 2-10 year series of exceptionally wet or dry years. These have the effect of temporarily obliterating or reducing patches of fauna and flora in the fine scale moisture mosaic. Under natural conditions, the sites of these patches are reinvaded when the weather pattern changes. However, in small dry forest preserves surrounded by agricultural land, there is no place from which this reinvasion can occur.

Nocturnal low temperatures range from 16-23 C, and diurnal maxima range from 26 to 38 C in most Mesoamerican lowland dry forest habitats; GNP is not an exception. The dry season is substantially hotter than is the rainy season, but the reverse seems true to humans because the dry season winds create evaporative cooling.

In general, the lands once occupied by western Mesoamerican dry forest have been converted to the pastures, breadbaskets and cotton fields of their countries *(e.g., Figure 9-11).* Dry forest is easy to clear and maintain clear with felling and fire; introduced African grasses *(Figure 11)* and cebu cattle *(Figure 12)* give high yields from pastures; the dry season has somewhat of a northern effect on soil nutrients and pests; the dry season allows easy access and field preparation by machinery; grain crops grow as well in the rainy season as they do in many extra-tropical summers; soils often receive the downwind ash flow of the Central American volcanic chain; and the weather is generally more cheerful than it is in the rainforest habitats on the Atlantic side of Central America. Overall, the dry forest environment is relatively similar to the tropical and extra-tropical habitats from which large-scale farming and ranching enterprises have been imported to Mesoamerica over the past 400 years. If rainforest were as easy to farm with extra-tropical agriculture as is tropical dry forest, we would have no rainforest over which to argue today.

It is commonplace to think of the Pacific Mesoamerican dry forests as ecologically distinct and separate from the rainforests and upper elevation forests of central and Atlantic Mesoamerica. However, recent studies of flying animals in Santa Rosa and other parts of Guanacaste Province's dry forests make it abundantly clear that many "rainforest" insects and some birds spend the rainy season in the dry forest and the dry season in the rainforest or in nearby moist forest refugia *(e.g., Figure 24).* Obliteration of either wet or dry forest will obliterate these animals. One cannot view Costa Rica's national park system as a series of islands but rather must view it as a network partly connected by migrants. Some migrants can and do move hundreds of kilometers (e.g., sphingid moths, birds) while for others, the moist refuge during the dry season must be as close as a few hundred meters. GNP contains both moist refugia and flyways between Guanacaste dry forest and rainforest on the Atlantic side of Costa Rica.

It will be many years before we know what fraction of the "dry forest" fauna has to have immediately adjacent evergreen forest (such as the cove forest on Cerro El Hacha *(Figure 24)* and the evergreen forest on the two volcanos *(Figure 26-27)* if it is to persist in the dry forest. What is, however, abundantly clear is that these refuges are necessary if the dry forest fauna is not to be severely reduced in species-richness (such as is presently encountered, for example, in the dry forests of the Mexican Yucatan Peninsula where there are no moist dry season refugia owing to the highly permeable limestone substrates).

HABITATS

GNP consists of the Santa Elena Peninsula (85 million years old and above the sea during that time; this is the oldest continually exposed surface in Mesoamerica; *Figure 17 lower),* the Santa Rosa plateau (3-6 million year old volcanic ash flow deposit; Cover), the ancient volcanic core known as Cerro El Hacha *(Figure 24-25),* the twin young volcanos of Orosí and Cacao (the most recent material being perhaps as young as 10,000 years; *Figure 26-27),* small areas of coastal marine deposits, and various alluvial fans eroded off all the above substrates. Volcán Orosí and Volcán Cacao are the most northern and most isolated of the string of volcanos that extends south to Volcán Turrialba, which is east of San José.

The original GNP vegetation contains a few to tens of km^2 of virtually all kinds of dry forest habitat to be found over the broad latitudinal range of Mesoamerican dry forest. It contains a complex mosaic of the following Holdridge Life Zones: Tropical Dry Forest, Tropical Dry Forest Moist Forest Transition, Tropical Moist Forest, Premontane Wet Forest Basal Belt Transition, Premontane Wet Forest, Premontane Rainforest, and Montane Rainforest. The Islas Murciélagos and the tip of the Santa Elena Peninsula are probably the driest sites in the country. At its margins and interior, GNP has a variety of interfaces with coastal vegetation, river-margin vegetation and evergreen rainforest. It has no natural lakes (but does contain seasonal swamps) and both seasonally dry and everflowing rivers *(Figure 8, 13-15).*

Owing to the diverse topography and geology of the GNP area, its many habitats existed originally as a very complex mosaic. Today, these habitats have been variously overlain and partly obliterated (and homogenized) by a complex pattern of cutting, burning, grazing and farming, followed by secondary succession ranging from 0 to 400 years in age. However, it is also clear that somewhere within GNP lie minute to large patches of all the original habitats and population fragments of all the plants and animals that were present when the Spaniards arrived. The most pristine habitats lie in Santa Rosa (Cover, foreground), in the ravines on the lower slopes of Cerro El Hacha, on the upper slopes (above 600 m) on the volcanos *(Figure 26-27),* and in a few isolated patches up to a few tens of hectares scattered over the remainder of GNP. The most seriously altered areas are the upper parts of Cerro El Hacha *(Figure 25 upper),* the Santa Elena Peninsula (including parts of Murciélago National Park) *(Figure 17-18, 23),* and the wooded and brushy pastures in all of the ranches to the east of the Interamerican Highway *(e.g., Figure 9,20).*

Just as is the case with animals (to be discussed below), most GNP plant species are widely distributed in the Neotropics. However, the widely distributed species tend to have distinctive dry forest populations (whether the unique traits are genetic or ecological is unknown). Even the uniquely dry forest species are distributed widely throughout the Mesoamerican dry forest. However, as is the case with animals, nearly all of these widespread species are having their populations reduced to the tiny local populations in small reserves; GNP will shortly be the home of an ever-growing list of Costa Rican "anthropogenic endemics". GNP is also the only Costa Rican home of *Ateleia herbert-smithii (Figure 31 upper),* the world's only wind-pollinted legume and the tree that has become one of those selected to be widely distributed as a tropical fuelwood species.

GNP's namesake is the guanacaste tree *(Enterolobium cyclocarpum).* It is the national tree of Costa Rica and one of the best-known trees in Guanacaste Province (which was named after the tree). Ironically, this tree probably did not occur naturally in Costa Rica in the period from 10,000 years ago to

when the Spaniards arrived, but was probably a more northern Mesoamerican tree that came to Costa Rica as seeds riding in the guts of the first Spanish horses and cattle. For the next 400 years it was distributed throughout Guanacaste through seed dispersal by the horse and cow (just as it probably was dispersed by the prehistoric giant mammals, including horses, that ranged through Mesoamerica until 10,000 years ago. Today it is being extinguished in many habitats through restriction and reduction of horse populations, destruction of habitats by fire, and death of adult trees (through senescence and lumbering).

The most prominent 15 dry forest habitats in GNP are briefly characterised below:

1. SEASONAL (INTERMITTENT) RIVERS AND CREEKS *(Figure 8, 13)*. During the dry season, all watercourses within GNP dry up except for a few springs and the everflowing ones from evergreen forest (2 below). During the rainy season, the amount and duration of flow in the seasonal watercourses depends on the rainfall pattern. GNP's seasonal watercourses are important dry season water sources (pools and springs), and the more evergreen vegetation along the banks produces a cool and humid refuge as well. The watercourses and watercourse banks are a major natural habitat for a large fauna of ruderal plants and animals. The composition of this fauna and flora, and the degree to which animals are dependent on a particular seasonal watercourse depends strongly on its exact location, size, and rate of drying. GNP will add one major seasonal river (Río Potrero Grande, *Figure 13)* to the three already protected in Santa Rosa, and numerous small ones (of which there are very few in Santa Rosa).

2. EVERFLOWING RIVERS AND CREEKS *(Figure 14-15)*. The everflowing rivers have their origin in the rainforested sides of the volcanos, and then move out into the seasonally rain-free lowlands, generating linear dry season oases. Such rivers are a major part of western Mesoamerican dry forest ecology, but throughout the remainder of Costa Rica's dry forest habitats and throughout most of western Mesoamerica they have been biologically obliterated by deforestation, irrigation schemes and agrochemicals. In GNP, these rivers (Río Centeno, Tempisquito, Góngora, San Josecito, Sapoá) contain a unique flora and fauna (including fish and aquatic invertebrates that cannot persist in the seasonally dry watercourses, but reinvade them each rainy season from the everflowing rivers), serve as major dry season refuges for animals, and have wet forest plants (on their banks) that do not otherwise occur in the area. The existing dry forest parks, Santa Rosa and Murciélago, do not contain any everflowing rivers because they are topographically isolated from the volcanos and too low in elevation. It is equally distressing that no extant dry forest park in all of Mesoamerica contains an everflowing river system.

3. MANGROVE SWAMPS *(Cover, Figure 16)*. The small estuarine embayments along the coast from the southern boundary of Santa Rosa to Cuajiniquil contain fine examples of dry Pacific coast mangroves. This habitat has been generally destroyed over the past 200 years by bark (for commercial tannin), post and firewood collectors along the Mesoamerican coast. However, the area of the mouth of the Río Potrero Grande in Santa Elena contains the only pristine mangrove stand that occurs in northern Pacific Costa Rica.

4. DRY FOREST MARINE INTERTIDAL (Cover). Owing to inaccessibility, the marine intertidal habitat is still relatively intact along the GNP coast, in strong contrast to the remainder of northern Pacific Costa Rica (where snail and clam collecting for food has all but eliminated most molluscs,

for example). The turtle nesting beach is protected within Santa Rosa (Cornelius 1986) but if farmers were to colonize Santa Elena, the nesting beach would be virtually impossible to protect from human egg gatherers and turtle meat hunters. The five coastal preserves (Corcovado, Manuel Antonio, Cabo Blanco, Ostional and GNP) would serve as an adequate Pacific coast national seashore for Costa Rica.

5. ISLANDS. The Islas Murciélagos off the tip of the Santa Elena Peninsula *(Figure 5)* contain a perturbed but naturally severely depauperate dry forest fauna and flora. In view of the decreasing rainfall gradient westward along the Santa Elena Peninsula, and in view of the total absence of dry season water on the islands, they are probably the driest terrestrial habitat in the entire country. They have not yet been studied ecologically, but experience with other Pacific coastal Costa Rican islands suggests that they will be found to contain very peculiar combinations of plants and animals, and may have endemic populations (though not species). These islands are regularly visited by fishermen and are being progressively deforested by anthropogenic fires. Some, but not all of the islands still have enough of their original vegetation to be able to return to their original forest if protected from fire and fire-wood collectors.

6. FRESH AND BRACKISH WATER SEASONAL MARSHES. These marshes occur on the Santa Rosa plateau in the interior of Hacienda El Hacha and Orosi, near the highway intersection at the northeastern corner of Hacienda Santa Elena, and inland from the coast in the southern lowlands of Santa Rosa. Small in area and severely disturbed by deforestation, fire and cattle, these sites nevertheless contain a unique flora and fauna (e.g., *Isoetes*, L.D. Gómez, personal communication) which would likely recover its original structure were it allowed to do so.

7. POST-MANGROVE PROSOPIS SWAMP. Immediately behind the mangroves in Santa Rosa and a few places in Santa Elena and Murciélago are unique patches of cacti, mesquite, divi-divi and other dry-land perennials. This forest type has been obliterated by harvest of firewood (to be used in salt extraction) in almost all other dry coastal Pacific sites in Costa Rica.

8. ALLUVIAL SEMI-DECIDUOUS BOTTOMLAND FOREST *(Cover)*. Behind the coastal beaches were expanses of tens to hundreds of hectares of flatland forest on rich and moist alluvial soil. They contained several hundred species of trees, about 20% of which were evergreen. In Santa Rosa, as well as elsewhere (e.g., Potrero Grande River valley bottom in Santa Elena), these forests were severely but patchily felled; however, within Santa Rosa a mere 14 years of protection has allowed them to replace all fields and pasture with 3-20 m tall secondary woody succession that contains the original animals and plant species (though in very different proportions than originally). Smaller versions of this forest occurred in Murcielago and behind other seasonal river mouths in Hacienda Santa Elena.

9. STRONGLY DECIDUOUS HILLSIDE FOREST *(Cover, Figure 17-18)*. The sides of the Santa Rosa plateau, the hillsides of the Santa Elena Peninsula, and the small slopes throughout GNP below 300 m elevation bear a complex deciduous forest ranging from 2 m tall and totally deciduous in the dry season (on south-facing upper slopes on ridges, especially on the peridotite or serpentine substrates of the Santa Elena Peninsula) to 30 m tall with as many as half of the trees evergreen. At least 600 species of broad-leaved plants occupy this vegetation. A salient feature of this forest is that after it is cut, the woody regeneration that appears in its place is much more deciduous than was the original (until after the several hundred years that are necessary for the slow-growing evergreens to strongly reoccupy the site). Owing to the complicated

disturbance regime over the past 400 years in the GNP area, extensive and detailed study is required to know to what degree a particular patch of deciduous forest is pristine or a product of secondary succesion. Cutting and fire has long ago cleared most of the deciduous hillside forest from most of the Santa Elena peninsula *(Figure 19),* but small patches remain sprinkled over the surface, patches that will spread and coalesce if the fires are stopped. A peculiar and depauperate version of this forest occurs on a single minute limestone hill in the Santa Rosa bottomlands.

10. EVERGREEN CANYON FOREST. The many escarpments and small canyons of the Santa Rosa plateau bear (bore) a nearly evergreen forest that was 30-plus m in height and dominated by guapinol *(Hymenaea),* tempisque *(Mastichodendron),* ojoche *(Brosimum),* terciopelo *(Sloanea),* nispero *(Manilkara),* caoba *(Swietenia),* guavo *(Inga),* higo *(Ficus)* and other large evergreen trees lacking common names. These species also occur on the upper slopes of the two volcanos, but intermixed with at least 100 other species of trees that do not occur at the elevation of the Santa Rosa plateau. Just as with the deciduous forest mentioned above, when this evergreen forest is cleared it first regenerates as strongly deciduous secondary successional forest. The shady and leafy evergreen canyon forests are extremely important local moist refugia for animals of the deciduous forest during the dry season. GNP will more than double the amount of this forest type under protection.

11. EVERGREEN OAK FOREST *(Figure 20-22).* The Santa Rosa plateau (220-350 m elevation) and its extension to the base of the modern volcanos at about 500 m elevation, was once covered with a nearly monospecific stand of encino *(Quercus oleoides)* growing on a volcanic ash flow (rockhard substrate with poor water retention and supporting only slow-growing plants). This unique forest (it is the southernmost lowland oak in the Neotropics) extended as far south as Bagaces and is the southern-most extension of what is known in the US as Virginia live oak *(Quercus virginiana).* Scattered throughout the GNP oak forest are members of at least 80% of the deciduous and evergreen forest species of plants; when the oak forest is cleared, they then take over the site and convert it to deciduous or semi-evergreen forest. If the cleared site is also burned, it changes to natural or introduced grassland occupied by the most fire-resistant of the deciduous forest trees. If pristine or partly cleared oak forest is protected from grass pasture fires, it very slowly reinvades the site. However, while virtually all of Santa Rosa's oak forest is too seriously perturbed to perpetuate itself, GNP contains at least five 5-20 ha patches of essentially pristine oak forest, and several thousand hectares of only mildly disturbed oak forest.

12. PASTURE HABITATS *(Figure 12, 23, 25, 27, 31, 35, 36)* Between 250 and 800 m elevation in GNP there are at least 200 km^2 of pasture (locally termed sabanas or llanos). They are arranged in a complex network and mosaic, and with many different histories. All GNP grasslands are maintained as grasslands by anthropogenic fires every 1-3 years *(Figure 30-31),* most are occupied by introduced African grasses, all had their origin in forest clearing, and all begin to revert to woody vegetation as soon as the fires are stopped *(Figure 30 lower).* The rate of reversion depends on grass species, soil type, wind exposure, proximity of seed trees, pasture size, and wild and domestic animal density as seed dispersers and grass suppressors *(Figure 36).* While at least a quarter of GNP is now pasture, the configuration of the pastures and their proximity to forest fragments is such that they revert rapidly to woody vegetation; the process of this reversion is of great academic and applied interest, and undergoing intensive field experimentation and analysis at Santa Rosa at present.

13. ATLANTIC-PACIFIC SEMI-EVERGREEN FOREST *(Figure 26-28).* The broad erosion valleys and some slopes of the lower half of Cerro El Hacha are still partly clothed in virgin forest. The forest is a checkerboard with 1-5 year old corn and bean fields. Even so, it contains more standing tall virgin dry forest than is contained in all Mesoamerican conserved areas put together. One block of about 200 ha is the largest block of Mesoamerican tall virgin dry forest in existence. The Cerro El Hacha forest is so evergreen that it creates ever-flowing creeks despite its six month rain-free season. It contains enormous individuals of trees that are known as fence-post trees throughout the remainder of Guanacaste (e.g., *Gliricidia sepium).* The presence of "Atlantic rainforest" plants and animals (e.g., the terciopelo, *Bothrops asper;* dumb cane, *Dieffenbachia*) on Cerro El Hacha reinforces the impression from Santa Rosa National Park that Guanacaste Province is now substantially drier than it was when covered with its original forests. When cleared, the Cerro El Hacha forest becomes grassland *(e.g., Figure 24-25, 37)* and its streams stop flowing in the dry season. When the cut forest is allowed to return to forest after a farming cycle, the vegetation is largely deciduous. During the dry season, the Cerro El Hacha forest is extraordinarily rich in insects that are obviously local migrants from the nearby dry forest.

14. VOLCANO SLOPE EVERGREEN RAINFOREST *(Figure 26-28).* From about 500 to 1000 m elevation on the western slopes of Volcán Orosí and Volcán Cacao lies a nearly pristine rainforest that contains an amazing number of Guanacaste dry forest species (but with much taller and more evergreen life forms) as well as many species of the wetter portions of Costa Rica. Likewise the animals in this forest are a mix of Atlantic and Pacific species; at present we do not know which of the species from the dry forest are migrants and which are residents). The extremely tall and large trees are very peculiar in that they bear almost no vascular epiphytes and vines. This suggests that the soil is moist but the air is dry. This habitat has at least a 7 month rainy season, is 4-8 C cooler than is GNP as a whole (and therefore relatively more moist), and displays much slower rates of forest invasion into pasture than is the case in GNP at lower elevations. This forest, and the semi-evergreen virgin forest mentioned above, are major dry season refugia and corridors to Atlantic rainforests for the many animals the pass the dry season away from the dry forest.

15. CLOUD FOREST. The upper 500 m of elevation of 1500 m Volcán Orosí and Volcán Cacao are bathed in clouds *(Figure 26-27)* at least 11 months of the year. The forest is dwarfed, heavily laden with lichens and other non-vascular epiphytes, and drips continually. Its water is the starting point for the everflowing rivers passing through the lower reaches of GNP. Because the volcanos are very conical and pointed, these are the smallest habitat islands of cloud forest in Costa Rica, and those at the lowest elevation (cloud forest normally starts above 1800 m elevation in Costa Rica). This vegetation and its animals have never been inventoried.

16. ATLANTIC RAINFOREST. Above about 600 m elevation, the eastern slopes of the two volcanos *(Figure 3,* Orosi Forest Reserve) are covered with nearly intact rainforest. This forest blends gradually into the evergreen forest on the western volcano sides *(14 above).* Inclusion of this relatively small area of rainforest in GNP is highly appropriate because it will maximize the survival of the numerous populations whose members occur on both sides of the volcanos. These are in turn essential to the survival of the populations that occur only on the drier western sides of the volcanos and use the western sides as moist refugia during the dry season.

GNP SIZE

Guanacaste National Park needs its large size for five biological reasons: maintain habitat diversity, maintain adequate species population sizes, provide dry season refugia and migration routes, minimize edge effects, and maintain some replicated habitats for human park users.

1. MAINTAIN HABITAT DIVERSITY. Even a pristine "dry forest" habitat is fractured into a mosaic of literally hundreds of kinds of tiny habitats. This is because the physical and biotic diversity in slope, soil type, seasonal change in water flow, exposure to wind, bulk of vegetative cover, degree of evergreeness, fire regime, rainfall pattern, etc. becomes magnified through its impact on the amount and timing of water availability as the dry season comes and goes. The scarcity of water during a tropical dry season is less homogeneous than is the cold in a northern winter; the abundance of water in a tropical rainforest obliterates many of the potential inter-habitat differences that are so conspicuous in a tropical dry forest.

The high species richness of tropical dry forest is largely due to pooling across the many different habitat types created by the heterogeneity described above. This pooling occurs not only in the biologist's mind. Many species use different habitats at different times of the year. A riparian tree may be pollinated by bats that at other times of year are visiting flowers on trees in open upland dry sites. Many animals spend all or part of the dry season in a fragment of evergreen forest understory and then move into the more resource-rich canopy of deciduous forest when the rains come; others, such as seed weevils, may reproduce once per year in the dry season seeds of early successional herbs and then spend the rainy season hiding in rolled leaves in the deciduous forest understory, waiting for next year's seed crop.

To accumulate a reasonable area of any one of the dry forest habitat fragments, habitat fragments must be summed over hundreds of km^2. Three processes hamper the viewer's ability to see this:

(1) Until very recently, most research in the Costa Rican tropics was done by visitors from extra-tropical regions; being largely from universities, they visited during the northern summer, which is Costa Rica's rainy season. In the rainy season, the dry forest is painted green and wet, and habitat differences blur.

(2) Humans are accustomed to thinking in terms of vertebrates and large plants, and these are the most generalist organisms, the organisms least likely to depend on very fine scale inter-habitat differences. The white-tailed deer, collared peccary, jaguar, mountain lion, tapir, and white-faced monkey may be encountered in all GNP habitats, albeit at different densities. However, the vast majority of the species in GNP are small –for example, there are 3,000–plus species of moths and butterflies and many more other species of insects. Such animals show high habitat fidelity in where they breed, mate, rest, etc. For example, if you want *Bardaxima perses* (a notodontid moth) in your dry forest, you have to have a evergreen understory and it has to have *Ouratea lucens* (Ochnaceae) shrubs for the caterpillars to eat. And so on and so forth.

(3) Animals wander and plants are widely dispersed. This means that habitats characteristically contain a large number of species that may best be described as strays. This blurs habitat distinctiveness. On the other hand, strays are also important parts of the food chain and pollinator and seed disperser networks.

There is another reason why a dry forest reserve must be large enough to contain many small replicates of habitats. From year to year, dry forest is

subjected to frequent and violent changes in weather. At Santa Rosa, for example, the annual rainfall during the past five years has varied from 900 to 2400 mm of rain. The small dry season in the middle of the rainy season has varied from 0 to 8 weeks in length. Habitats altered by these weather changes recover largely through immigration from habitats and species pools in other sites that were affected. In GNP, where the absolute number of habitats has been severely reduced through habitat destruction, the problem will be even greater until nearly total reforestation has been achieved. The scarcity of habitat types is rarely reflected in collective terms like "dry forest". For example, there are only 5 known ever-flowing springs in Santa Rosa's 108 km^2. Santa Rosa contains only two small canyons that are moist enough to maintain vanilla orchids. In all of GNP there are only about 20 km^2 of habitat suitable for the endemic legume tree *Ateleia herbert-smithii (Figure 31).* There is only one pool in Santa Rosa large enough to serve as a dry season refugium of muscovy ducks (but the everflowing rivers in GNP *(Figure 14)* will also serve in that capacity if hunting is stopped). There is no patch of pristine oak forest in Santa Rosa more than a few tens of meters on a side.

2. ADEQUATE SPECIES POPULATION SIZES. For large vertebrates such as the jaguar, mountain lion, and tapir *(Figure 32),* the breeding population in Santa Rosa (10-50 individuals) is simply not large enough to avoid inbreeding and subsequent genetic decay, genetic drift, and obliteration by disease epidemics. The same applies to at least 30 species of dry forest trees in Santa Rosa. Santa Rosa is not large enough to maintain even a single herd of white-lipped peccaries. While insects and other small organisms would appear to exist at population densities high enough that even a few km^2 of habitat would be adequate to maintain them, in fact the past 5 years of intensive census of moths at Santa Rosa has demonstrated enormous species-specific fluctuations in density among years, with the species appearing to disappear at the bottom of the fluctuation *(e.g., Janzen 1984b).* Likewise, small animals (and plants) are often much more habitat-specific than are the large ones, with the consequence that a much smaller proportion of the overall habitat is suitable for them.

There is an important, but often overlooked, aspect of the loss of tropical animals from a habitat. Almost all play conspicuous roles in internal habitat structure through seed dispersal, seed predation, selective browsing, pollination, predation on herbivores, etc. The biotic impact of the loss of species is most dramatically displayed on islands, where whole suites of species display demographies and behaviors grossly different from that of conspecifics on nearby mainlands.

3. PROVIDE DRY SEASON REFUGIA AND MIGRATION ROUTES. A substantial fraction of the dry forest animals use local moist areas as dry season refugia. Many of the mobile ones move as far as the semi-evergreen virgin forest on Cerro El Hacha and the evergreen slopes of the volcanos (up to 30 km from the farthest point in GNP). It is likely that the final blow to the white-lipped peccary in Santa Rosa was the opening of the pastures along the Interamerican Highway; these pastures form a broad unforested barrier between Santa Rosa and the volcanos. Movements between the dry lowlands and moist rainforest are not restricted to movements to escape the dry season, however. It is clear that Santa Rosa is visited by some species of rainforest birds only during the early dry season.

Strongly cross-tropical migratory species are also involved. For example, at least 40 species of sphingid moths arrive in Santa Rosa at the beginning of the rainy season (from the rainforest), have one or two generations in Santa Rosa, and then fly back over to the Atlantic side of Costa Rica to spend the

remainder of the year *(e.g., Janzen 1984c)*. A dry forest preserve the size of GNP is needed to maximize the survival of migration routes, maximize the area of the breeding grounds for the rainforest species, and minimize the possibility that they will disappear because they cannot find a little dry forest dot called Santa Rosa.

4. MINIMIZE EDGE EFFECTS. As a general rule of thumb, when wildlands connect abruptly with agriculturized land, edge effects in biological and physical processes penetrate at least 1-2 km into the wildlands. Different animals and plants will experience this differentially, but at an absolute minimum the habitats on 50-100 km^2 of GNP will suffer edge effects. These habitats will be quite rich in vertebrates (owing to high productivity of vertebrate food by secondary succession and edges). However, the blessing of increased wildlife density is mixed. These animals then use nearby pristine vegetation more heavily (browsing, fruit eating, trampling), and disperse many more secondary successional seeds in and into it than is normal. Even with all the protection that Santa Rosa receives, for example, this process in strongly altering the small pieces of pristine forest within the park *(Janzen 1983a)* The concept of small blocks of pristine forest in the neotropics is simply an optical and temporary illusion.

5. HABITAT REPLICATION FOR HUMAN USE. A user-friendly national park must have a variety of areas and habitats that are freely open to moderate to heavy public educational and recreational use. An area sufficient for this purpose is likely to be considerably larger than the area required simply for traditional biological reasons. Humans have an impact, whether they are individual researchers, school groups, tourists or solitary hikers; complex tropical ecosystems are easily perturbed by human presence and there must be enough habitat replicates that some can be used by humans without fear of eliminating a unique habitat. Likewise, some major research projects may require the relatively exclusive use of a particular habitat piece for many years. Finally, long-term manipulative reforestation model projects will require substantial space. GNP is large enough to contain small to moderate numbers of replicates of at least some of its more spectacular but fragile habitats (e. g., everflowing rivers, beaches, evergreen canyon forests, mangrove forests, pristine forest of all kinds, xeric ridges, springs). It also contains sufficient area for replicated substantial natural and manipulative reforestation projects.

FAUNA

Of the area to be included in GNP, only Santa Rosa National Park has detailed faunistic surveys to date. Its 750 species of plants sustain at least 175 species of birds, 115 species of mammals, 3140 species of moths and butterflies, and at least 10,000 other species of organisms. Extrapolating from preliminary visual surveys of the remainder of GNP and from surveys of other parts of Costa Rica, the birds of GNP should be about 300 species, the mammals about 140 species, the moths and butterflies about 5000 species, and the plants about 3000 species when all of GNP is surveyed. Most of this increase is due to the inclusion of the semi-evergreen virgin forest on Cerro El Hacha and the western sides of the volcanos. If these estimates err, they err on the low side.

The GNP fauna is overall representative of that of dry forest throughout Pacific Mesoamerica. It contains many wide-ranging species that also range into rainforest and into South America. There is, however, an abundant distinctive dry forest fauna that is found, in Costa Rica and elsewhere, only in the dry forest. When a GNP faunal list of a major group such as birds, moths,

bats, or beetles is compared with one from a Costa Rican Atlantic rainforest, there is only a 10-20% reduction in species richness. This reduction is so small because there are many dry forest species that do not occur in the rainforest; the latter category substantially lengthens the GNP species list. Owing to the extreme seasonality of GNP, one might expect that its species richness would not be great in comparison with extra-tropical seasonal habitats. For many groups, however, this is not the case. There are more species of butterflies, large moths, and mammals in GNP's 700 km^2 than in all of the US east of the Mississippi River.

Many animal life forms classically thought of as "rainforest animals" (e.g., sloths, tapirs, white-lipped peccaries, spider monkeys, howler monkeys, white-faced monkeys, army ants, morpho buttherflies, scarlet macaws, toucans, red-lored parrots, carnivorous bats, etc.) occur in GNP but at lower density or only as seasonal members of certain habitats. GNP does not receive a heavy dose of extra-tropical migrant birds (though dry forest does do so in other parts of Mesoamerica); these birds appear to make more use of Costa Rica's evergreen rainforests than her dry forests. Furthermore, the northern migrants leave Costa Rica for extra-tropical regions about the time (or earlier) that the rainy season begins and the large flush of food appears during the first two months of the rainy season.

Along with the many wide-ranging species that occupy Santa Rosa there are a very few endemic species (e.g., the saturniid moth *Schausiella santarosensis* and see Cover). However, many of the dry forest species that once occupied all of the Costa Rican dry lowlands are having their populations dramatically reduced to tiny populations in widely scattered preserves such as GNP, thereby rendering them "anthropogenic endemics". In addition, many of the less mobile animal species in GNP's dry forest belong to a population that is morphologically distinct from the same species on the wet side of Costa Rica. In general, GNP individual birds, moths, and monkeys are smaller and lighter in color than are their rainforest conspecifics. We do not yet know how much of this difference is genetic and how much an ecological expression of the shorter rainy season, longer dry season, greater insolation, greater temperatures, and other seasonal forces.

The GNP fauna is conspicuous in that it reinvades abandoned pasture vegetation more rapidly than occurs in analogous habitats in Costa Rican rainforests. The same is true for the woody vegetation, and the two are mutualistically related. The animals move seeds as well as eat the fruits and foliage. There is also a distinct gradient within GNP; pasture invasion by forest is much more rapid in the central and western parts of GNP (drier, warmer and lower elevation) than it is on the slopes of the volcanos (moister and cooler).

HUMAN OCCUPATION OF GUANACASTE NATIONAL PARK

PREHISTORIC

The GNP area overall has been at best trivially surveyed or developed for its archaeological sites. Santa Rosa contains a variety of unstudied ancient grave-sites as well as at least one very large village site in the lowlands near the ocean. The headwaters of the Río Sapoa on the lower slopes of Cerro El Hacha have been thoroughly studied and related to Indian groups living slightly more to the north. The recent spectacular results from intensive archaeological exploration of the Tilaran region (at the elevation of the volcanic slopes in GNP) 80 km to the southeast suggest that there may be still much of value to be understood about the site's archaelogy.

CONTEMPORARY OWNERSHIP

Land ownership of GNP is almost entirely in the form of large holdings (Figure 4) managed as business investment and owned by persons living elsewhere. At least in 1986, seven owners of large properties, one owner of a small property, and one collective colony of settlers on small parcels are the people with which direct negotiations are necessary. In addition, several tiny land fragments need to be obtained from large ranches on the south boundary of Santa Rosa. The ownership of each of the parts of GNP is described below in detail. The relationships with settlers and ranchers living near the boundaries of GNP will be discussed later.

1. SANTA ROSA NATIONAL PARK (SANTA ROSA SECTION). (Cover). 108 km^2. On 27 June 1966, SRNP was expropriated and declared a National Monument (Law No. 3694). By Executive Decree No. 1562-A of 20 March 1971 it was declared a National Park. On 4 May 1977, Santa Rosa was enlarged by Executive Decree No. 7013-A so that the park's major drainage basins were almost completely enclosed by the park. Santa Rosa is occupied by a small staff of about 20 administrators and rangers, about ten of which are in the park at one time; all of them have homes elsewhere in Costa Rica.

2. SANTA ROSA NATIONAL PARK (MURCIELAGO SECTION), 122 km^2. On 13 November 1980, Hacienda Murciélago was expropriated and established as an addition to Santa Rosa National Park by Executive Decree No. 12062-A. Law No. 6794 of 25 August 1982 ratified both sections –Santa Rosa and Murciélago– as Santa Rosa National Park.

Murcielago is occupied by a tiny staff of about 4 administrators and rangers, all of whom have homes elsewhere in Costa Rica.

3. ISLAS MURCIELAGOS. About 3 km^2. These multiple small islands off of the tip of the Santa Elena Peninsula *(Figure 3)* belong to the Costa Rican

government and are in the process of being officially declared part of Santa Rosa National Park. They are unoccupied but are frequently used as rest stops by fishermen from Cuajiniquil.

4. HACIENDA SANTA ELENA *(Figure 12, 17, 23).* About 130 km^2. Santa Elena occupies the area between Santa Rosa and Murciélago on the north and south, and the Pacific and the Interamerican Highway on the west and east. Santa Elena is apparently owned as investment property by the Odol Corporation in the United States. It is currently undergoing infrastructure development (roads, airport, buildings), annually subject to free-running wildfires that then threaten Santa Rosa and enter Murciélago, and lightly grazed by cattle. It is occupied by a Costa Rican overseer with a few helpers and their families (headquarters near the Interamerican Highway). There are irregularities in locations of the fences between Santa Elena and Santa Rosa National Park, but these will be unimportant if GNP can incorporate Santa Elena.

5. CERRO EL HACHA *(Figure 24-25).* About 50 km^2. The north and northeast portion of Cerro El Hacha is part of Hacienda El Amo/El Hacha/Aguas Buenas/Guitarra belonging to Sr. Luis Roberto Gallegos and other large ranches, while the southern and southestern portion belongs to the Colonia, a collection of small farms occupied by about 16 owners since 1980 and coming originally from the area of Santa Elena and Monteverde (Puntarenas Province). All owners are willing to discuss sale of their respective portions of Cerro El Hacha. While Sr. Gallegos recognizes the watershed value of Cerro El Hacha for the remainder of his cattle ranch holdings, the farm owners are in the process of clearing the forest to grow 1-2 corn or bean crops and "improve" the land value. The Colonia has already cleared approximately one third of the unique forest on Cerro El Hacha and will destroy much of the remainder in the 1987 and 1988 dry seasons

6. HACIENDA EL HACHA DE RANCHOS HORIZONTES *(Figure 20 background).* About 40 km^2. This investment property is owned by Mr. Cecil Hylton of the US and managed by Sr. Gustavo Echeverri of Ranchos Horizontes, an agricultural corporation operating out of Liberia. At present, El Hacha is operated as a minimum density cattle ranch. It is occupied by about 2 administrators and their families.

7. HACIENDA OROSI *(Figure 26).* About 30 km^2. This investment property has the same ownership as does Hacienda El Hacha de Ranchos Horizontes. At present Orosi has had almost all of its cattle removed and is occupied by 1 administrator and his family (at the ancient Orosi ranchhouse). Mr. Hylton has very kindly agreed to donate Hacienda Orosí, piece by piece, to the Nature Conservancy as part of GNP. Sr. Echeverri has promised no further development and that GNP may begin patrolling Hacienda Orosí to prohibit hunting and other intrusions (this patrolling begins in March, 1986).

8. OROSI FOREST RESERVE. 105 km^2. The portions of Volcán Orosí and Volcán Cacao above about 550 m elevation *(Figure 26-27)* are government forest reserves and cannot be legally cleared of forest. There is even a questionable law (Ley 1917, 1955) that declares the area within 2 km of the volcano craters as a national park *(Bonilla 1983).* The land ownership, however, is still in the hands of private individuals (e.g., portions of Hacienda Orosi, Hacienda Centeno and Hacienda San Josecito are within the Orosi Forest Reserve). At the present time, almost no one lives within the Orosi Forest Reserve on the west, north and east sides of the volcanos, but settlement has crept well past the margin of the Orosi Forest Reserve on the southern flank of Volcán Cacao. While the Reserve is legally protected, in fact it is gradually being cleared because regulations are not enforced.

9. HACIENDA POCO SOL *(Figure, 8, 9, 20, 22, 26).* About 40 km^2.

This operating cattle ranch has been in the Burgos family for at least 40 years, but the owner, Sr. Mario Burgos, lives in San José and is willing to sell the property for fair market value. Sr. Burgos has kindly promised, in deference to GNP, to do no development modification of Poco Sol during 1986 (but he will continue with his development planning). His son, Sr. Gustavo Burgos, lives on the property and manages it, along with his other agricultural properties in Guanacaste. There are about three administrative families and several ranch helpers living at the Ranch Headquarters near the Interamerican Highway. In local terminology, Hacienda Poco Sol consists of two properties known as Poco Sol and Garzal. A newly constructed Voice of America transmission station occupies a few hectares of Poco Sol near the Highway *(Figure 20).*

10. HACIENDA CENTENO *(Figure 15).* About 40 km². This investment property is owned by Mr. Gene Peacock, a US citizen resident in San José. It consists of three properties, Centeno, Guancastillo and Mata Redonda; the latter is the most interior and on the slopes of Volcán Cacao. Mr. Peacock plans to lease Centeno as cattle grazing land to neighboring ranchers, and has plans to develop the river bank alluvium for coconut orchards and the ever-flowing river for snail ponds. However, he has kindly agreed to stop development for 1986 in deference to GNP. He will consider sale of the entire Hacienda for a fair market value. Hacienda Centeno is occupied by one administrator and his family.

11. HACIENDA SAN JOSECITO *(Figure 27).* About 30 km². This property has been in the Baltodano family since 1935 and is currently owned by Sr. Aristides Baltodano of San José. Sr. Baltodano is eager to sell San Josecito and is currently receiving offers from other individuals; however, he is attracted to the idea of having it end up in GNP. He does not plan development during 1986. San Josecito is currently occupied by one administrator and his family.

12. HACIENDA TEMPISQUITO *(Figure 14).* About 15 km² is of interest to GNP. This property has also been in the Baltodano family since 1935 and is currently owned by Sr. Jorge Baltodano of Liberia. Sr. Baltodano is willing to consider selling the semi-forested portion of the northern part of Hacienda Tempisquito, leaving the ranch headquarters near the Interamerican Highway in his hands. He does not plan development of the area of most interest to GNP in 1986. Hacienda Tempisquito has two administrators and their families.

13. FINCA JENNY *(Figure 9, 21).* 4 km². This small piece of investment property is owned by the Gulf Land Company of Sra. Jenny Pérez of San José. It was carved out of the corner of Hacienda Santa Rosa more than 200 years ago as a real estate scheme. Sra. Pérez is willing to sell Finca Jenny, but is currently asking a price roughly double its market value. This small piece of relatively intact forest is critical to the biological integrity of the largest and deepest evergreen canyon forest (Quebrada Puercos) in Santa Rosa National Park. Finca Jenny is occupied by an administrator and his family.

14. FINCA GUAPOTE. About 2 km². The site is a tiny corner of Finca Guapote which is in turn owned by a very large cattle ranch, Hacienda Ahogados, along the southern boundary of Santa Rosa National Park. The site contains a large spring that is an important dry season watering site for animals from the park; Hacienda Ahogados prohibits hunting in Finca Guapote, but the prohibition is only partly effective because it is at the extreme northern boundary of the Hacienda. This site and Finca Jenny combined will seal off the Quebrada Puercos canyon forest from outside threat and intrusion. The possibility of sale of the site to GNP by Hacienda Ahogados is being investigated at present. No one lives at the site.

15. HACIENDA ROSA MARIA *(Figure 10).* About 3 km^2 is of interest to GNP. The site is a strip of sorghum and cotton fields along the southern boundary of Santa Rosa National Park. While almost all of Hacienda Rosa María drains to the southeast (Río Tempisque drainage to the Gulf of Nicoya), a small border area drains into Santa Rosa (Pacific drainage) and poses an imminent and serious threat to the finest of the large seasonally dry rivers in the park (Río Poza Salada); agrochemical and silt drainage from these fields has already destroyed (1984) a major creek system within Santa Rosa. The owner is Sr. Pedro Abreu of Miami, and the Hacienda is managed by his son, Sr. Carlos Abreu of San José. They have agreed to help with avoiding pesticide contamination for the time being, with the understanding that in the final negotiations over sale of this tiny fraction of Rosa María to GNP, there is discussion of the possibility of connecting Hacienda Rosa María to the Santa Rosa electricity line. No one lives on the site under consideration, though a ranchhouse with one administrator and family is nearby.

16. SOUTHWEST MARGIN OF SANTA ROSA. About 10 km^2. While presently unthreatened, the southwestern corner of Santa Rosa was established through rough terrain and unbroken dry forest without consideration of the drainage details. This minute area has yet to be explored in conjunction with the Santa Rosa neighbors. No one lives at the site.

HUMAN RESOURCES IN THE AREA

While overlapping in capabilities, inclinations and potential, three somewhat distinct groups of human resources are already present in GNP and its inmediate vicinity.

1. RESIDENTS. A large number of people living in the GNP region (roughly La Cruz to Liberia, and the small town areas of Cuajiniquil and Quebrada Grande) have residence roots 2 or more generations in length. Many of these people have grown up with minimal formal schooling (though all are literate) but have lived a varied life rich in the details of survival where farming, ranching, fishing timber extraction, civil service, and small business are the primary occupations (hunting has largely been extinguished along with the game). The overall social structure is Spanish/European/US/modern to the extent that resources permit. Upward mobility is minimal and therefore individuals with strong mental and psychological ability are encountered at substantially lower income levels than would be the case were native ability to strongly determine an individual's economic level and social status. Town and country residents display very strong curiosity about anyone or anything that approximates a learning experience, remember copious amounts of material and instructions without writing them down, and leap on opportunities to better their material goods.

The residents around GNP *(e.g., Figure 29)* form an obvious and unexploited knowledge and labor pool for the day-to-day management of GNP. They already know how to carry out most of the technical aspects - fighting fires, placing fences, maintaining horses as riding and pack animals, maintaining trails and buildings, herding cattle, identifying and understanding vegetation and trees, dealing with biotic challenges (snakes, ticks, diseases, thirst, hunger, wounds, etc.), etc. They learn rapidly about vehicles if the are not already familiar with them. If they know it is part of their job, they are self-motivated to do these things. However, they need training in the facts of biology (a combination of organizing the biological miscellanea they have already accumulated and teaching them major biological facts), in how to tell biological (sensu latu) stories to others, and in having the self-confidence to

somewhat aggressively guide others through a learning routine. The major focus of park managers drawn from this pool will be on the interface between the users of GNP and GNP biology, though these managers will also have basic maintenance responsibilities. These will be minimized through the enactment of the principle that the park interior will largely take care of itself; if labor-intensive manipulation is required for a research or reforestation program, that labor will largely be provided by the program itself.

A minimum number of 50 well-trained and apprentice residents will be needed to manage GNP in the early stages. These people will have to live in or immediately adjacent to GNP, on homesteads that will belong to GNP (if they are inside GNP) but allow individual initiative in gardens and milk cows, and in house modification and upkeep. It is clear that some of them will be drawn from the personnel already managing the various haciendas in GNP *(Figure 29 right)* while others will come from nearby farms and the towns of Cuajiniquil, La Cruz, Liberia, etc. *(Figure 29 left)*. The GNP resident managers will be maintained permanently in GNP and have individualized responsibilities. They will be sufficiently unisolated that their children have access to schools and the family has access to a normal social life.

It is assumed that certain local residents will sufficiently excel in the challenge outlined above that they will climb through the GNP administrative structure. Likewise, it is likely that some will find research and teaching activities to be sufficiently interesting and rewarding to use them to move into those worlds, either within or outside of the GNP area.

2. COSTA RICAN VISITING MANAGERS. Costa Rican managing visitors to GNP will range from students from other parts of the country who come to participate in a research/teaching program or do their own research/teaching, to technical advisors that are temporary parts of the GNP managing staff. Some of these may stay on as part of the resident managing staff, but it is assumed that they will then become residents of the area. Such persons will often bring specific important skills with them, but will require training in the technical and philosophical peculiarities of living and working in the GNP area, and in the art of making the park maximally user-friendly.

3. FOREIGN VISITING MANAGERS. Foreign visiting managers will be largely research scientists and research students. While they conduct their own studies they will also be active participants in the development of the user-friendly status of GNP. Their contribution will include aggressively making their studies well-known to the resident managers, collecting and providing background data on what organisms are in GNP and on their natural history, being advisors for Costa Rican apprentices in field biology, aiding in planning specific management programs (including the development of the tourism value of the park), and giving public lectures on their research at GNP in other Costa Rican institutions as well as in their home societies.

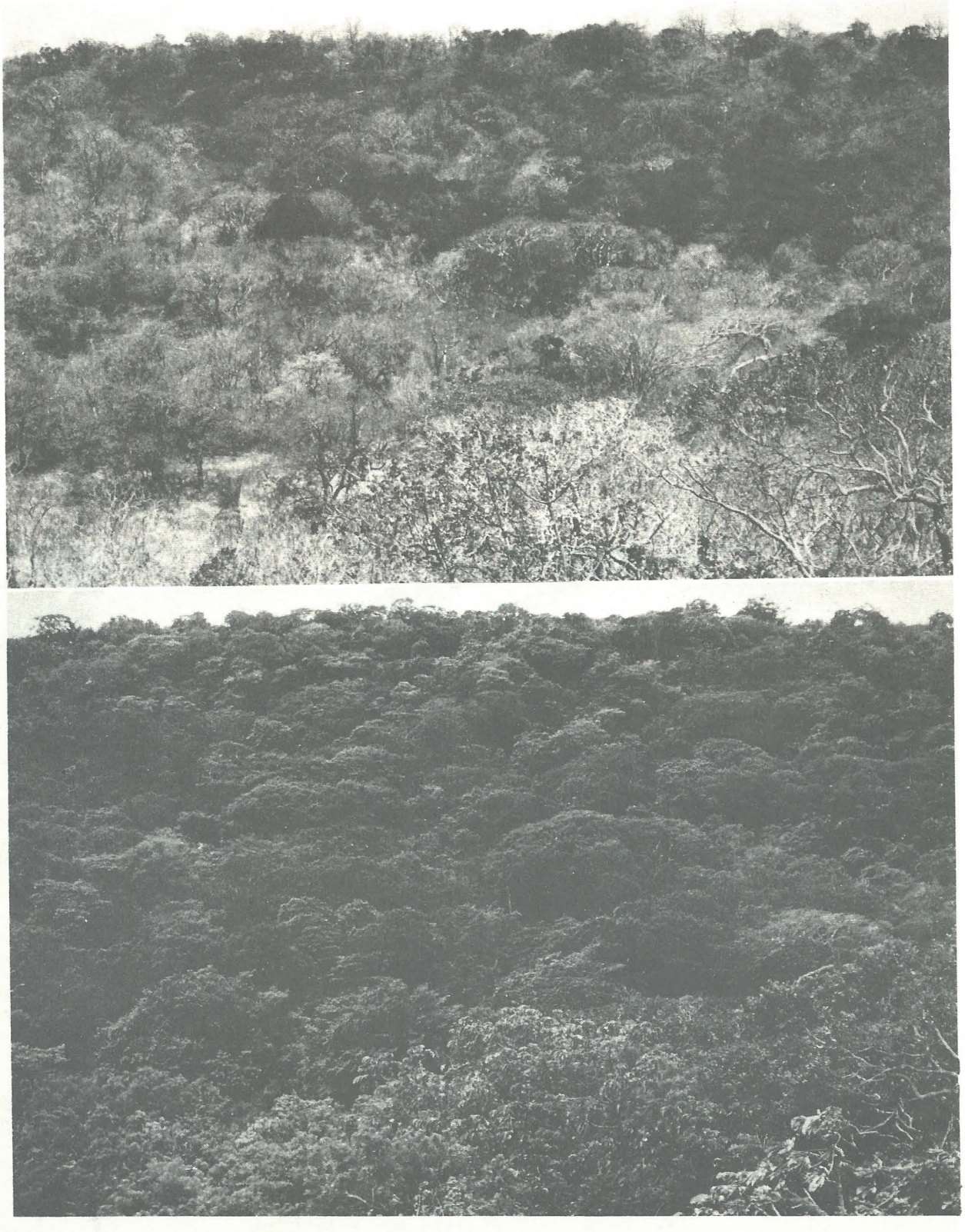

Figure 6. (Upper). Semi-deciduous dry forest in the middle of the dry season (March); the very dark tree crowns in the center are evergreen guapinol *(Hymenaea courbaril).* (Lower). The same semi-deciduous dry forest as above, but in the middle of the rainy season (July). Nature Trail, Casona area, Santa Rosa.

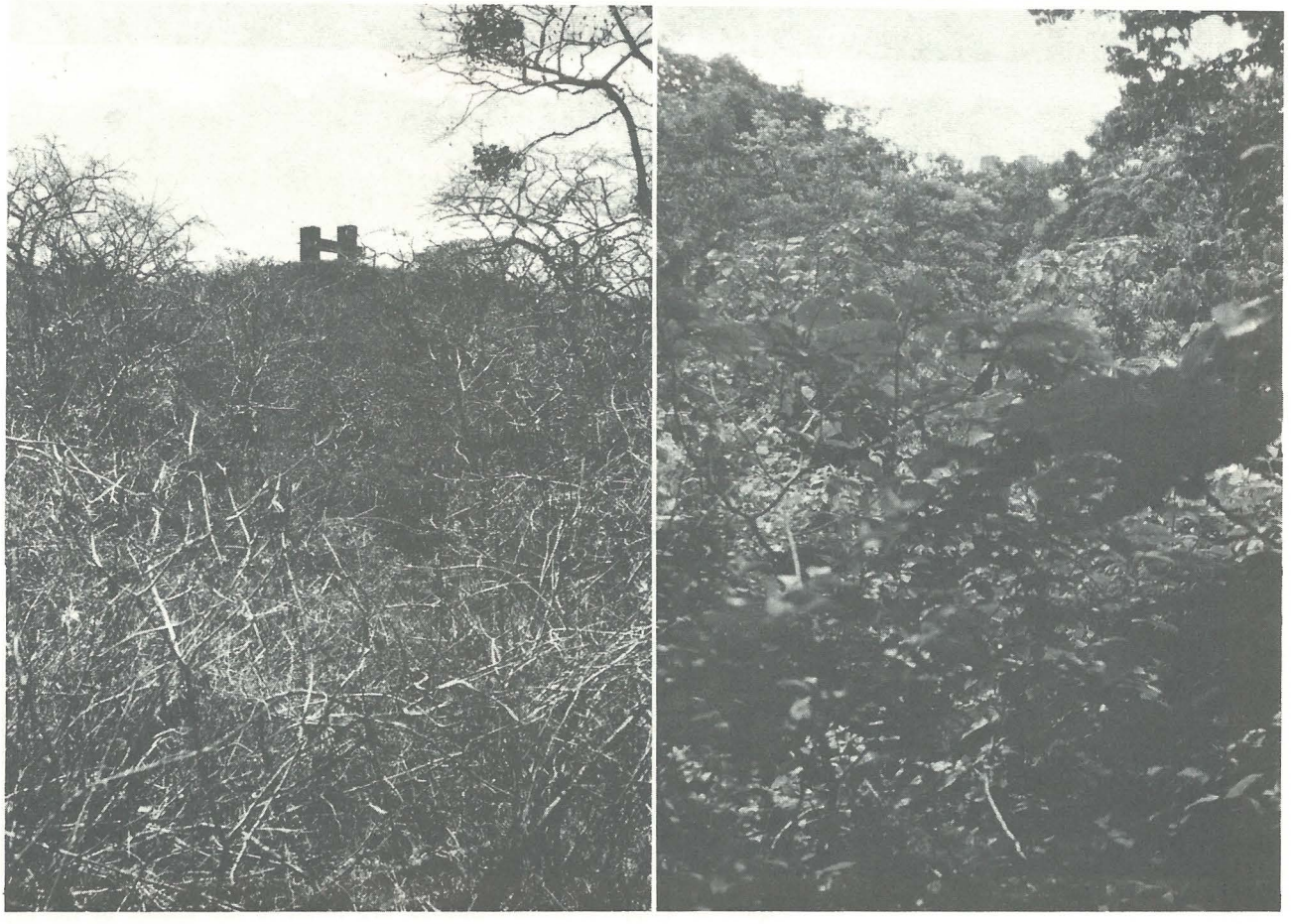

Figure 7. (Left). Same forest as in Fig. 6 during the dry season, but from the interior, looking up at the Monument behind the Casona. (Right). Same forest and view as on left, but during the rainy season.

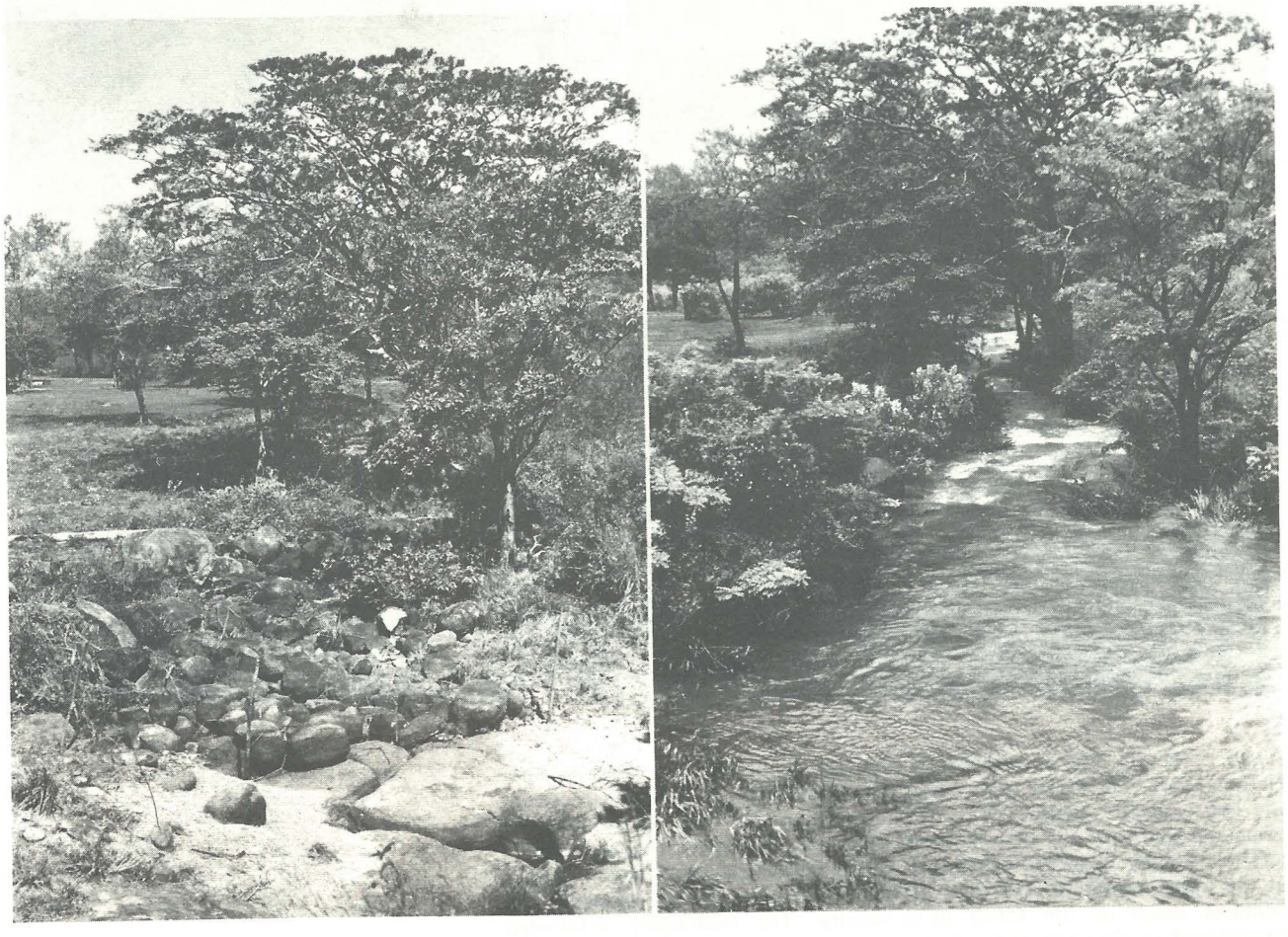

Figure 8. (Left). Quebrada Pitahaya, a seasonal watercourse, in the early dry season (January). (Right). Same view of Quebrada Pitahaya during a rainy period in the late rainy season (November). Near the Interamerican Highway, Hacienda Poco Sol.

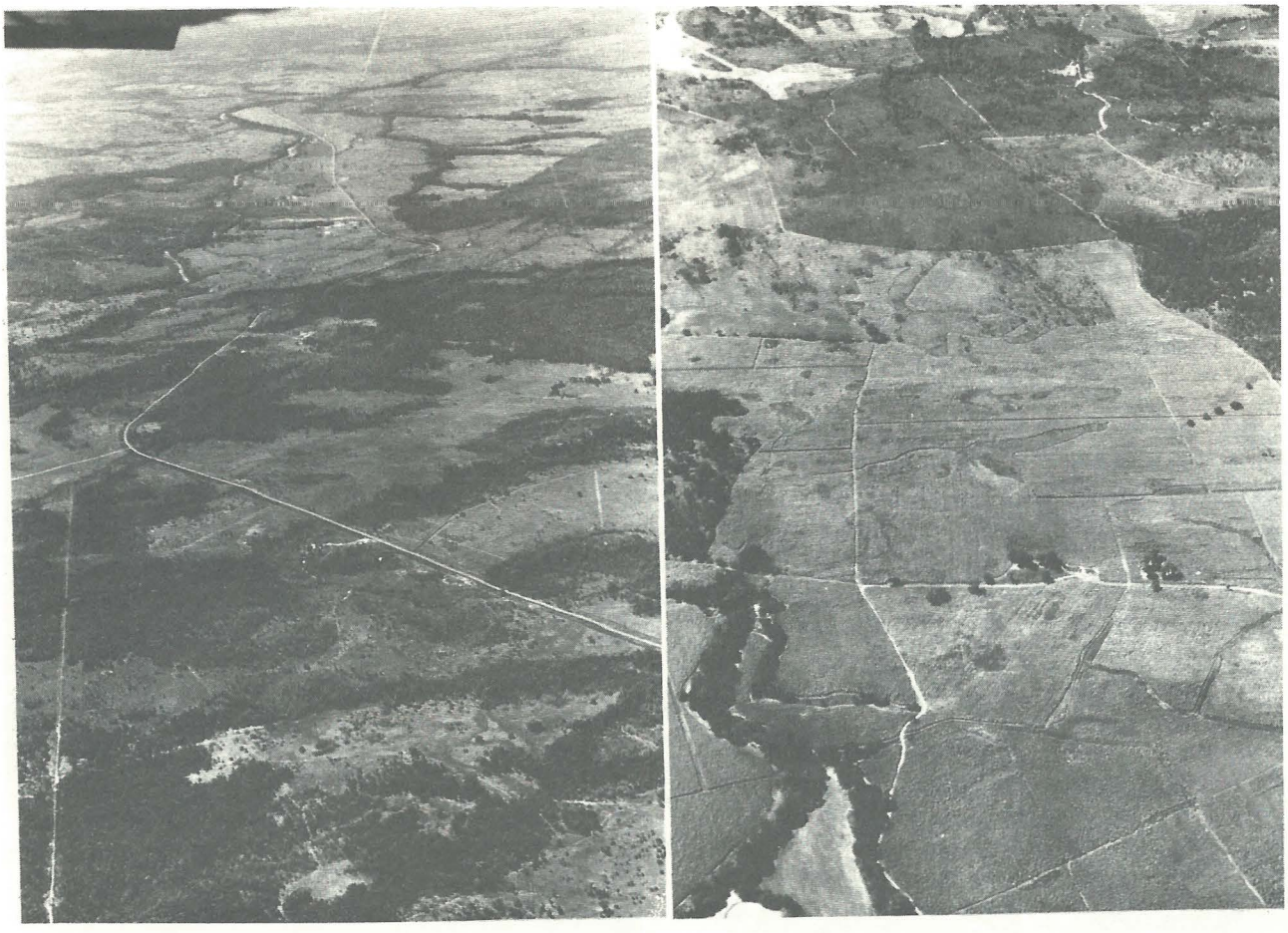

Figure 9. (Left). The Interamerican Highway at the east end of Santa Rosa National Park. The Park entrance is at the middle of the long diagonal section; the two elongate pastures at right center (in the Park) are several hundred years old and cut out of oak forest. The area below the Highway (lower left) is patchily disturbed oak forest in Hacienda Poco Sol. Finca Jenny lies at the upper center (to the right of the severe curve in the highway) and contains much of the forest in its vicinity. The thoroughly deforested pasturelands to the south of the Park are evident at the top of the photograph. (Right). Rice fields and other representative farm and pasture land in the Liberia area. This thoroughly deforested habitat has only remnant large trees and almost no reproduction by large forest trees. It is also lacks almost all forest vertebrates and insects.

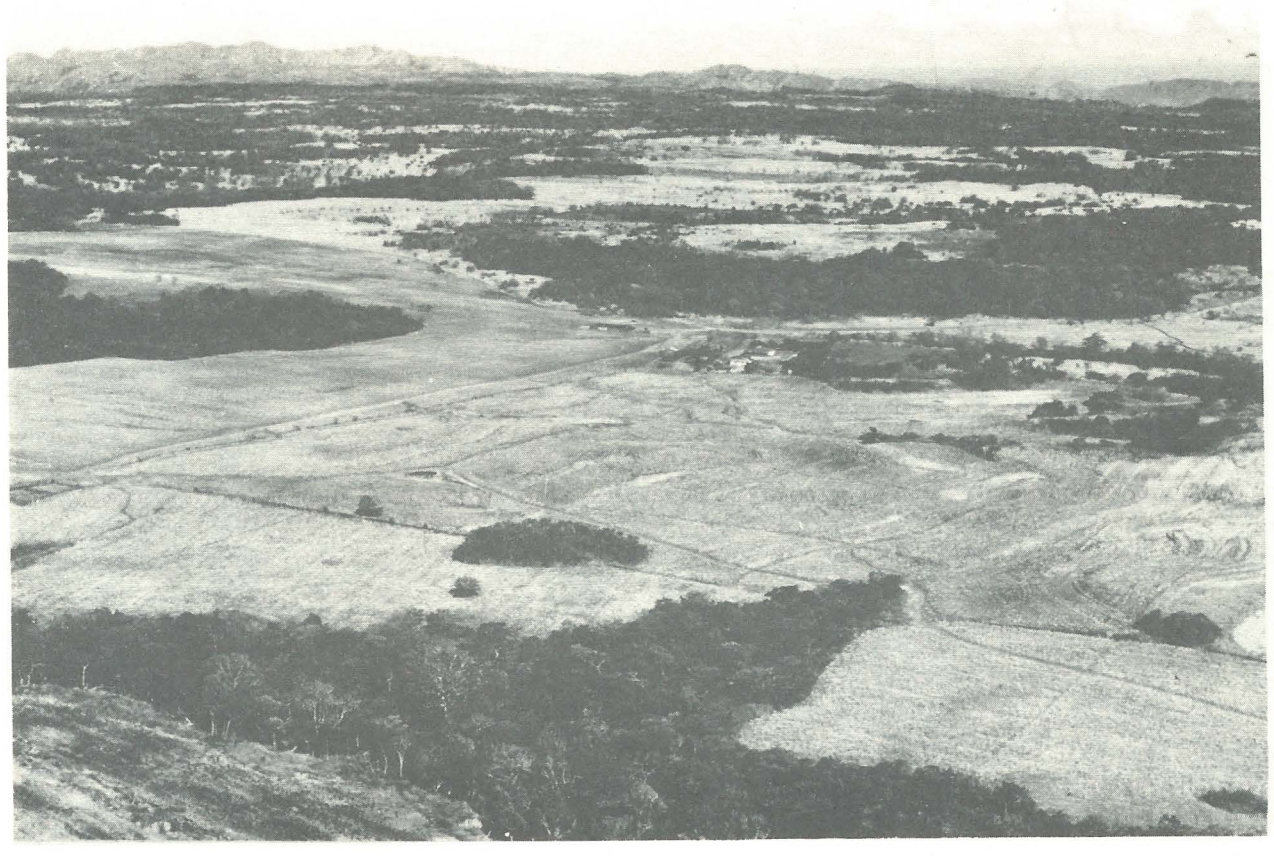

Figure 10. View northwest across Santa Rosa National Park from about 300 m elevation over Hacienda Rosa María (Santa Elena mountains on the background horizon). The uniform gray fields in the foreground are unharvested cotton. The pale jaragua pastures in the background (in the Park) are intermixed with deciduous forest patches of various ages. The cotton fields adjoin directly with the Park's unused jaragua pastures.

Figure 11. View to the north from the eastern central part of Santa Rosa National Park. Volcán Orosí is under the clouds in the background, and an ungrazed and unburned jaragua pasture (Llano Guacimal) lies in the foreground. Pastures such as these can be eliminated by stopping fires, moderate grazing by cattle, and allowing wild vertebrate seed dispersers to persist at natural density.

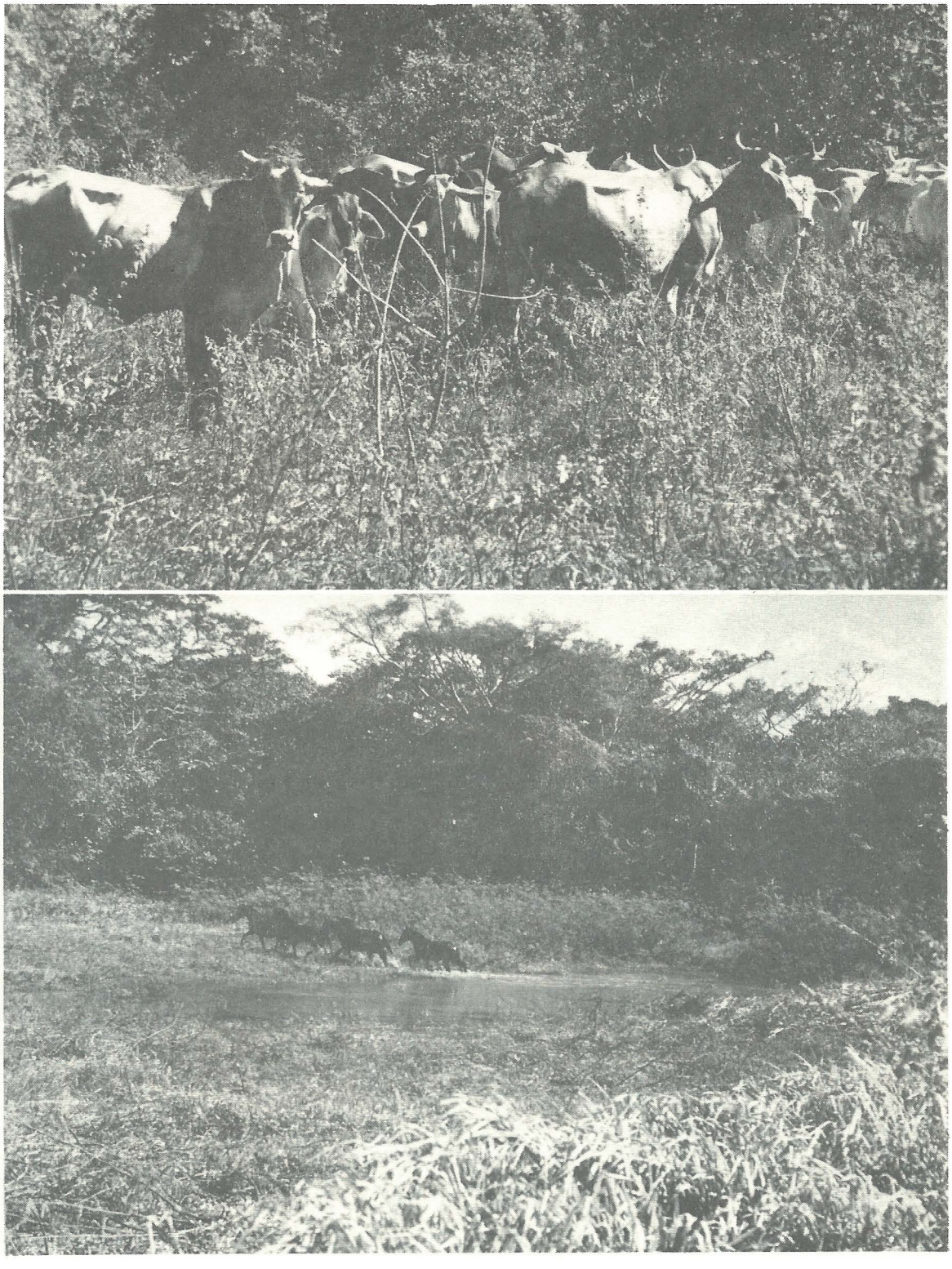

Figure 12. (Upper). Representative cebu cattle in a herbaceous pasture from which they have eliminated almost all grass by their grazing. Hacienda Santa Elena. (Lower). Free-ranging horses at Laguna Escondida in Santa Rosa National Park. Both the cattle and horses are important dispersers of forest tree seeds into large expanses of grassland, and important in reducing the grasses that compete with tree seedlings.

Figure 13. Lower Río Potrero Grande, a seasonally dry river passing through semi-evergreen and deciduous forest during the dry season. When the upper drainage basin of such a river (Figure 18, lower) is deforested, it thoroughly dries out during the dry season; if the original forest cover is retained (e.g., Figure 17, upper), the upper riverbed has pools that last through the dry season.

Figure 14. Río Tempisquito (upper Río Tempisque), an everflowing river, where it passes through Hacienda Tempisquito. During the dry season, almost all of the water in this river originates in the evergreen forests on the sides of Volcán Orosí and Volcán Cacao. Such rivers are missing from Santa Rosa National Park, but were characteristic of the Guanacaste lowlands to the south of Guanacaste National Park.

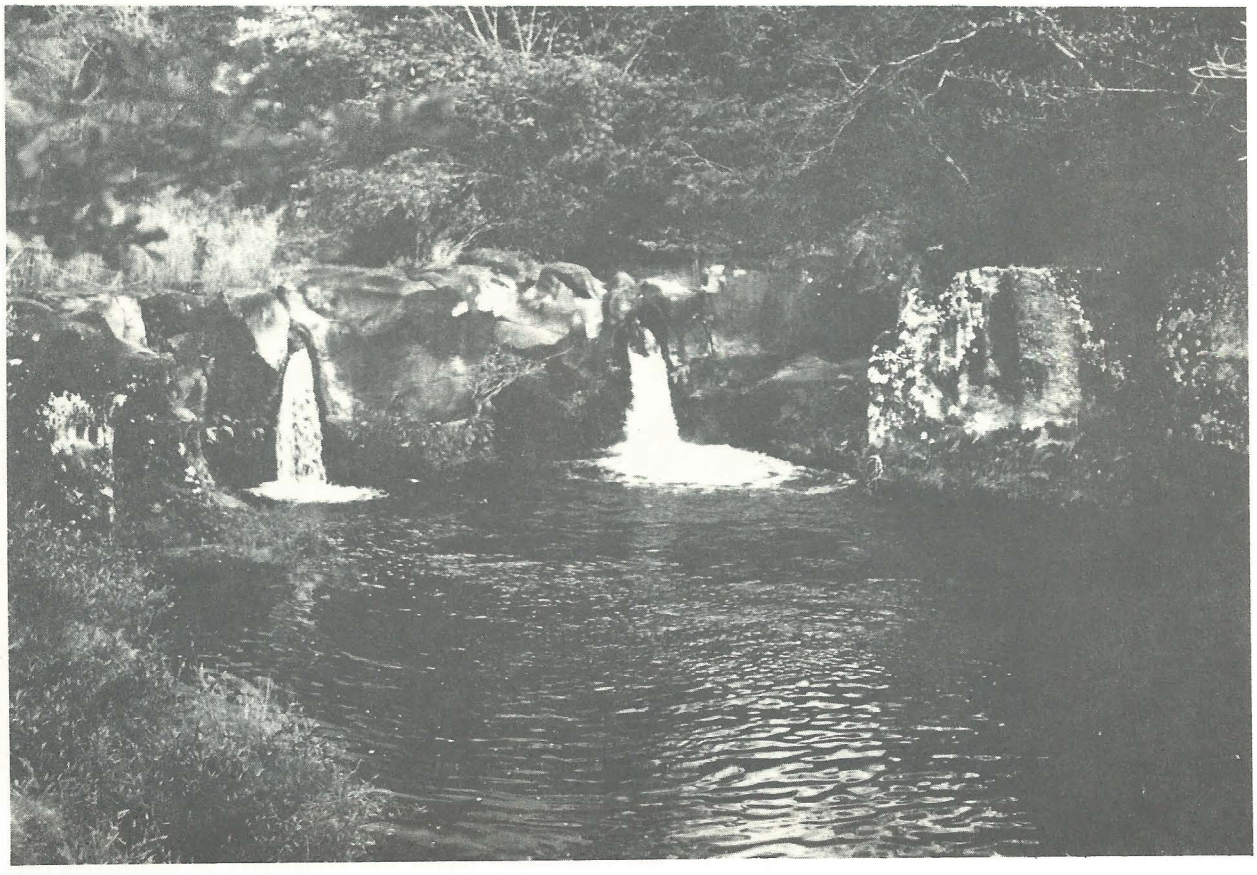

Figure 15. Río Centeno, an everflowing tributary of the Río Tempisquito (Figure 14) in Hacienda Centeno. In addition to being unique for their everflowing water, such rivers in Guanacaste National Park are also unique in being free of agrochemical contamination and being totally unstudied.

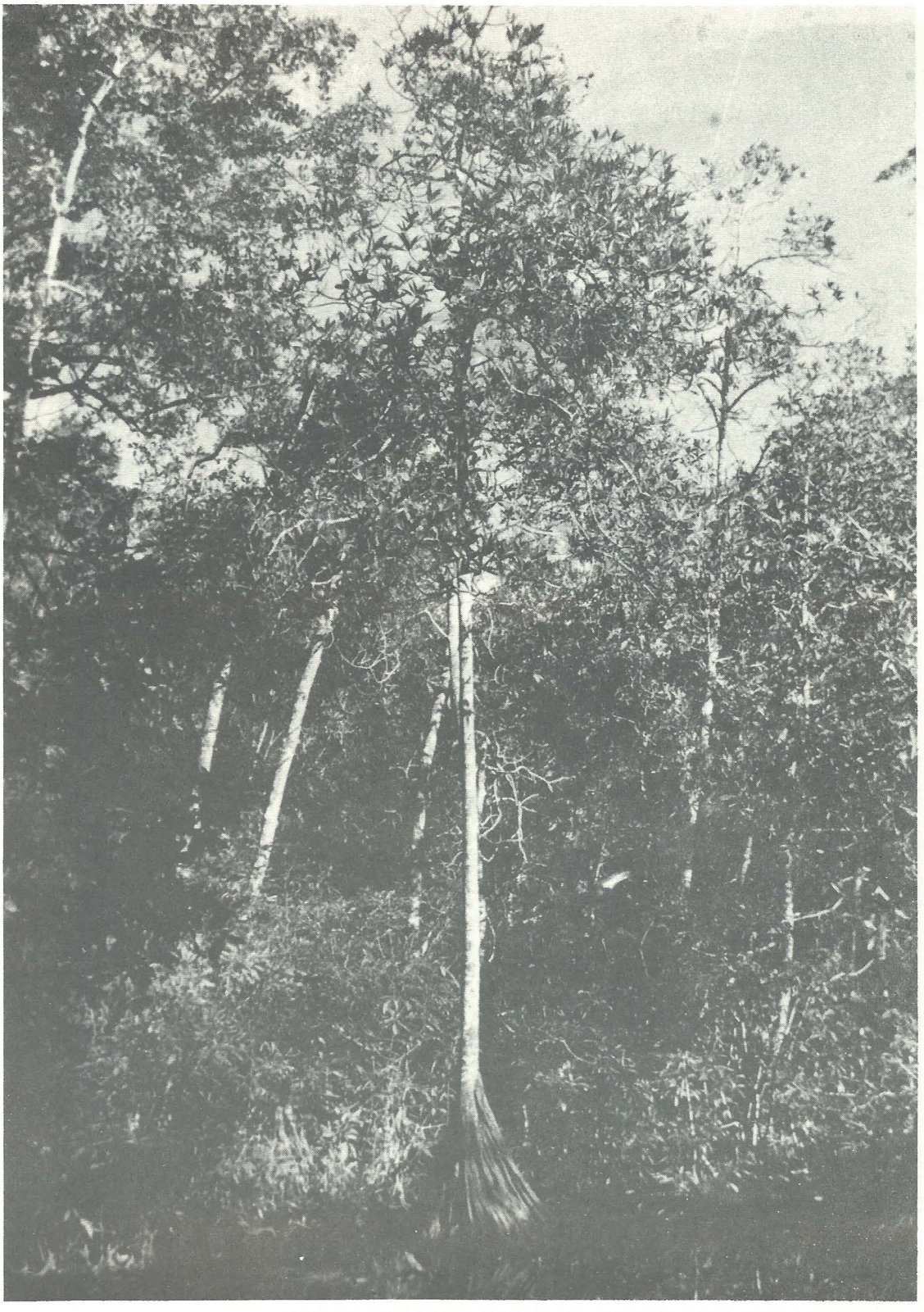

Figure 16. The tea mangrove, *Pelliciera rhizophorae*, growing in the back portion of the mangrove swamps at the mouth of the Río Potrero Grande in Hacienda Santa Elena. In northern Guanacaste Province, this species of tree is known only from this site.

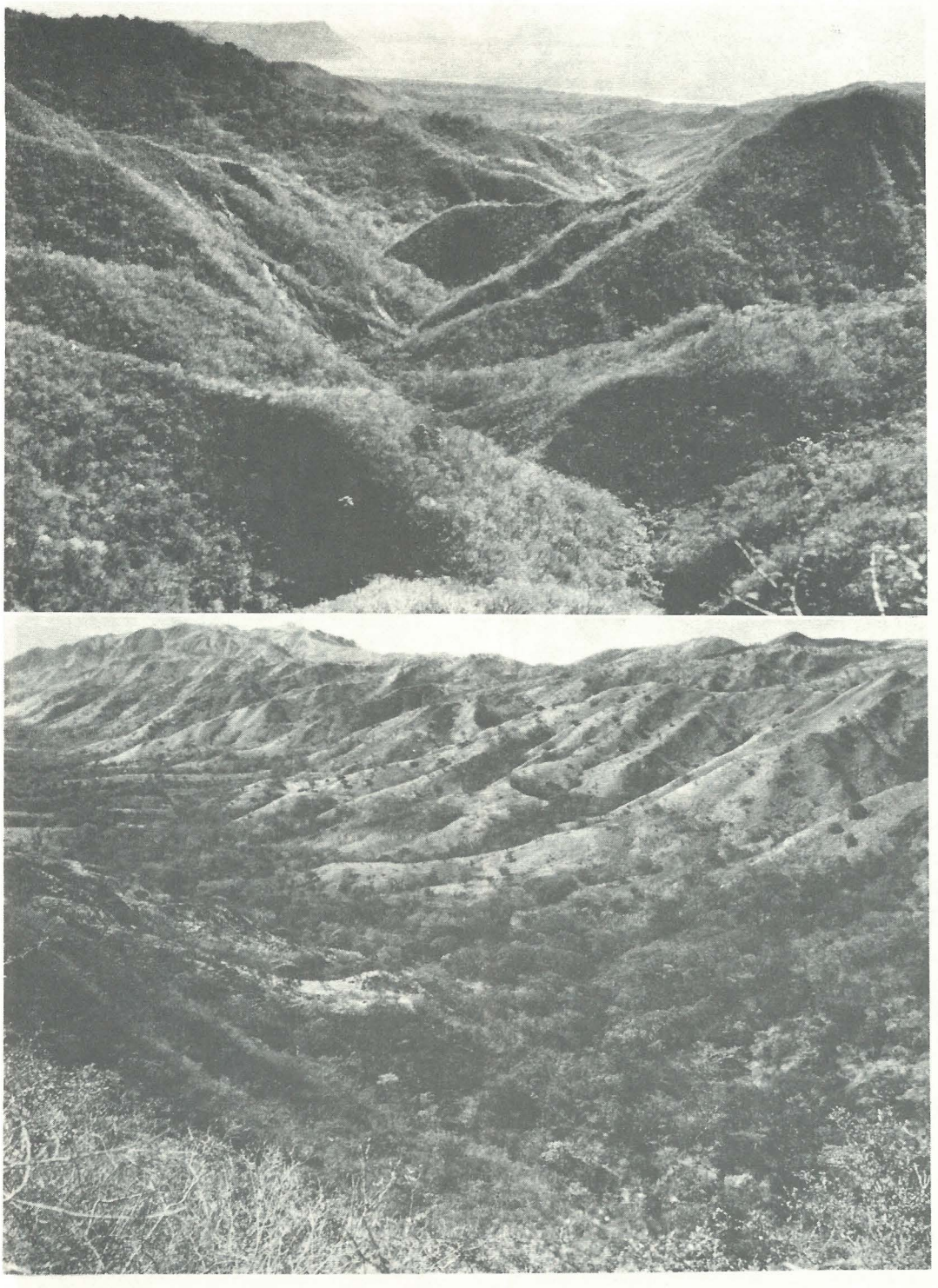

Figure 17. (Upper). The upper drainage basin of the Río Nisperal, as viewed from the north toward Playa Naranjo in Santa Rosa National Park. This deciduous forest once covered all of the dry hills of the Santa Elena Peninsula, and will be a major source of animals and plants to restore Hacienda Santa Elena as part of Guanacaste National Park. (Lower). The upper drainage basin of the Río Potrero Grande in Hacienda Santa Elena, or seasonally dry river lying adjacent to the Río Nisperal above. These deforested hills were once covered with the same forest type as in the upper photograph. The upper and lower photographs were taken from the same site.

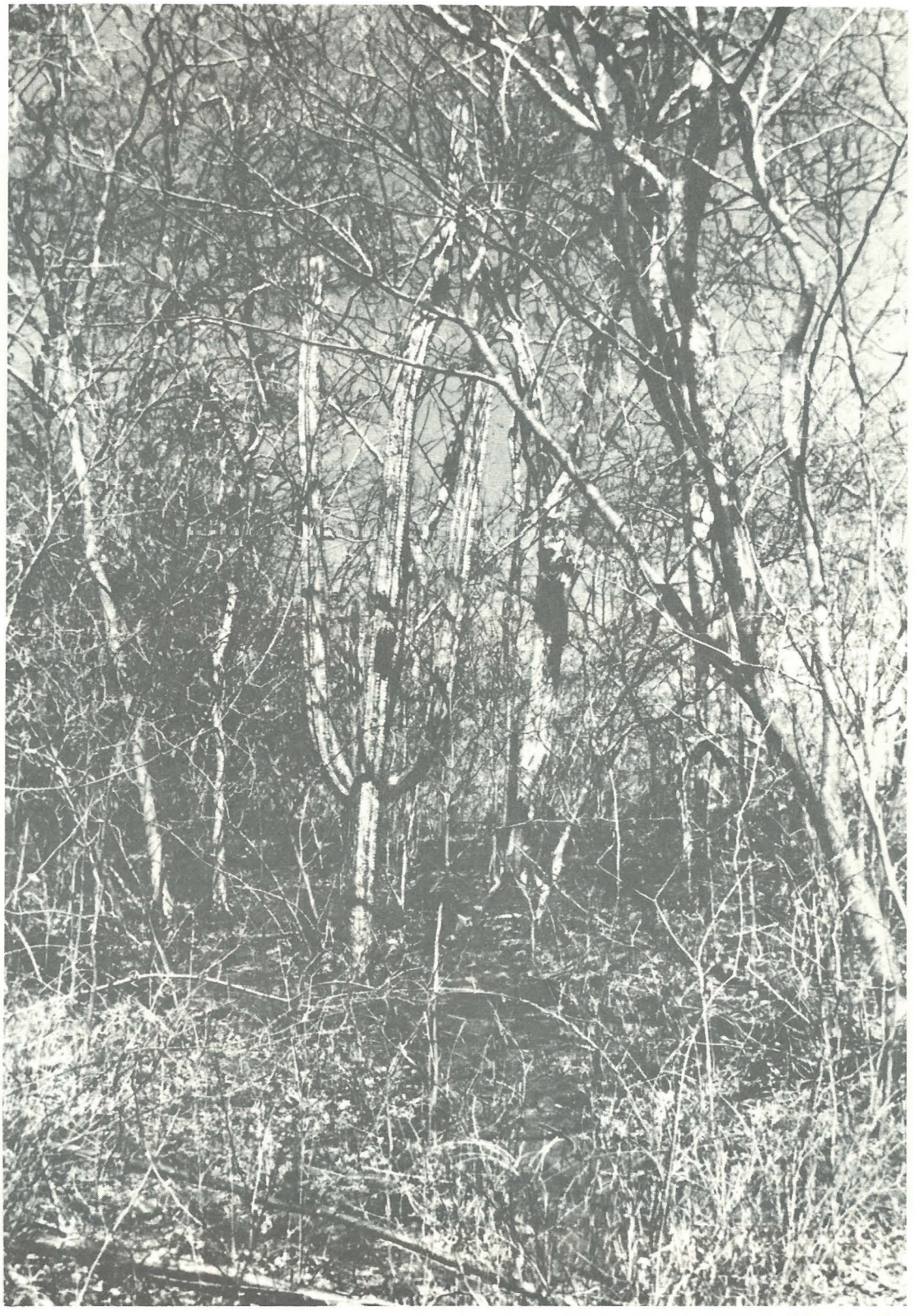

Figure 18. Dry season deciduous forest on the lower slopes behind the coastal plain in Santa Rosa National Park (the same vegetation type as in the posterior part of Figure 17, upper). The native columnar cactus *(Lemaireocerus aragonii)* lives in a seasonally available desert.

Figure 19. (Upper). Deforested hills on the sides of the upper valley of the Río Potrero Grande (Figure 17, lower). This deforested state is maintained purely by fires. (Lower). Deforested hills on the sides of the valley at the mouth of the Río Potrero Grande; on the left, a grass fire has burned upwind to the ravine in the photograph center but failed to cross the rocky and relatively grass-free ravine bottom. Such heterogeneity of burning pattern creates heterogeneity in rates of forest regeneration and kind of forest type to appear on a site.

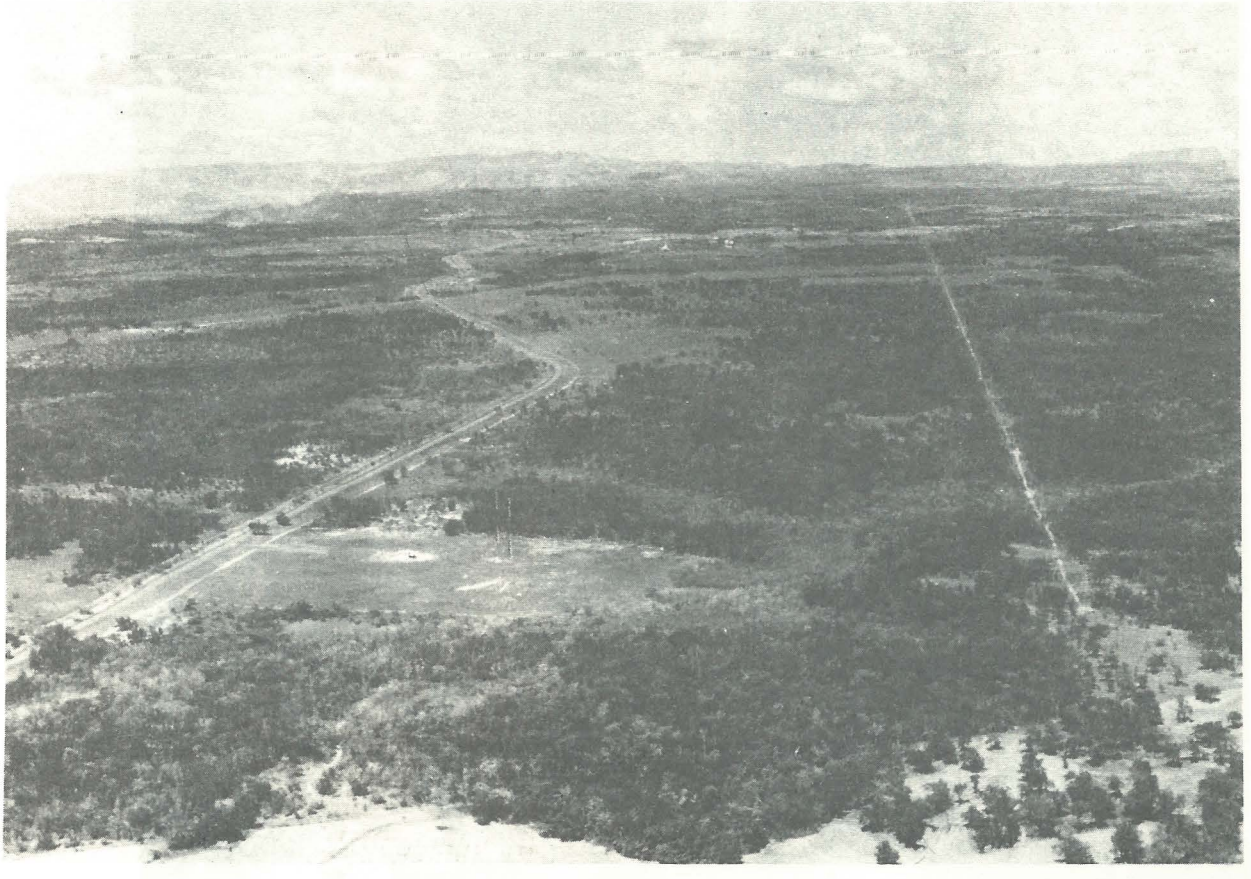

Figure 20. View to the north from over the inland center of Guanacaste National Park. Hacienda Poco Sol is directly below and grades into Hacienda El Hacha in the upper center. Hacienda Santa Elena is to the left of the highway on the left. The electric power transmission line passes through on the right. The Voice of America transmitting station is to the left of lower center. Almost all forest in the photograph is mildly to badly perturbed oak forest.

Figure 21. A 300-plus-year-old oak *(Quercus oleoides)* in a remnant of pristine oak forest along the interior margin of Finca Jenny. Such trees occur in pristine forest patches only in areas outside of Santa Rosa National Park, though there are a few individuals remaining in the Park.

Figure 22. Soil and rock erosion of an old road on white volcanic ash soils where oak forest once stood in interior Hacienda Poco Sol.

Figure 23. Upper hilltop grass pastures in central Hacienda Santa Elena. These native grass pastures are maintained by annual fires but were once covered with a 2-6 m tall deciduous forest.

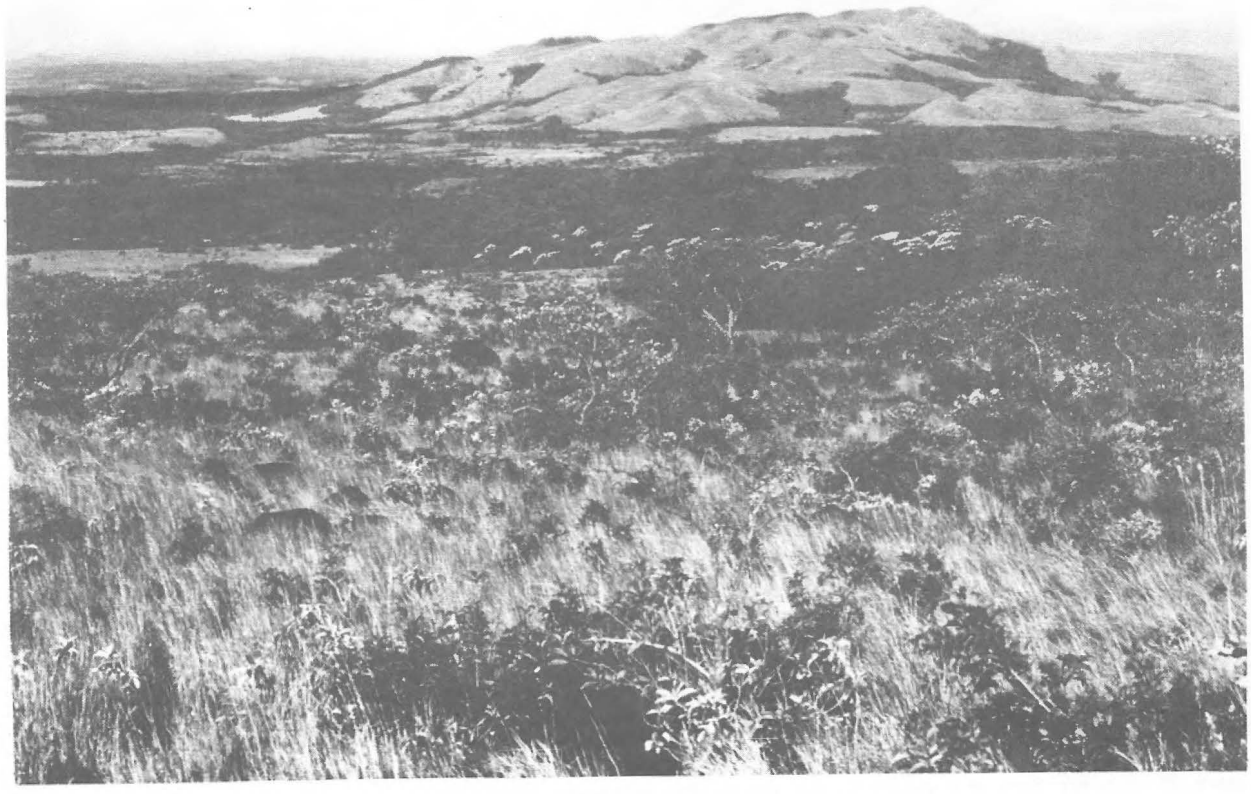

Figure 24. Cerro El Hacha as viewed from the lower slopes of Volcán Orosí (looking northwest). The nearly totally deforested (and annually burned) upper slopes stand in sharp contrast to the somewhat sheltered ravines containing remnants of pristine semi-evergreen forests that are important dry season moist refugia for dry forest insects.

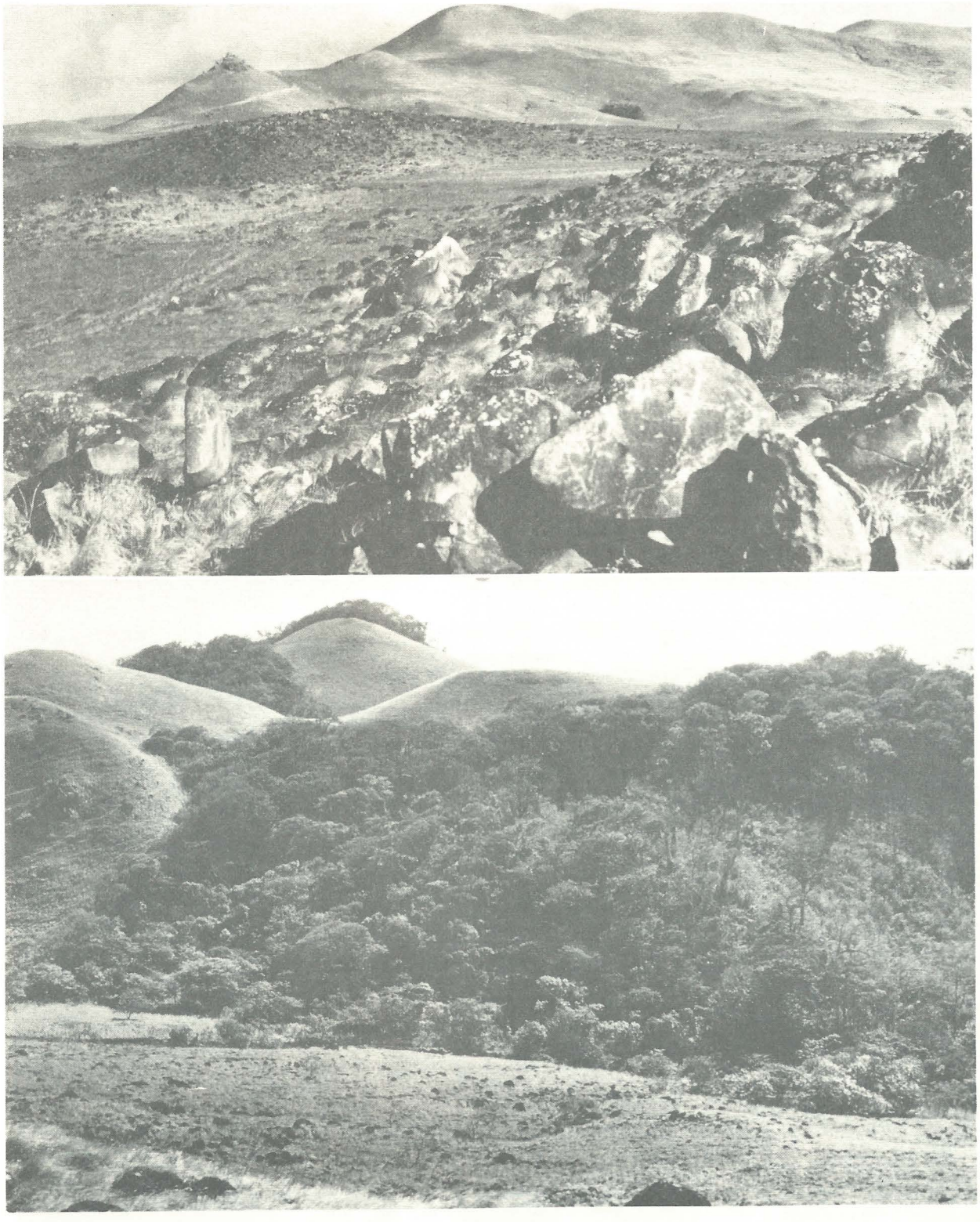

Figure 25. (Upper). Top of Cerro El Hacha (Figure 24), currently covered only with native grasses but once forested. (Lower). One of the few remaining forested upper slopes of Cerro El Hacha in the process of being deforested. On the right is a recently cleared corn field, in the center and top left is intact forest, and on the left and foreground is pasture cleared of forest sometime in the past several hundred years.

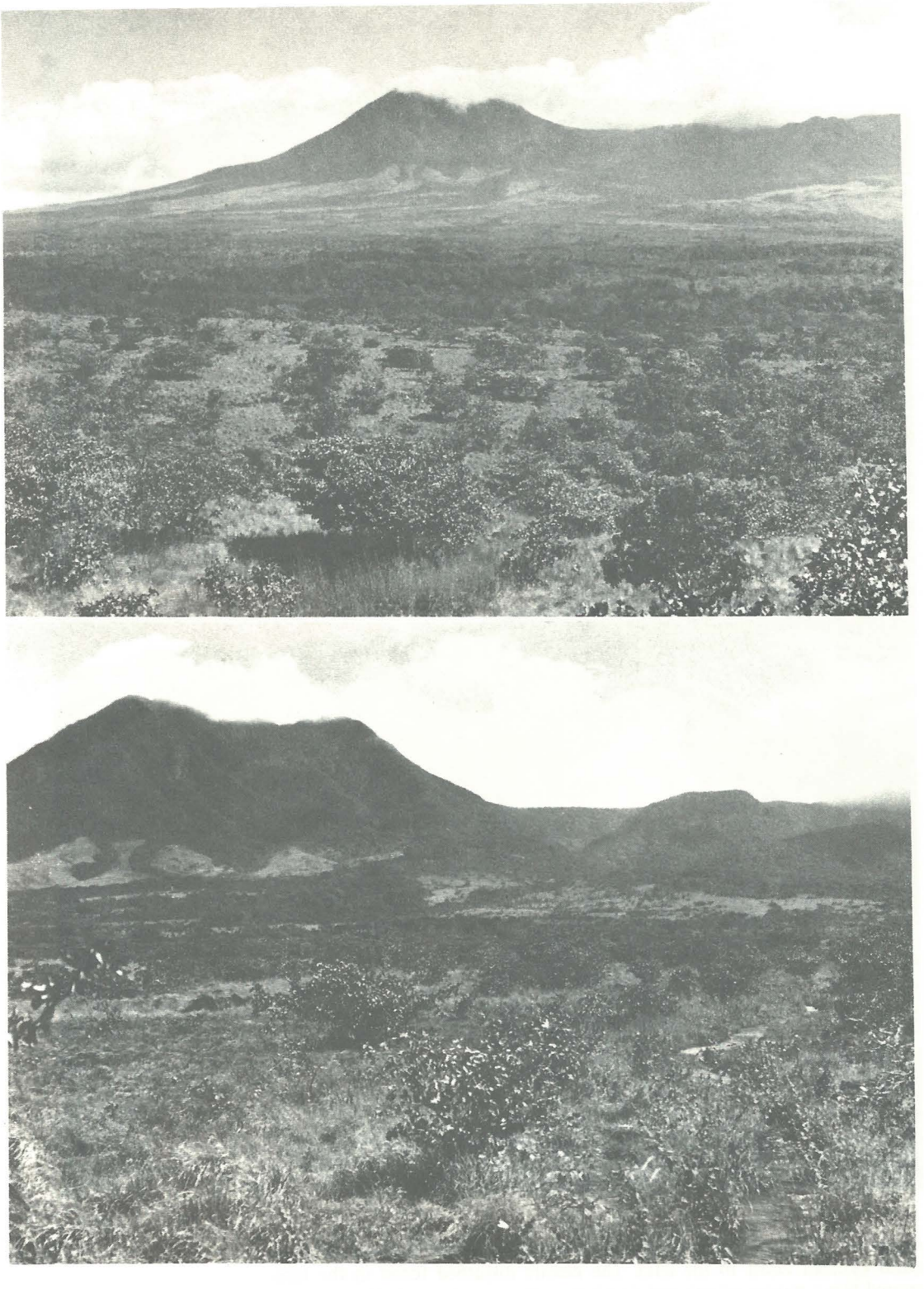

Figure 26. (Upper). Volcán Orosí as viewed from the center of Hacienda Poco Sol (Volcán Cacao to the right). The foreground was once covered with oak forest and still has a few remnant patches. (Lower). Volcán Orosí as viewed from Hacienda Orosí. The pastures cut out of the lower volcanic slope pristine forest are only 20-30 years of age, but will return to forest very slowly.

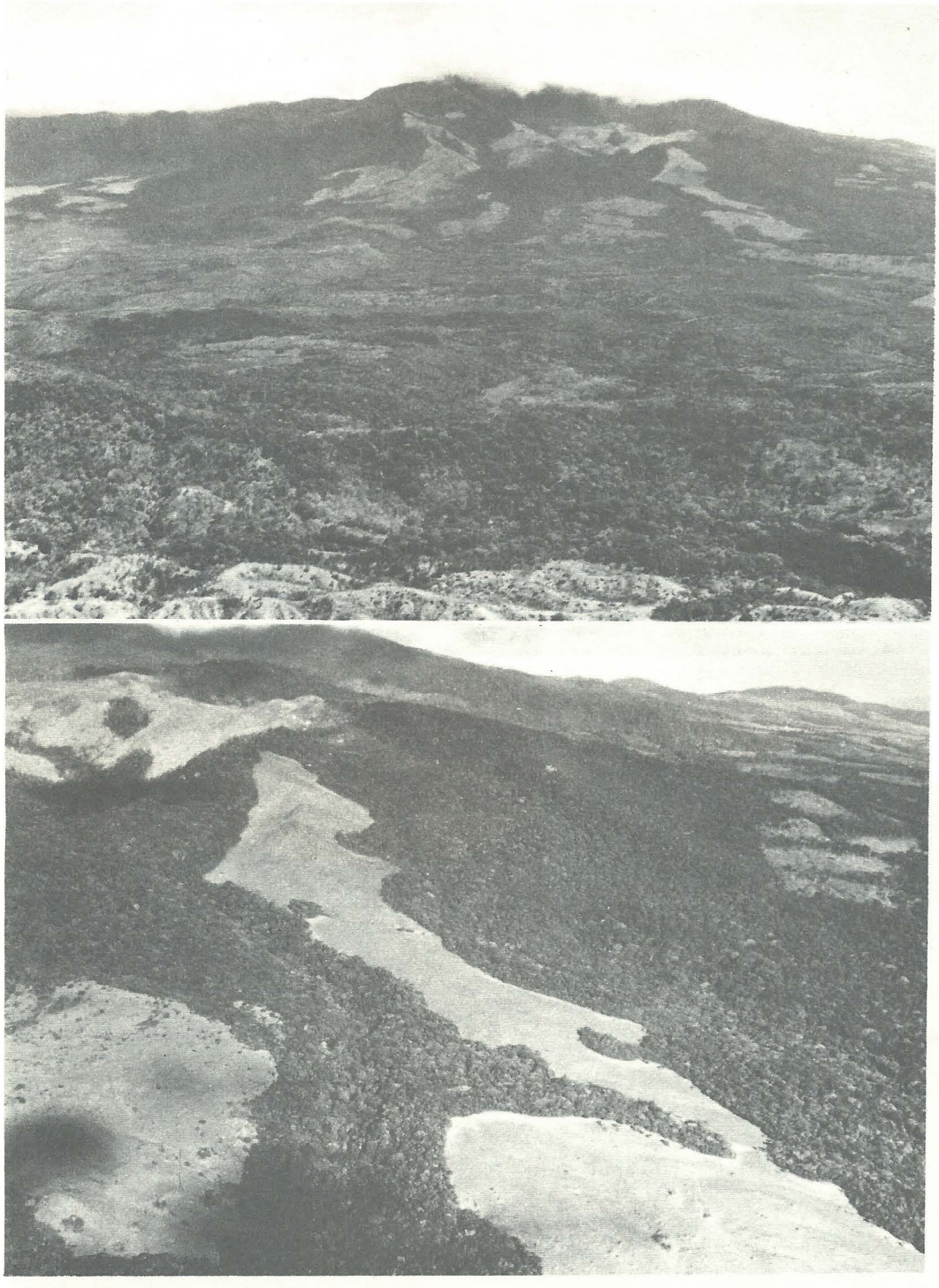

Figure 27. (Upper). Volcán Cacao as viewed from above Hacienda Tempisquito (Volcán Orosí to the left). The heavily disturbed forest in the foreground was a mosaic of oak and deciduous forest, grading into the evergreen forest on the lower volcanic slopes. (Lower). The sinuous elongate pasture on the right slope in the photograph above. It is assumed that the southern boundary of Guanacaste National Park will pass along the spine of the ridge down this pasture, or slightly to the right of it. As on Volcán Orosí, such upper elevation pastures (400-800 m) return to forest only very slowly as compared with those of lower elevations.

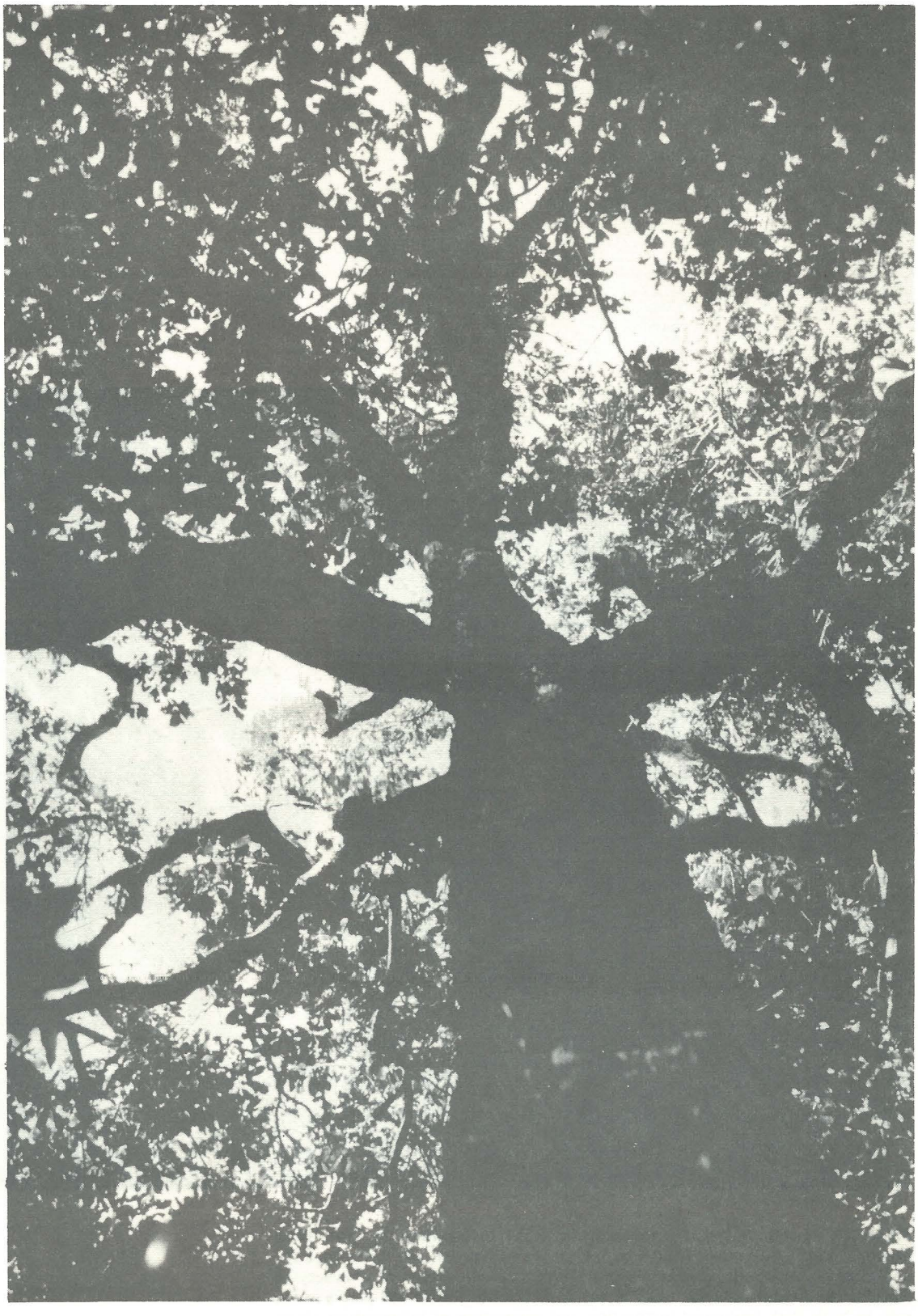

Figure 28. A view through the pristine evergreen forest canopy on the western slopes of Volcán Orosí. This tree is 40 m tall, and like the other trees in this forest, very free of vines and vascular epiphytes.

Figure 29. (Left). A research assistant, Sr. Roberto Espinosa, in Santa Rosa National Park. He comes from Cuajiniquil, has spent his life living out the challenges in this area, and is responsible for the execution of a variety of complex biological research tasks in the Park. Such a person will play a major role in both Park biological instruction and generation of information about the Park. (Right). The caretaker of Hacienda Orosí, Sr. Mateo Mata. He comes from the area, is very competent at the daily tasks of running a dry forest cattle ranch, and is the kind of person who would constitute a major part of the management of Guanacaste National Park.

Figure 30. (Upper). Aerial view of natural pasture reforestation in Santa Rosa National Park after five years without fire (center left, and see below). The paved road serves as a firebreak, protecting the experimental area from the recently burned control area (center right and see Figure 31). On the far right is regularily burned jaragua pasture that had not yet been burned at the time of this photograph. (Lower). The experimental jaragua pasture mentioned above that has been protected from fire for five years. Almost all the broad-leafed plants are seedlings and saplings of large forest trees, and almost all are wind-dispersed..

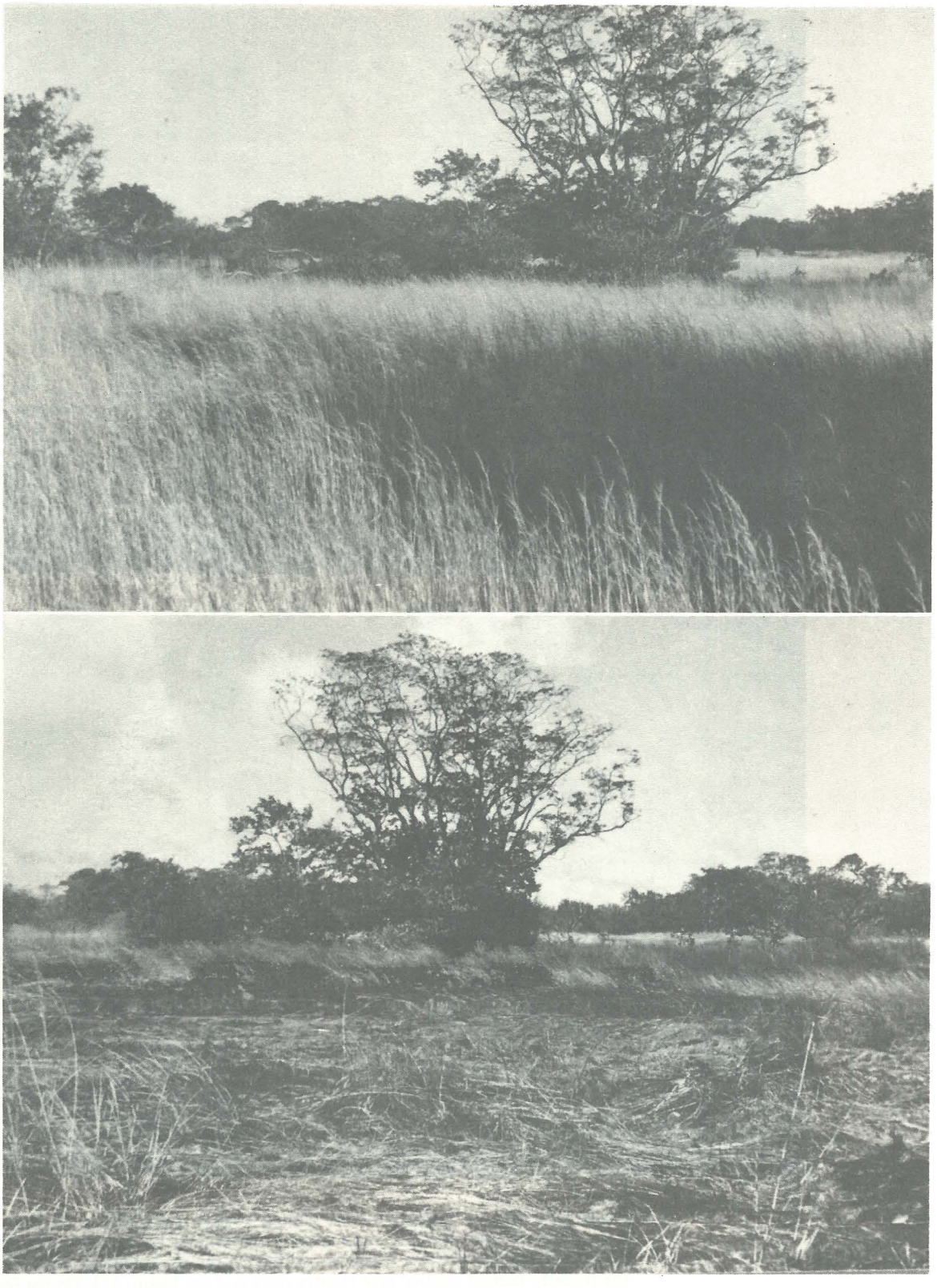

Figure 31. (Upper). The jaragua pasture control for the experimental plot in Figure 30 (lower). This grass stand is burned annually. The single surviving tree is *Ateleia herbert–smithii.* (Lower). The above control plot after its annual fire.

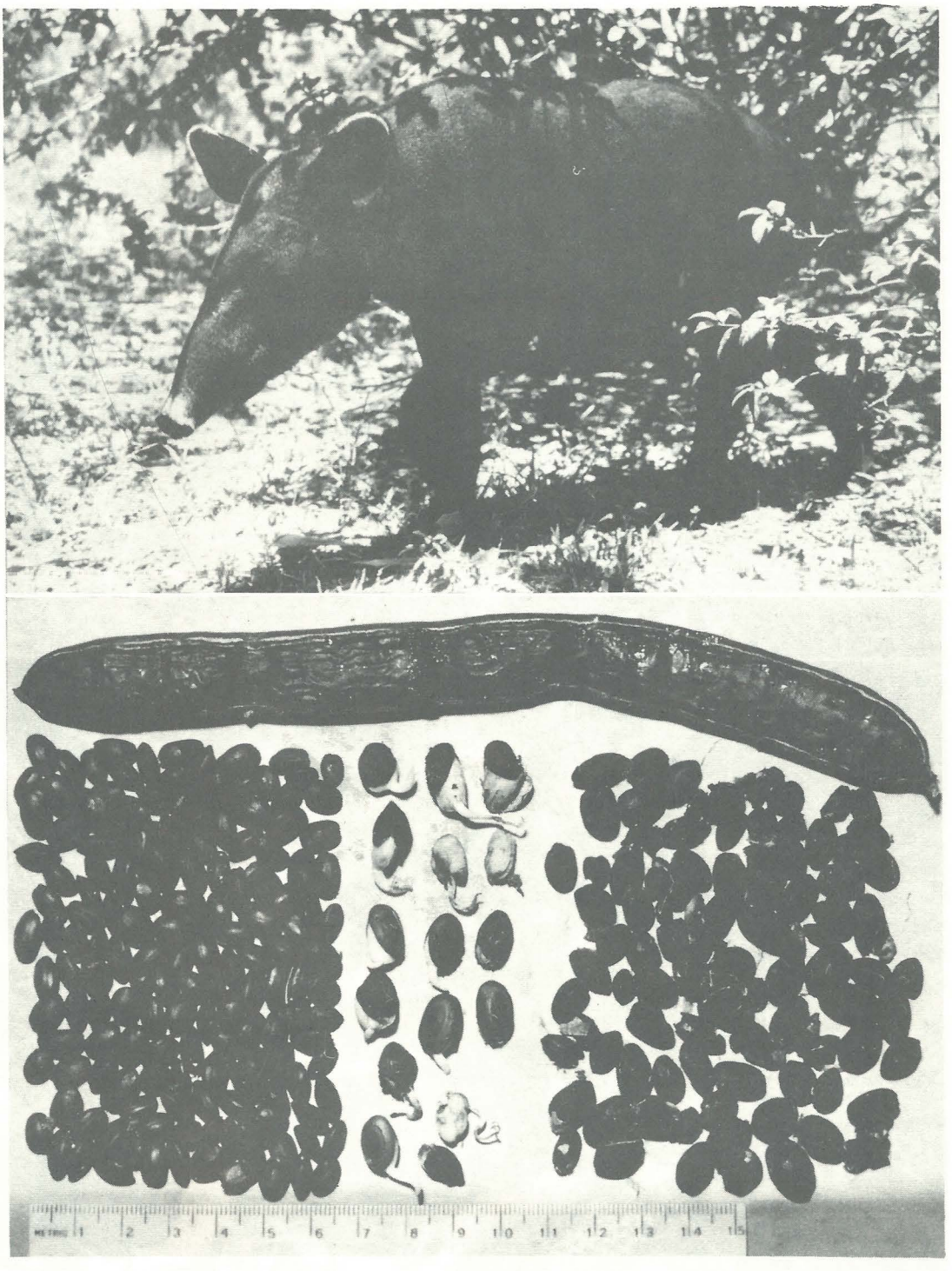

Figure 32. (Upper). The tapir *(Tapirus bairdii),* an important seed dispersal agent in Guanacaste National Park. This relative of the horse does not live in open pastures, but crosses them and therefore sometimes defecates in them. (Lower). All of these seeds were in a single defecation of a wild tapir in Santa Rosa National Park. The seeds are of cenizero *(Pithecellobium saman),* a major timber tree of Guanacaste dry forest. A cenizero fruit 19 cm in length is included at the top for scale. The seeds on the left are dormant and viable, those on the right were killed by germination and digestion in the tapir, and those in the center germinated shortly after being defecated.

Figure 33. (Upper). The coati *(Nasua narica),* an important seed dispersal agent in Guanacaste National Park. This relative of the racoon eats many fruits and defecates the seeds in a viable state. (Lower). A pile of coati dung containing over a hundred viable seeds of *Styrax argentea,* a rare evergreen dry forest tree in Santa Rosa National Park.

Figure 34. A small cluster of the winged wind-dispersed seeds of mahogany or caoba *(Swietenia macrophylla).* In Santa Rosa National Park, the dry season winds carry these seeds as far as 200 m into abandoned grass pastures, where their seedlings are among the numerous species of wind-dispersed seeds to first invade small pastures.

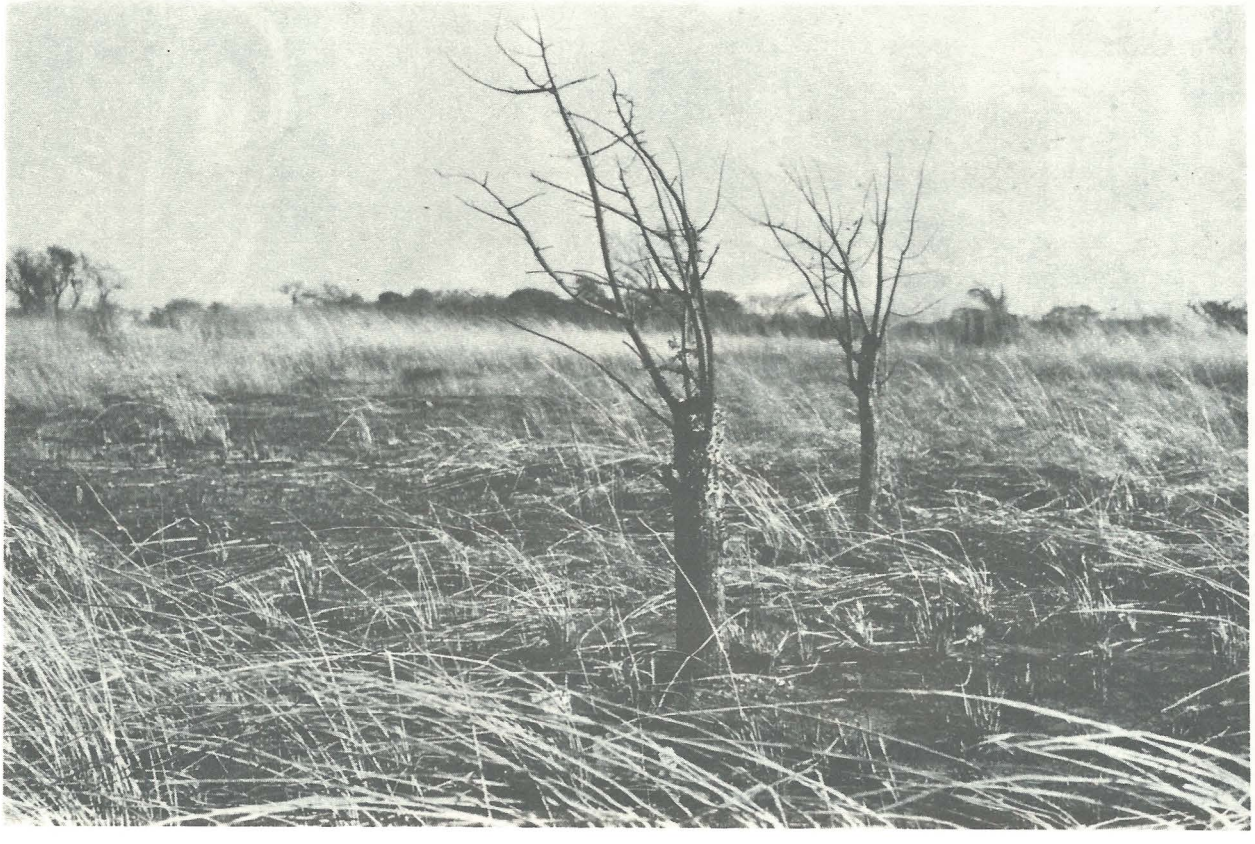

Figure 35. Posts isolated in the center of a several-hundred hectare jaragua pasture. Birds flying across such pastures stop at such posts and defecate seeds upon resuming flight, resulting in an accumulation of tree seeds in the area of a post. These seeds produce small forest nuclei that gradually spread and coalesce into continuous forest if not burned.

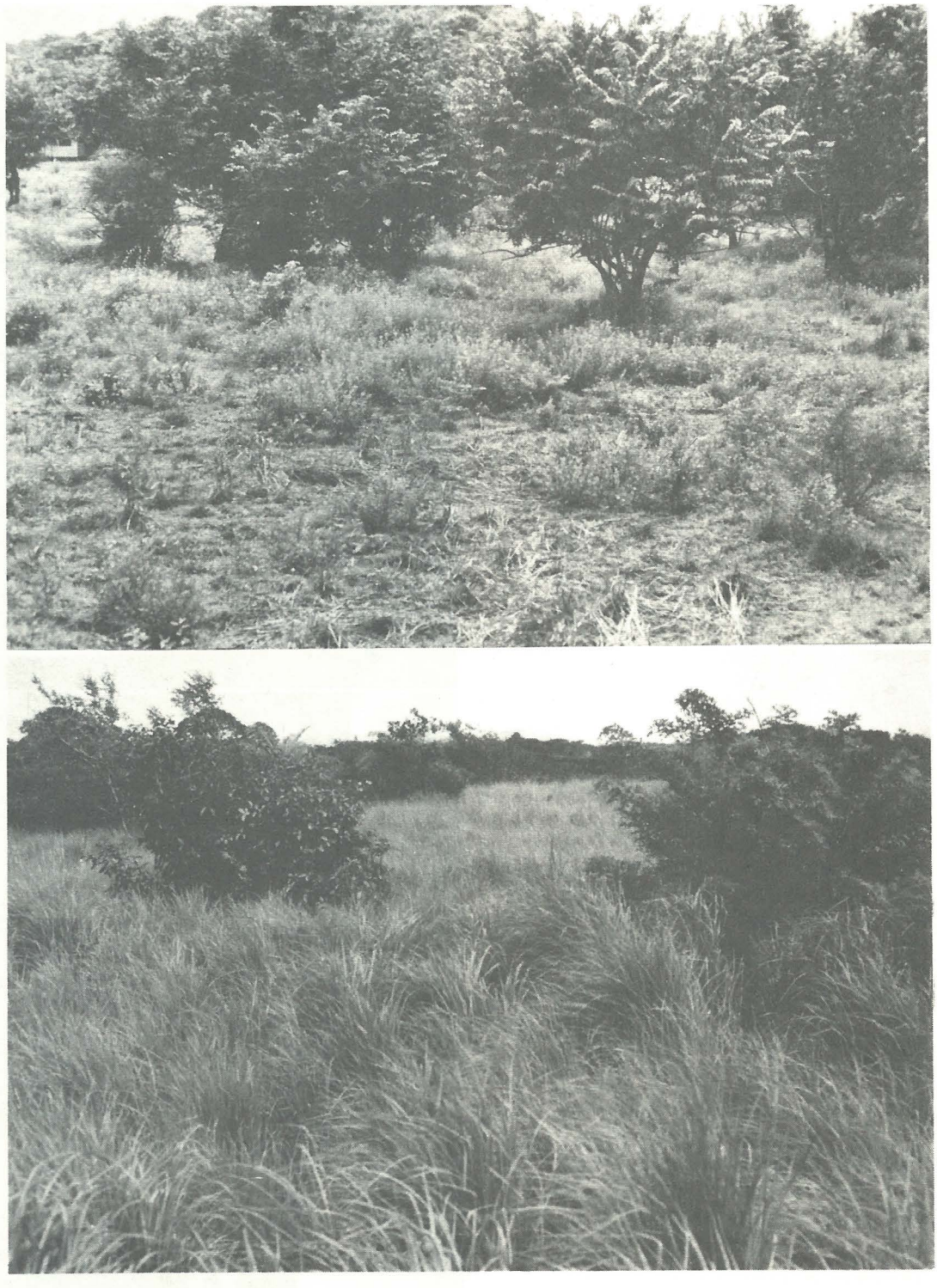

Figure 36. (Upper). A horse-grazed jaragua grass pasture in Santa Rosa National Park during the rainy season. Such an open habitat is ideal for tree seedling establishment if seed dispersal occurs into the area and the site is neither burned nor cleared with a machete. (Lower). The same pasture as in the upper photograph, but on the other side of the fence. The dense jaragua stand is a severe competitor for tree seedlings and offers a heavy fuel load for grass fires in the dry season; such fires are hot enough to destroy the above ground parts of almost all woody plants.,

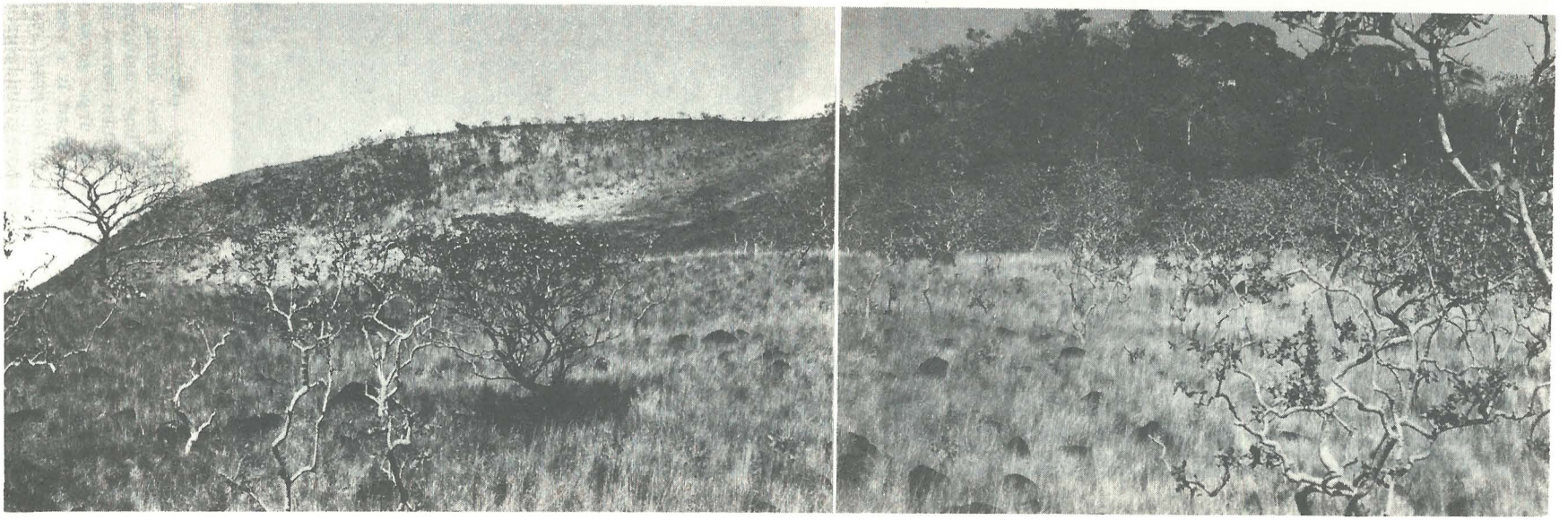

Figure 37. A small remnant patch of forest on the pastureland on the lower slopes of Cerro El Hacha. The pasture is maintained by fire and occupied only by woody plants that are extremely resistant to fire. In moist years, the forest patch expands and on dry years it contracts due to penetration by the annual fires.

THE ACTION PLAN

As will become evident below, we already have the biological knowledge that is needed to make GNP a reality. There is already an audience for its products and that audience will grow. There is no doubt that people can be found with a deep interest in carrying out GNP's working operation. What we do not have is the money to purchase the terrain or for the endowment that will generate the management funds.

A. ALLOW FOREST REINVASION

If all fire and livestock were deleted from GNP today, and the site simply allowed to revert to its own vegetation, the grass patches of less than 5-10 ha would be largely woody vegetation within 20 years while the largest expanses of pasture *(e. g.,* in the Santa Elena Peninsula, *Figure 17, 19, 23, 24)* will require 50-200 years to attain this status. Dry forest populations and habitats will immediately begin to return to their original sizes and areas. The entire area will require at least 100-1000 years to begin to approximate the full structure of pristine dry forest. As will become evident below, some of the forest reinvasion processes can be substantially speeded up by habitat manipulation, and this will be done in GNP as resources permit.

Below we briefly summarize the biological and managerial aspects of the forest reinvasion process at GNP. Again, as mentioned earlier, it is important to note that these processes, and especially their rates, will be different in other parts of the tropics (and outside of them).

1.–FIRE. WITHOUT A SUCCESSFUL FIRE CONTROL PROGRAM, GNP WILL CONTINUE DOWN THE TRAIL TO ALMOST PURE GRASSLAND

Fire will be the single largest threat to GNP for decades. Furthermore, in those GNP habitats that are too fragile to allow cattle grazing as a way to depress grass density, fire will be even a greater threat after GNP formation than before; in a single growing season an ungrazed GNP pasture generates enough grass fuel to carry a fire hot enough to kill all aboveground woody small plants and sublethally damage the large trees. The most dangerous grass stands are unbroken (ungrazed) 2 m tall dense swards of jaragua *(Hyparrhenia rufa),* the introduced African grass *(e.g., Figure 31).* However, even the lower and less dense native grass pastures in Santa Elena *(Figure 23)* are a fire threat when not grazed. On the other hand, when the fires are stopped the grass pastures rapidly fill with seedlings and saplings of large trees.

Fires in Guanacaste's dry forest are not "forest fires" in the sense of the

popular imagination. They either burn in grassland and consume both the grass and woody vegetation, or they burn through the litter layer underneath an established forest. Such fires are easily extinguished by backfiring from previously burned fuel-free lanes or beating out (especially at night). A continuous problem with fires in grasslando and dry forest mixes is that the fire ignites old logs and standing dead trees, and these continue to burn and generate burning cinders that are blown across fire lanes for days afterwards. The past five years of fire control (and lack of it for the past 14 years) at Santa Rosa make it clear that the technology of fire elimination is feasible and straightforward; the problems lie in the social problem of insuring that the technology is applied year after year without fail.

All fires in the GNP area are anthropogenic. Lightning does not occur during the dry season and when it occurs at the beginning of the rainy season it is accompanied by rain. GNP fires (as are Santa Rosa and Murciélago fires) are of two kinds: those that start in surrounding ranchland and burn or blow into the park, and those started by humans within the park. There is absolutely no circumstantial or biological evidence that natural fires were ever part of the Guanacaste dry forest environment *(e.g., Figure 25, 27).* However, some forest edge destruction may have occurred through fires escaping from Indians burning secondary succession in preparation for planting.

All incoming fires can be stopped by the simple procedure of burning a 100-200 m wide fire lane along all park boundaries that have grass on either (or both) sides. For GNP, this will be about 30 km of fenceline. Ideally, the fire lanes are burned on pastureland belonging to neighbors. The fire lane is set by mowing two 3-6 m wide parallel strips 100-200 m apart in the first month of the dry season (late November to early December) and burning these mown strips at a time of day when the standing grass is too moist to carry a fire. About 2 months later the wide strip between the fire lanes is burned (preferably at night). The annual fire lanes must be burned in the same place each year, resulting in a strip free of dead tree trunks. In the case that a fire burning toward the park is moving fast downwind in the daytime, a backfire may also be started from the wide fire lane.

In addition to the above lanes, strategic narrow fire lanes must be cut and burned such that they partition the park into major blocks of grassland--forest mix with the long axis across the wind. These blocks serve in combating fires that begin within the park either by being blown in or from accidents. Fires within the park are combated most effectively by getting to them inmediately while still small, and both backfiring and directly beating out the fire. This requires rapid location of the fire and rapid mobilization of a maximum number of persons to fight it. If treated properly, such fires rarely consume more than a few ha of vegetation. GNP fires are smoke-rich and can be located easily from a high point if a fire watch is maintained during the dry months.

GNP is oriented such that the long axis points upwind and the easternmost end is sealed with unburnable evergreen forest. This will render the firebreaks along the northern and southern boundaries especially effective. Additionally, intensification of agriculture in the areas to the south and north of GNP will lower the incidence of dry season fires as ever more land is shifted from pasture to cropland and more ranchers realize that fires damages most types of pasture.

An occasional fire will probably escape or invade GNP. Does it matter? Each time a grassy or young wooded area burns, it further postpones the day when the vegetation will have returned far enough to forest to be essentially unburnable.

A few words on the biology of Guanacaste fires are in order here:

a. When a cinder blows into intact dry forest and ignites a snag or log, that log normally burns up on the spot without creating a fire that spreads through the litter; the living deciduous woody plants do not sustain a fire in dry forest. However, if such a fire occurs in the early afternoon late in the dry season, deciduous forest litter may continue to burn slowly along at ground level until evening humidity increases and falling temperatures extinguish it.

b. When a grass fire burns downwind into a dry forest, the heat is sufficient to kill and incinerate marginal trees (and saplings) and the wind carries the fire tens of meters into the forest. An outcome is that when a pasture is cut out of dry forest, the annual fires cause the pasture to move downwind.

c. The later it occurs in the dry season, the more thorough is a fire's incineration of patches of woody succession and isolated trees, and the less likely it is to burn around moist swales and creek banks (and see *Figure 19).*

d. While creeping litter fires appear to do little more than kill the occasional sapling, they do severe cryptic damage. As the fire burns the litter accumulated against large tree bases, the heat kills the cambium in small areas that are not visible at the time. If another ground fire passes within the 5-20 years that are required for the tree to grow over this wound, the fire finds ready access to the tree core through the dead area and the large living tree is cut off at the base. The same process occurs in pastures, where trees that are sufficiently heat-tolerant to survive for decades in the light grass fires of grazed pastures have their bases damaged and then cut off by the intensive fires of ungrazed accumulated fuel.

e. When a small fire does occur in dry forest (and especially, in young secondary successional dry forest), it kills a small area of saplings and overhead tree crowns. This allows more light at ground level in the following rainy season, and the site grows a dense ground cover of herbs and grasses. When this material is added to the dead woody stems from the previous fire, it makes the site particulary susceptible to a strong local fire that creates an enlarging and grass-choked hole in the forest. Subsequent burning creates a rapidly growing brushy pasture *(e.g., Uhl and Buschbacher 1985).* This process, associated with selective lumbering and road and trail penetration, has been a major process for conversion of dry forest to brushy pasture in Guanacaste during the past 400 years. When cattle are added to the habitat, the process is accentuated or retarded, depending on details of season, stocking rates, pasture quality, fire frequency, etc.

f. While fires kill aboveground parts of woody plants, many dry forest species freely sucker sprout from roots and stumps. A 2 m tall sucker shoot may belong to a root system that is hundreds of years old, and such a sucker shoot often again grows into a large tree when the fires are stopped.

g. In GNP habitats, so much grass accumulates in a single rainy season in the absence of livestock that its fire kills all aboveground woody small plants and many trees. So-called "controlled burning" to depress fuel levels is disastrous.

h. When the fires are stopped, the return to woody vegetation can be rapid even in the absence of livestock to depress competing grasses. In the oldest experiment in Santa Rosa, five growing seasons have been suf-

ficient to convert a 200-year-old 4 ha jaragua grass pasture to a rapidly closing stand of young trees *(Figure 30-31).*

2.—SEED MOVEMENT AND SEEDLING ESTABLISHMENT

Seed dispersal and seedling establishment is under intensive study at Santa Rosa and all of the last 14 years of observations and experiments are directly pertinent to forest restoration in GNP. There is a rich fauna of wild animals in dry forest that move seeds into pastures, fields and woody succession *(Figure 32-33).* These animals, and their consequences, are much more evident in Costa Rican dry than in wet forest habitats (though this difference may not be real because this kind of succession has yet to be studied in Costa Rica in a rainforest area where the animals are sufficiently protected to occur at natural densities). The ingredients of greatest importance are distance to seed sources, seed dispersal mode, interdigitation of pasture and forest patches, and species and number of animals. Once the seeds have arrived, their ability to generate forest depends on the traits of the soil and pasture grass.

The first wave of woody succession into GNP pastures *(Figure 30)* has a very high proportion of wind-dispersed trees *(e.g., Figure 34)* on the downwind side of forest. Such seeds are moved in abundance up to 200 m by the dry season winds. However, such wind-dispersed plants do not readily get to the centers of pastures of hundreds of ha in area (though they could very easily be scattered there by hand).

Trees with animal-dispersed seeds, on the other hand, have much more diverse patterns of input to pastures and other open areas. Large seeds (as well as small) are swallowed in the forest and then defecated or regurgitated at various distances out into pastures by the animals crossing or using them (deer, peccaries, coatis, tapirs, cows, horses, coyotes) *(Figure 32-33).* The behavior of these animals tends to concentrate defecated seeds along ravines, at rock outcrops, near isolated trees and in other sites potentially protected from fires and desiccation. Seeds defecated in stream beds in forest by these animals are also carried into open areas far from the forest.

Forest birds and bats do not readily venture into the expanses of large pastures, but they do cross smaller pastures and often temporarily perch in isolated trees (just as mammals walking through pastures often pass or pause beneath such trees) *(Figure 35).* Before or while flying off, these birds defecate. The consequence is that the growing island of woody vegetation that begins to appear around large isolated pasture trees is usually entirely made up of species that are animal-dispersed. This process emphasizes the importance of the appearance of isolated large trees in large pastures; in GNP, such trees are often guanacaste *(Enterolobium cyclocarpum)* trees and cenizero *(Pithecellobium saman)* trees, both of which are dispersed by horses and cattle.

Once seeds have arrived in GNP pasture (and other kinds of old field habitats), their primary challenge is the 1-2 m tall dense stand of grass that blocks sunlight, collects nutrients, and physically blocks growth. Livestock at moderate to low density encourage woody succession into pastures by reducing the amount of grass *(Figure 36).* They do eat some woody plants but most species are ignored unless grass is in short supply. The resultant woody succession has a somewhat different species structure than does succession without livestock. The use of livestock in grass depression and succession management in GNP will be highly controlled, and terminated as sites reach a stage where the grass is no longer seriously threatening the woody succession through competition and fire.

3. INTENSIVELY MANAGED REFORESTATION

Left to itself without fire, GNP will revert to forest, and do it more rapidly if the pastures are manipulated with livestock. However, GNP contains suffciently large areas of grass that it can fill an important educational role by explicity generating forest types with certain compositions that are desired by the agroforestry community. These experiments should be large enough to serve as significant models and placed strategically to aid in dissecting the largest blocks of grassland in GNP. For example, it would be technically easy to establish wide strip forests of fast- and slow-growing timber species on the downwind margins of major traditional firebreaks, thereby eventually eliminating the need for the maintenance of the firebreaks. Such a mixed forest might well, for example, be composed of cedro *(Cedrela odorata),* caoba *(Swietenia macrophylla),* pochote *(Bombacopsis quinatum),* guanacaste *(Enterolobium cyclocarpum),* cenizero *(Pithecellobium saman),* guapinol *(Hymenaea coubaril),* níspero *(Manilkara chicle)* and tempisque *(Mastichodendron capiri).* These trees are all native to GNP, part of the natural secondary succession in GNP, and widely recognized in Costa Rica and elsewhere as valuable timber trees. They range from fast-growing light-weight timber to extremely slow-growing and dense timber. Much is already known of the biology of these trees in the GNP area, quite enough to begin experiments as soon as land is available.

The labor and other costs of such intensive land management within GNP will not be provided by the regular managerial staff of GNP, but rather will appear as explicit research programs within other budgets. The same applies to harvest, care and manipulation of the natural seed and gene bank that GNP obviously is.

GNP is not the place for the explicit introduction of "valuable" exotics. We are already paying a huge price for one such - jaragua. The last thing we need is to have to try to eradicate eucalyptus, melaleuca, Australian acacias, and other such useful trees. The same applies to introduction of wild "useful" animals. The indigenous dry forest flora is rich in species with the useful properties of exotics plus many other useful traits. In like manner, it is imperative that the indigenous dry forest plant and animal gene pools in GNP be kept as pristine as possible. Trees and animals introduced even from other parts of Costa Rica represent a serious genetic threat, to say nothing of the diseases and parasites they carry. The release of confiscated pet wild animals into the GNP area must also be halted.

4. CESSATION OF HUNTING

Poaching in Santa Rosa is presently a trivial problem, but there is a serious problem with hunting in the remainder of GNP. The wild mammals and large birds are important not only for their own sake, but because they are major seed dispersal agents. Santa Rosa contains a naturally high (but heterogeneous) density of peccaries, deer, agoutis, pacas, monkeys, tapirs, coatis, coyotes, bats, guans, curassows, and other seed dispersers; these animals are at severely endangered densities in the remainder of GNP. This is due to both hunting in the past and present and to habitat modification. However, they are sufficiently mobile that with protection they will again attain their natural densities in GNP.

The mammal most threatened with extinction in Costa Rica today is the white-lipped peccary *(Tayassu pecari).* A herd is believed to still be resident in the upper rainforest on the volcano slopes, and in January 1986, a small herd

of 31 animals was encountered while it was passing through Santa Rosa (W. Hallwachs, personal communication). While a reforested GNP is large enough to support one or even two white-lipped peccary herds, there is only a small chance that hunters will allow a herd to survive in the general area long enough for this to come about.

The major hunting in the GNP area is by pleasure hunters from La Cruz, Liberia, and San Jose, rather than by rural hunters desperate for meat. Cessation of this hunting requires three things. First, the GNP managerial staff will be strategically placed, and there will have to be selective vehicle checks at key places. Second, and much more important, the community of pleasure hunters will be subject to an intensive and personal education campaign by GNP biologists. Third, the GNP staff will have to be trained out of the attitude that they are highway patrolmen and that the loss of an occasional deer is a serious threat to their egos.

In addition, there is some local hunting for meat in the area that will become GNP. It is clear that much, if not all of this hunting can be stopped by directed education at the elementary school level; children will be among GNP's best ambassadors. Additionally, some of the better hunters are likely to end up on the GNP managerial staff. As with the pleasure hunters, the loss of an occasional deer or collared peccary to a local meat hunter is trivial compared to the potential impact of an arrested and bitter poacher during the period that it takes to educate the local population away from hunting within GNP.

B. ORGANIZATIONAL INFRASTRUCTURE

GNP will be organized and run under an elaborate constitution that is explicitly designed for it and embedded in Costa Rican public law and decree. Neither current traditions nor current national park laws are adequate to guide the complex interactions necessary between a society and a national park as a cultural institution.

The constitution will be the output of one or more national and international workshops held in GNP, and attended by interested parties and representatives of all relevant Costa Rican institutions and organizations. These workshops will be organized and conducted by a consortium of the foundations and government organizations in Costa Rica that are most directly interested in the maintenance and survival of GNP (e.g., National Park Service, National Park Foundation, Fundación Neotrópica, CATIE, Wildlife Service, Forest Service, Institute for Agricultural Development, Institute for Tourism, Guanacaste Province Government, University of Costa Rica, Universidad Nacional, Ministry of Planning, Ministry of Education, Ministry of Agriculture, etc.).

GNP will be the exclusive property of the National Park Service of Costa Rica and a small portion of its budget will be derived from the NPS budget. However, the bulk of its budget will be derived from the investment revenue generated by the Guanacaste National Park Endowment Fund. This fund is currently within the Costa Rica Program of the International Program of the Nature Conservancy, but will be transferred to the National Park Foundation of Costa Rica as GNP becomes a reality.

The directorship of GNP will be guided by the GNP constitution and answer to the National Park Service and to a relatively small executive committee made up of those with most direct interest in GNP function and survival. The director will reside in or adjacent to GNP and be a Costa Rican citizen, as will the other full-time employees of GNP. While GNP administrators at all levels may participate in training and organization at other Costa

Rican national parks, they will not be transferred to them unless they wish to be transferred.

C. USE PROGRAMS

All three primary goals of GNP center on the use and relevance of GNP to the people that live outside the park, from local to global. Many details of making GNP maximally user-friendly will be formalized in the park's constitution; others will be invented as circumstances arise. However, there are a few major subjects that can be briefly mentioned here since their inclusion is a certainty. When we state that GNP must be maximally user-friendly, it must be recognized that there are many kinds of users. Furthermore, if GNP fails to make the Costa Rican population fully aware and understanding of its presence, even its short-term success as a traditional biological preserve will be very short-lived.

1. INFORMATION STORAGE

There will be thorough documentation of GNP vegetation with aerial photographs and ground truthing so as to have a reference point for the multitude of regeneration experiments that will be automatically set in motion simply by establishing the park. Where possible, animals will also be censused. In addition, an elaborate set of records of management regimes, experiments, errors, and other perturbations will be kept both on-site (in a building with no fire and humidity risk) and in some distant protected place. All information will be available to all interested parties (though commercial users will be expected to make appropriate contributions to the GNP Endowment Fund). Rapid and detailed publication will be encouraged for observations, experiments and results from GNP. Journalists, science writers, educators and others wishing to write about GNP information will be encouraged.

Where habitat manipulation has occurred, the experiments themselves are a form of living information storage and their protection will be maintained to perpetuity (as will their records).

2. INVENTORY

While certain groups of organisms are fairly well known for Santa Rosa, we are woefully ignorant of just what organisms live in GNP and where. Inventory surveys of flora and fauna are desperately needed and will be encouraged as a contribution from the world of taxonomists. Likewise, the taxonomic status of Central American organisms is sufficiently poorly developed that it is imperative that GNP specimens are widely circulated in the world's taxonomic centers such that revisionary work is certain to include GNP materials. Finally, the arduous task of providing basic field guides and reference collections to the tens of thousands of GNP species must begin, group by group. As researchers, we cannot come to understand what holds GNP together without names for the units in the matrix. What is equally important, but too little appreciated, is that we cannot bring the biological stories of GNP to the external audience without having names for the organisms. These names allow not not only local reference, but also allow us to connect what we find out about GNP to what is known elsewhere.

3. RESEARCH

Research within and about GNP is a critical aspect of its development

as a cultural institution. You have to do more than take people to the symphony; you have to have something to play for them. Furthermore, if GNP is to realize its many pragmatic biological functions (gene bank, seed bank, reforestation, etc.), there must be active research programs within GNP. There are many small and very cheap ways to make a tropical area maximally attractive to field researchers, ranging from streamlined administration of red tape to meals at cost to erecting spacious primitive dwellings. The GNP area is often a more foreign environment to Costa Rican researchers than it is to foreign field biologists, and active steps will have to be taken to change this as well. GNP can easily become a model meeting ground for researchers from different cultures but with interests in problems in common.

It is traditional for tropical research results to move out of the tropics into the common knowledge (courses, journals, symposia) of extra-tropical countries, and then trickle slowly down the educational ladder and back into the tropics through courses taught much later to students in the tropics. Direct participation by Costa Ricans in research projects within GNP, first as technicians and apprentices and later as principal investigators, has great potential to short-circuit this lengthy process.

4. ACCESS

All points within GNP are accessible, though sometimes only after considerable effort, by some combination of vehicle, horse and/or foot travel. However, to make GNP maximally user-friendly, a strong system of trails, seasonal roads, and all-weather roads will have to be established. The Interamerican Highway, cutting through the center of GNP, is an ideal starting point for many kinds of access and public education. Properly signposted and with forest regenerated to its sides, it will not be a serious barrier to animal movements. Guanacaste Province, rich in roadbuilding activity and mechanized agriculture, is not poor in the machinery needed for road development within GNP; what is lacking at present are the connections to mobilize this machinery once GNP is a rality.

5. USE ZONING

GNP will be heavily used by people, and these people will sometimes have conflicting interests as well as pose potential threats to some aspects of park biology. The evolving management constitution for GNP must contain a detailed and broad-minded zoning system for various uses, and this must be developed with not only GNP's biological peculiarities in mind, but with strong consideration given to GNP's development as an educational institution and intellectual stimulus. As mentioned earlier with respect to the size of GNP, quality use zoning will be greatly augmented by the presence of habitat replicates.

6. EDUCATIONAL FACILITIES

GNP must be developed as an outdoor, living educational institution. In addition to the traditional services of extensive educational centers rich in displays and printed information, and the traditional abundantly signposted nature trails, there must be a strong ability and availability within the management personnel to serve as educational guides. Costa Rican society is very oriented toward verbal communication; this makes education more labor-intensive, but also allows it to be more tailor-made for particular audiences. The written material appropriate for a group from the University of Costa

Rica is not likewise appropriate for an elementary school group from Cuajiniquil.

Perhaps the greatest amount of educational return for the smallest intellectual and cash output within GNP (and even Santa Rosa at present), would be the development of a cheap scheduled truck that serves as a reliable bus, complete with a driver with a minimal understanding of habitat locations and what they offer of biological interest.

However, among the most important educational facilities for GNP will be several individuals with the primary responsibility of serving as field biology teachers at large. They must circulate among the schools, high schools, technical schools and the branch campus of the University of Costa Rica in the GNP area, and provide illustrated lectures on the kinds of biology in GNP. They must give other public lectures and serve as prominent guides when there are "open house" days at the park (e.g., Guanacaste Day on 25 July; Santa Rosa Anniversary Day on 20 March). They must be available as knowledgeable biological guides within the park, as well as be aggressively involved in training park guards to be both good biologists and good teachers in the field. They will be essentially ambassadors for GNP, and their knowledge of both established GNP biology and current research programs will have to be extensive. On a geographically more distant basis, it will be important that GNP research and development programs be prominently represented in international research and educational symposia (and especially those held in the tropics).

Simultaneously GNP must aggressively introject its presence into the contemporary efforts by the Costa Rican Open University and other organizations to increase the teaching ability of school teachers in biological subjects. This must include not only traditional written materials and lectures in courses, but organized field trips to GNP designed to aid school teachers to understand the rich educational material offered by a national park. There is also a growing awareness in Costa Rica of the value of collaborative seminar series and courses among the four university-level institutions; GNP must be both a contributing participant and occasionally the host in such activities. While Santa Rosa is already visited occasionally by field trips from the universities, CATIE and the Organization for Tropical Studies, there has been almost no aggressive sale of the cultural offerings of a site like GNP.

The tourists, be they from other parts of Costa Rica or international, will obviously benefit directly from the development of GNP as an educational as well as a recreational, research, etc. institution. However, it is important that GNP become more than a simple stop along a tourist route. This will require some imaginative activity in developing tourist living facilities within and near GNP. It is also assumed that private individuals in the GNP area, as well as in more distant places, will develop their own guiding and other tourist services as the opportunity presents itself. The staff and planning of GNP must reach out aggressively to interact with the growing ecotourism infrastructure in Costa Rica. It will not be difficult to sell GNP as a major tourist attraction, since GNP is an extraordinarily beautiful place and will become extraordinarily interesting as well. However, it will require major improvements in roads and other minimal facilities within GNP. Additionally, a small amount of dry forest "affirmative action" will be necessary, so that the tourism world does not come to view Costa Rica as clothed only in rainforest.

D. LAND ACQUISITION

The biologically correct and socially most desirable procedure would be

to immediately freeze all habitat perturbation (except to leave the cattle in certain areas) and purchase all private lands in GNP. It would then take 1-2 years to fully develop a constitution and the detailed management technologies for GNP, except that it is obvious that the fire control program around the park margins would begin immediately in October-November 1986. Such a plan likewise assumes that the endowment fund is in place and functioning.

However, the human world does not function for either its own best interest or that of the biological community it occupies; GNP acquisition will have to proceed piecemeal as funds become available. Hacienda Orosí is being gradually donated, but this gracious gift does not alleviate the worry over the volcano sides, since Hacienda Orosí contains only about 15% of the rainforest block. All owners other than those of Santa Elena, Finca Jenny and the Colonia on Cerro El Hacha have graciously cooperated with the GNP plan by agreeing not to pursue active development in 1986. The owner of Rosa María has promised to attempt to avoid pesticide runoff into Santa Rosa in 1986.

What crises are there before the end of 1986? Today, as you read this, the tiny patches of pristine semi-evergreen forest on the sides of Cerro El Hacha are being cut by members of the Colonia who are preparing new fields for corn, rice and beans. The owner of Finca Jenny could decide at any moment to convert her forest to sawlogs or cashew plantations. The rentors of Rosa María's croplands may not wish to abide by the owner's restrictions on pesticide use. A forest guard must be hired and provisioned to patrol the donated portions of Hacienda Orosí. We have no promises or understanding from the owners of Santa Elena.

The Cerro El Hacha situation must be placed at the top of the emergency list. Barring unforseen events, Finca Jenny and the few ha of Rosa María should be next. Poco Sol, Centeno and San Josecito-Tempisquito should follow. El Hacha will hopefully be donated and major portions of Santa Elena should be last.

In addition to the above purchases, it is imperative that Islas Murciélagos be decreed part of Murcielago National Park, and that the southern boundary of the Orosi Forest Reserve be reinstated so as to avoid gradual invasion by neighboring landowners in that area. The rainforested Atlantic side of Volcán Orosi and Volcán Cacao (apparently unoccupied and of questionable ownership) must be explored as a possible inclusion in GNP so as to maximize protection of the evergreen forest on the Pacific side of the volcanos.

It is important that the large properties be purchased as single blocks. There are small patches of valuable real estate on each of them, and many of these patches are of extreme biological value because of their water, soil type, pristine forest, etc. If the large property becomes broken up as a consequence of partial sale, then these small pieces will be sold to purchasers who will hold them as investment property at astronomical prices (if they will sell them at all); such inholdings are to be zealously avoided. Additionally, the willingness of several owners to sell to GNP is based on the assumption that the entire property will be purchased.

Land values will be determined by open market values in Costa Rica, with the prices established by government assessors.

E. BUDGET

1. LAND PURCHASE

Including the area to be donated in Hacienda Orosí, there are approxi-

mately 470 km^2 to be obtained. Assuming the acquisition of Orosi (30 km^2) to be successful through donation, the cost for the land to be purchased to form GNP will be $8,800,000, assuming an average figure at $200 per ha ($81 per acre). This per ha figure is representative for undeveloped low-grade wildlands and farmland throughout the country at the present time.

2. ENDOWMENT

Management costs for GNP will be a minimum of $300 000 per year. This means a minimum start-up endowment of $3 000 000. It is assumed that this endowment fund will continue to grow after the establishment of GNP through use fees (tourists, researchers, seed bank developers), donations, cattle rental fees, publication sales, etc.

3. ORGANIZATION AND FUNDING CAMPAIGN

All costs for this campaign are being borne by personal contributions, the Nature Conservancy International Program, the National Park Foundation of Costa Rica, Fundación Neotrópica de Costa Rica, and the National Science Foundation of the US.

4. SOURCES OF FUNDS

Funds are being sought throught through public campaign presentations and application to foundations, individual donors and governmental institutions throughout the world. Contributions are tax-deductible in the US and may be sent to "Nature Conservancy Guanacaste Fund, 1785 Massachusetts Ave., NW, Washington, D.C. 20036", or to "Parque Nacional Guanacaste, Fundación Neotrópica, Apdo. 236, San José 1002, Costa Rica".

5. COSTA RICAN SUPPORT

All possible connections between Guanacaste National Park and the many relevant sectors of Costa Rican society are being actively explored at the present time. While these connections are not likely to result in direct financial support of GNP, they will be a critical part of the social approval and local indirect support that are essential for GNP establishment and survival.

F. ENDORSEMENTS

The GNP development plan has been discussed and described widely within Costa Rica and the plan as here presented incorporates feedback. No governmental or private opposition has been identified. Supporting letters from the Costa Rican National Park Service, the National Park Foundation of Costa Rica, and Fundación Netrópica are attached *(Appendix 2)*. Within the US, the Nature Conservancy International Program is the official administrator of the project, while in Costa Rica the same role is played by the National Park Foundation and Fundación Neotrópica.

Until substantial funding is in hand, it is inappropriate to ask for final approval and direct involvement from the populace of the GNP region, since GNP cannot pay its own way at present. On the other hand, during 1986 a number of the educational aspects of the GNP plan will be developed on a trial basis using Santa Rosa National Park, its personnel and its researchers as a resource base.

CONTINGENCY PLANS

1) What if GNP cannot be obtained? We retreat to Santa Rosa (Murciélago will be roasted off the map by the wildfires from Santa Elena) and carry out all of the philosophical and educational goals for GNP on an inferior scale and in a gradually decomposing habitat. All of the inventory and other biological studies for GNP will still be priceless as salvage biology, and at least tell future generations what they lost.
2) What if the land can be acquired but endowment funds cannot be located? We use a skeleton staff to keep the fires out of GNP, rely on aerial photography for baseline reference, and maximize the educational effort. We grow cows for meat and management, and get out there and find the endowment funds; the progressive agriculturization of Guanacaste and all of Costa Rica acts in our favor in this case; when the national and international audience can see only clean croplands except in GNP, willingness to pay to maintain GNP will increase. Likewise, the general educational level in Costa Rica, and the international sophistication of the international users of tropical biology is steadily growing.
3) What if only sufficient funds for some land are available? We follow the purchase priorities established earlier under Land Acquisition. With Cerro El Hacha we save both the unique vegetation of the virgin semi-evergreen forests and save a major dry season insect refugium. With the southern margins of Santa Rosa secure, we avoid further agrochemical contamination and save a very important canyon forest. With the Poco Sol/Centeno/San Josecito-Tempisquito block, we save the everflowing revers and the major transition zone between the evergreen forest on the sides of the volcanos and the dry forest that covers the bulk of GNP. With Santa Elena, we allow forest restoration to start on both Santa Elena and Murciélago, save numerous very dry unique hillside and ocean-edge habitats and protect the northern boundary of Santa Rosa.
4) What if we have a run of drought years and then a colossal fire gets away from us? So, what's new? GNP has already been roasted hundreds of times before. We lose some ground, but a stump that has had five years without a fire has a healthy root system. Furthermore, all the explicitly experimental areas can be kept free from fire by backfiring once the battle is obviously lost. Finally, every year that passes without a fire, the forest advances more and the overall grass area is reduced.
5) What if the poachers are undefeatable? In the short run we lose some animals but we do not lose the breeding population (the same applies to the marine turtle eggs). In the long term there is no reason why poacher

intrusions cannot be lowered to the level found in national parks around the "developed" world.

6) What if serious squatter pressure develops? Squatters have never been a problem in Costa Rica on government or private land under conspicuous use. The GNP managerial staff will be more than mere employees, they will be part owners in a very real sense. Furthermore, all indications are that in the social game of property invasion, the populace in the area of GNP will be largely on the side of the park. In the worst scenario, GNP might lose some marginal land to squatters. However, Costa Rica has already lost almost all of its dry forest to agriculturization. While restoration of *any* of this land to forested wildlands, there is nowhere to go but up.

7) What if GNP is not big enough? Then we lose some species. So be it. The world will not give Guanacaste Province back to nature. However, no known species in the area will be lost.

8) What if one of the volcanos erupts? It will be the first time in history that a tropical volcanic eruption has been laid down on a documented wild landscape.

9) What if the conflicts to the north spread into Costa Rica? The history of Mesoamerica suggests that care of GNP might be delayed and reduced, but if there are concerned persons in the area, minimal maintenance can be continued during the conflict. Furthermore, an extremely effective barrier to social strife is a resident population that knows itself well and is satisfied with its resource base. The cultural opportunities offered by GNP are part of bringing a population to this stage.

10) What if the government of Costa Rica should change its overall emphasis on enlightened development and turn against a project such as GNP? Such an event is about as likely in Costa Rica as in the US. Were Costa Rica to lose its substantial population of citizens who already view national parks and other kinds of preserves as highly desirable parts of the landscape, GNP would be threatened just as would be the other national parks. However, a major activity of GNP is producing environmental awareness in the next generation of Costa Rican decision-makers and their offspring.

11) What if the biologists lose interest in GNP? GNP needs people with biological understanding and training for its management and display to the public. With independent funding, GNP will always attract an interested managerial staff. This in turn, plus the biological properties of GNP, will always serve as a magnet to biologists from within as well as without the tropics.

12) What if the director or the executive committee or the GNP constitution fails to function properly? As part of GNP development, all three of these components will have provisions to assist in the replacement of non-functioning components. With the executive committee constituted of members from Costa Rican institutions with strong mandates in the areas in which GNP has conspicuous offerings, disinterest seems very unlikely.

PUBLISHED INFORMATION ON GUANACASTE DRY FOREST

There is virtually no biological literature on any part of GNP except for Santa Rosa National Park. However, this situation will change rapidly. A bibliography of papers on the biology (including agriculture) of Guanacaste dry forest habitats is in preparation and already contains over 500 citations (it will be available by the end of November 1986 from D.H. Janzen, Department of Biology, University of Pennsylvania, Philadelphia, Pa. 19104). Santa Rosa contributes more than 200 of these references. A few are listed below. There is also a very large amount of (as yet) unpublished information on Santa Rosa. I am preparing a book on Santa Rosa biology for the Costa Rican open university (UNED). The book "Costa Rican Natural History" (1983, D.H. Janzen, editor) is being translated to Spanish and will be published in late 1986; it contains over 100 individual species accounts and discussions of the ecology of many major groups of organisms for Guanacaste.

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WHAT DOES GNP MEAN TO COSTA RICA?

Properly developed, Guanacaste National Park will mean different things to many different people. Below we list some of these things, recognizing that the list has overlapping parts and is not exhaustive.

1) GNP will be a major regional, national and international cultural center. For many people of the region, it will be the difference between living as a physically healthy human draught animal living in rich but mindless agricultural pastures, and living as a cultured human being. Simultaneously, its successes and failures will offer examples to others developing the biological cultural and educational potential of other tropical sites in and out of Costa Rica.
2) GNP will be the first Costa Rican national park designed from the beginning as a cultural and educational resource. Simultaneously, it will be a major opportunity for Costa Ricans to put their traditional respect for education to work for themselves, rather than simply use their educations to respond to the cultural pablum served up by the steadily homogenizing public media.
3) GNP will demonstrate that the Costa Rican government has the foresight and flexibility to develop its national parks rather than simply to form and patrol them by decree.
4) GNP will be the first example anywhere in the tropics where a small and endangered habitat was given back a large area to reinvade and thereby get its population densities back to a more resilient level.
5) GNP will be the only dry forest reserve in Mesoamerica large enough to maintain healthy breeding populations and normal habitats of the animals, plants and habitats that were here when the Spaniards arrived. Whether it eventually becomes the only one in the Neotropics depends largely on how much of an inspiration it is to other regions to attend to their dry forests before they disappear.
6) GNP will be the only preserved intersection of two major habitat types, and the only preserved dry forest elevational transect, in Mesoamerica (if not in all of the Neotropics).
7) GNP will be a living gene bank for tens of thousands of species of wild organisms, some of which are already of established commercial value (e.g., timber trees, fuelwood trees, game animals) and many of which will some day be of commercial value.
8) GNP will be a large and diverse example and data source for studies

and projects in reforestation with dry forest plants, and in the manipulation of habitats to this end. It will also go a long way toward destroying the myth that tropical humans cannot be in control of their environmental destiny.

9) GNP will be the first neotropical national park with a substantial endowment fund and therefore the ability to survive a variety of economic perturbations and excercise some autonomy over its management plans.

10) GNP will offer salaried and secure local employment that will employ fewer people than if the land were colonized by subsistence farmers but substantially improve the cultural lives of Costa Ricans from local subsistence farmers to San José upper income residents. Furthermore, the annual management budget of GNP will represent a substantial cash flow into the local economy.

11) GNP will be an economic resource through significant development of the conventional and educational tourism industry; participation will range from local guide service and living accomodations to international-level tours. The stress will be on the educational aspects of tourism.

12) GNP will show that the international community is willing to recognize its financial and intellectual responsibility towards a portion of the tropics, a portion that has enormous collective value to the world at large.

APPENDIXES

APPENDIX 1. RELATIONSHIP OF GNP TO OTHER PACIFIC MESOAMERICAN DRY FOREST RESERVES.

Guanacaste National Park will be the largest link in the thin chain of tropical dry habitat national parks, forest reserves, wildlife refuges, etc. that stretches from tropical western Mexico to Panama on the Pacific coast of Mesoamerica. Additionally, within Costa Rica it is by far the largest island in a highly fractured archipelago of dry forest preserves. Except for Santa Rosa and Murciélago, which will become part of GNP, these sites will all make heavy use of GNP in the future as a reference point and will simultaneously contain some habitats that can never occur in GNP.

OUTSIDE OF COSTA RICA

1.– **Estación Biológica Chamela.** 120 km north of Manzanillo, Jalisco, Mexico. This 16 km ^{2} preserve and Biological Field Station is in lightly disturbed Tropical Deciduous Forest (Bosque Cauducifolio Tropical) on lightly dissected undulating terrain of sandy metamorphic rocks (50-100 m elevation). It has a well-developed biological research station (initiated in the early 1970's) and is owned by the Instituto de Biologia of the Universidad Nacional Autónoma de México in Mexico City. Address: Estación Biológica Chamela, Apartado Postal 21, San Patricio, Jalisco 48980, México.

2.– **Parque Deininger.** 5 km east of the city of La Libertad, La Libertad El Salvador. This 7.32 km^2 national park is lightly disturbed (though heavily hunted in the past) tropical deciduous forest on steep slopes (7-300 m elevation) and much like the deciduous forests in the central portion of Santa Rosa National Park, Costa Rica. Deininger National Park is relatively unstudied, except that its tree flora has been inventoried. Address: Lic. Manuel Benítez Arias, Jefe, Servicio de Parques Nacionales y Vida Silvestre, MAG, San Salvador, El Salvador.

3.– **Parque Nacional Volcán Masaya.** 20 km southeast of Managua on the asphalt highway from Managua to Granada, Nicaragua. This 43 km^2 national park is centered on two periodically active volcanos and clothed with heavily disturbed deciduous forest remnants.

4.– **Monumento Nacional Sarigua.** 235 km southwest of Panama City, and on the tip of the Azuero Peninsula on the Pacific coast of Panama. This new 60 km^2 national monument is in the process of formation on coastal foothills and shore (mangrove). The highly deciduous vegetation has been badly perturbed by farming and clearing, but may recover once

protected (Fundación de Parques Nacionales y Medio Ambiente de Panamá, personal communication).

In addition to the above, there are a few tens of km² of dry forest sites in central or eastern Mexico that are either in biological preserves or being considered for inclusion.

INSIDE COSTA RICA

While the conservation picture in Costa Rica is still fluid and expanding, dry forest habitats have been so thoroughly agriculturalized that there is almost no pristine forest remaining, outside of extant preserves, that can be used to increase conserved areas. Forest restoration is the only means by which one can substantially increase the area of Costa Rica's dry forests that are under protection.

1.– **Parque Nacional Santa Rosa.** (Santa Rosa Section). 35 km north of Liberia in Guanacaste Province. This 108 km² rectangular block stretches from the Interamerican Highway to the Pacific Ocean (0-350 m elevation) over plateaus, canyons and coastal plain. The vegetation ranges from 2 m tall totally dry season deciduous forest to 30-40 m tall evergreen forest, with successional stages of 0-400 years in age and numerous old pastures of 1-200 ha in extent. The site is under intensive study by biologists, and will be a major source of inoculum for GNP. Santa Rosa was the first large national park to be formed in Costa Rica (1972) and is firmly embedded in the national park system. Address: Parque Nacional Santa Rosa, Apdo. 169, Liberia, Guanacaste Province, Costa Rica, tel. 69-5598.

2.– **Parque Nacional Santa Rosa.** (Murcielago Section). Along the north half of the Santa Elena Peninsula, Cuajiniquil, Guanacaste Province. This 122 km² section covers rocky mountains to low hills that were once covered with deciduous dry forest but are now primarily covered with abandoned pastureland. It is rich in mangrove and intertidal habitats, and still contains enough small vegetation patches to reforest if allowed through exclusion of fires. This new addition (1980) to Santa Rosa National Park has not been investigated biologically. Once consolidated with Santa Rosa and the intervening Santa Elena peninsula, Murcielago will be a major dry forest patch; by itself, it has no chance to escape from the dry season fires that sweep the Santa Elena peninsula. Address: Same as Parque Nacional Santa Rosa.

3.– **Parque Nacional Palo Verde.** On the flood plain and east bank of the Río Tempisque as it spreads into the Gulf of Nicoya. This 94 km² park is the southern portion of the combined floodplain preserve of Palo Verde National Park and Refugio Nacional de Fauna Silvestre Dr. Rafael Lucas Rodríguez Caballero; this preserve was established largely to protect waterfowl. The site is largely cleared of forest, and has been heavily grazed and burned, but it may eventually return to approximately pristine vegetation if the fires are halted.

4.– **Refugio Nacional de Fauna Silvestre Dr. Rafael Lucas Rodríguez Caballero.** Upriver and bordering Parque Nacional Palo Verde. This 74 km² wildlife refuge has great potential for preserving dry season waterfowl habitat an the rich flood plain flora. Its aquatic habitats are, however, severely threatened by the agrochemical runoff from Guanacaste agriculture and by water control in the Río Tempisque. Both the park and the refuge are undergoing massive vegetation changes at present, owing to removal of cattle and intensification of the fire regime.

5.– **Parque Nacional Barra Honda.** 23 km NE of Nicoya in the upper

Nicoya Peninsula. This 23 km² national park was established on severely perturbed dry forest on limestone hills to protect an extensive cave system. The site is biologically unstudied, but may be found to be ecologically important for its limestone-based vegetation as well as its cave biology (and archaeology).

6.– **Reserva Natural Absoluta Cabo Blanco.** The tip of the Nicoya Peninsula (Puntarenas Province). This 12 km² reserve was established to protect seabird roosting and nesting sites. The forest behind the beach is significant in a protective sense, but may also be of relictual value as well.

7.– **Refugio Nacional de Fauna Silvestre de Ostional.** 35 km SW of Nicoya on the Pacific coast. This 0.16 km² wildlife refuge was established for the protection of Playa Ostional's sea turtle nesting sites.

8.– **Lomas Barbudal Reserva Biológica.** 15 km SW of Bagaces. This 30 km² newly established biological reserve is in a relictual deciduous forest on low hills. While the site has been severely perturbed by hunting and logging, it contains sufficient population relicts to eventually return to incomplete but superficially intact dry forest if the fires are halted.

APPENDIX 2. OFFICIAL LETTERS OF SUPPORT FOR GNP.

MINISTERIO DE AGRICULTURA Y GANADERIA
SERVICIO DE PARQUES NACIONALES

S.P.N. 259
January 28, 1986

Dr. Daniel Janzen
Department of Biology
University of Pennsylvania
U. S. A.

Dear Dr. Janzen:

I enjoyed the presentation you gave on the proposed creation of Guanacaste National Park.

As discussed, the new park coincides roughly with the area recommended by a study conducted by the Tropical Science Center on potential areas and additions to the system of national parks and reserves, a few years ago.

The National Park Service approves and supports this project. It strives to preserve an excellent example of Tropical Dry Forest and its remarkable biological diversity. However, I want to stress the need to establish an endowment fund to ensure proper management and consolidation, before the area is turned over to the Park Service.

Thank you Dan. We, and Costa Rica in general, are fortunate to have you working with us. Your contribution to the preservation of our renewable natural resources is invaluable.

I look forward with enthusiasm to the successful outcome of this challenging endeavor and I encourage you to keep working at it.

With kind personal regards,

Alvaro F. Ugalde
Director

FUNDACION DE PARQUES NACIONALES

January 28, 1986

Dr. Daniel Janzen
Department of Biology
University of Pennsylvania
Philadelphia, Pennsylvania 19104
U. S. A.

Dear Dr. Janzen:

The National Parks Foundation has reviewed your proposal for the establishment and the subsequent management of Guanacaste National Park.

We agree that the park will serve well to preserve the last remnants of the tropical dry forest in Latin America, the protection of this area will be an unprecedented endeavor in Latin America, and of great benefit to Costa Rica and visitors from around the world.

We are eager and willing to work with you as in the past, and assure you our full cooperation and support.

Due to the current financial difficulties the government of Costa Rica is experiencing in administering the system of protected areas, we recommend that your campaign include funds for land acquisition and to set up a management fund for the park.

We thank you for your continued interest in conservation, and wish you much success with the proposed project.

Sincerely,

Mario A. Boza, President

No. 1/86
January 27, 1986

Faculty of Arts and Sciences
Department of Biology
University of Pennsylvania
c/o Dr. Daniel Janzen:

Gentlemen:

We make reference to the project involving the creation and management of Guanacaste National Park. The proposed park includes the existing Santa Rosa National Park, Murciélago, Cacao and Orosi Volcanos and surrounding areas. Your proposal coincides with our interest in preserving the ecosystems already represented in Santa Rosa, but more importantly, we are concerned with the protection of those ecosystems found outside the current system of natural areas. In particular, we are concerned with the tropical dry forest which is very threatened and is underrepresented, perhaps three areas exist in all of Tropical America, that can be preserved.

We trust in success for which in advance we would like to express our most sincere appreciation.

Sincerely,

Dr. Rodrigo Gámez
President
Fundación Neotrópica

APPENDIX 3. MONTHLY PRECIPITATION (ROUNDED TO THE NEAREST MM) IN THE ADMINISTRATION AREA OF SANTA ROSA NATIONAL PARK, GUANACASTE PROVINCE, COSTA RICA (DATA COLLECTED BY PARK RANGERS AND EXTRACTED FROM THE METEOROLOGY INSTITUTE IN SAN JOSE).

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Tot.
1980	1	0	5	0	184	175	139	159	331	417	240	9	1660
1981	0	1	1	11	353	582	172	478	195	268	153	27	2241
1982	16	2	0	41	919	129	117	34	328	197	37	1	1820
1983	2	0	22	4	21	180	106	107	188	201	79	7	917
1984	6	8	0	0	118	218	278	162	613	261	52	7	1723

APPENDIX 4. PROTECTION STATUS OF THE AREA TO BE INCLUDED WITHIN GUANACASTE NATIONAL PARK (SOURCE: COSTA RICAN NATIONAL HERITAGE PROGRAM).

1986

	KM^2	HA	
Area protected in National Parks	229.90	22990	32.72%
Area semi-protected in Forest Reserves	105.45	10545	15.02%
Total protected	335.35	33535	47.74%
Continental area not protected	363.80	36380	51.79%
Island area not protected	3.30	330	0.47%
Total unprotected	367.10	36710	52.26%
Total area of Guanacaste National Park	702.45	70245	

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