3.0 Cultural Plant Geography

Introducer: Karl S. Zimmerer

Abstract Cultural plant geography has undergirded the research career of William M. Denevan. Rooted in human-environment geography, Denevan's contributions provided landmark advances. He first utilized cultural plant geography in research on the region-scale anthropogenic influences and human use of tropical pine forests in Central America. Denevan subsequently directed this approach to research on the landscapes and adaptive strategies of the tropical lowland agriculture of indigenous groups. Subsequently it was central to his comprehensive analysis of Amazonian and Andean landscapes, global-scale synthesis, and interpretation such as the anti-Pristine Myth project, and the current interdisciplinary subfields of historical ecology, social forests, and agrobiodiversity.

Keywords Plant geography · Culture · Amazon · Agrobiodiversity

Introducing Denevan's Cultural Plant Geography: From Biogeographic Imprints to Adaptive Strategies and Beyond

Cultural plant geography launched the research and writing of William M. Denevan by providing the framework for his first major publication, *The Upland Pine Forests of Nicaragua: A Study in Cultural Plant Geography* (Denevan 1961), based on his Master's thesis (1958). The monograph opens by stating "This is a study in cultural plant geography, a study concerned with the relation of human activities to the occurrence and distribution of the genus Pinus…." The opening sentences are anchored with a footnote defining this freshly minted field as "the study of vegetation changes resulting from man's occupance of the earth…" (Robison 1958).

Denevan's focus on cultural plant geography evolved significantly in his ensuing works that traced an arc increasingly directed in the 1970s and 1980s toward the adaptive strategies of the tropical lowland agriculture of indigenous groups. The study of vegetation change as cultural plant geography was central to this research

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that became synopsized in "Fields of the Mojo, Campa, Bora, Shipibo, and Karinya" (Denevan 2001). Crafted as a chapter in his volume on *Cultivated Landscapes of Native Amazonia and the Andes*, the design of "Fields" utilized the theme of cultural plant geography even as the term itself had become uncommon.

Drawing on the aforementioned publications, the goal of this essay is to trace Denevan's research on cultural plant geography from its early foundation of biogeographic imprints to subsequent interest in adaptive strategies. Initially contributing to the discipline of geography, it later influenced the vibrant interdisciplinary studies of historical ecology, social forests, and agrobiodiversity (including agroforestry and agroecology). This trajectory is crucial to the insights that Denevan marshalled in debunking the Pristine Myth of Nature in the Americas (Denevan 1992 and section "The Pristine Myth: The Landscape of the Americas in 1492" in Chap. 8) and advancing the awareness of pre-European Amazonian landscapes. I first provide a brief analytical review of each publication in sections "The Upland Pine Forests of Nicaragua: A Study in Cultural Plant Geography (1961)" and "'Fields of the Mojo, Campa, Bora, Shipibo, and Karinya,' in *Cultivated Landscapes of Native Amazonia and the Andes* (2001)". I then examine the theme of cultural plant geography in the broader context in Denevan's *oeuvre* as well as its major interlocutors from the past to the present (section "Discussion: Cultural Plant Geography in Context, Oeuvre, and Influences"). The essay concludes with a synthesis of this influential legacy (section "Conclusion: From Imprint and Adaptation to Historical Ecology, Social Forests, and Agrobiodiversity").

The Upland Pine Forests of Nicaragua: A Study in Cultural Plant Geography (1961)

The Upland Pine Forests of Nicaragua appeared in the University of California Publications in Geography, a series that had been founded by Carl Sauer, and denoted the scope of Denevan's early career success. "Upland Forests" furnished a geographic examination of the relations of pine forests and species distributions to human fires and settlement in northern Nicaragua. Denevan selected the country's Segovian highlands as part of "the southern geographical terminus of the genus in the Western Hemisphere" (Denevan 1961, iii). Interest in these pine forests was further justified by their value as important sources of timber and resin, with the latter valued for shipbuilding, fuel, and medicinal purposes (Denevan 1961, 297–299).

Denevan's focus benefitted from the growing number of studies of geographers, foresters, and ecologists investigating the role of fire in the distributions of pine species in tropical and subtropical regions. These studies had begun in the early twentieth century with the pioneering work of O.F. Cook that influenced cultural plant geography (Gade 1970). Research on pine forests and fire swelled in the 1950s with works by leading scientists and scholars such as James J. Parsons, who served as Denevan's graduate and thesis adviser at the University of California at Berkeley, G. Budowski, F. Egler, L. Holdridge, and C. Johanessen in addition to the pine specialist N. Mirov at the Berkeley station of the US Forest Service.

Denevan's monograph begins by reviewing the geographic distributions of the Central American pines (13 species in the genus *Pinus*) and the temperature-precipitation ranges of the species triad that occurs in Nicaragua (Denevan 1961, 254). It then amasses multifaceted evidence to argue that the upland pine forests of Nicaragua are dependent on human burning and, correspondingly, this vegetation formation occurs in conjunction with long-continued permanent settlement (Denevan 1961, 300).

"Upland Forests" integrates research in biogeography and ecology with the use of cultural and historical techniques. One core of Denevan's approach applied then-current ecological theory, in particular the concept of climate-driven climax vegetation, to understanding the distribution of these pine forests. It is the exceptions to the climax forest communities, Denevan deduced, that are created by edaphic conditions and the human activities of settlement and burning. Undertaking this approach required Denevan to integrate fieldwork with the mapping of plant and physical geographic distributions, the observation of human burning and other vegetation impacts, and the evaluation of historical records of human settlement.

"Upland Forests" devotes ample attention to the description of physical geographic parameters, especially geologic parent materials and soils, topography, and climate. It compares these distributions to biogeographic results based on the mapped occurrence of pine forests using air photos. Denevan then describes the role of fire, especially the regular practice of light burning by local inhabitants. His treatment of fire incorporated insights based on what are now termed natural experiments, such as the de facto fire exclosures created by crossing trails. In addition, Denevan created historical geographic estimates of the frontier of the denser settlement of human population at the eastern edge of the Nicaraguan highlands in the years of 1603, 1752, and 1957. He concludes the monograph definitively: "upland pine forests of Nicaragua are a deflected climax, a man-made formation resulting from clearing of broadleaf forest and repeated burning" (Denevan 1961, 300).

Overall, Denevan singles out the role of human fires as the major determinant of the distribution of upland pine forests in the Nicaraguan highlands. Human settlement and soil types influenced by geologic parent material also facilitate the success of these upland pines. It contrasts the absence of pines east of the settlement frontier in Nicaragua's central mountains, as well as the settled southern uplands. Denevan completes the conclusion by calling for more studies on the cultural plant geography of pines in the tropics, reflecting his deep-seated commitments as an empirical and comparative researcher. More broadly, this publication initiated Denevan's sustained analysis of anthropogenic landscapes.

"Fields of the Mojo, Campa, Bora, Shipibo, and Karinya," in *Cultivated Landscapes of Native Amazonia and the Andes* (2001)

Vegetation change related to human activities is critical to the expanding focus that Denevan developed on the agricultural field systems of the lowland tropics of South America. This research culminated in his publication of "Fields of the Mojo, Campa, Bora, Shipibo, and Karinya" in 2001. It provides the comparison of several distinctive swidden agricultural systems of indigenous groups in the Amazon and Orinoco basins from Bolivia and Peru to Venezuela. Drawing on field research and earlier publications (e.g., Denevan 1963, 1971; Denevan and Schwerin 1978; Denevan et al. 1984), "Fields" offers descriptions of the tropical lowland agricultural systems of the colonial Mojo (Bolivia), the extensive system of the Campa (Peru), the managed fallows of the Bora (Peru), the floodplain cultivation of the Shipibo (Peru), and the multiple-biome fields of the Karinya (Venezuela) (Denevan 2001, 75). Important to note in the present volume is that the description of the managed fallows and agroforests of the Bora is omitted in the reprint of "Fields" herein (section "Fields of the Mojo, Campa, Shipibo, and Karinya") since it overlaps with the material contained in section "Indigenous Agroforestry in the Peruvian Amazon: Bora Indian Management of Swidden Fallows" in Chap. 6.

Denevan's immediate goal was to assess the temporal and spatial variation of vegetation and related human activities in swidden field systems. By innovating the application of cultural plant geography, Denevan was able to describe this variation and, more broadly, the adaptive strategies of lowland tropical agriculture. Denevan extended this innovative deployment of cultural plant geography to the community-level properties of food plants, notably the diversity of cultivated species, as well as the importance of non-crop vegetation, with particular attention to the utilized tree flora that was culturally important and biodiverse.

Denevan's treatment of the swidden agricultural system of the Campa people is exemplary. The Campa or Asháninka reside in the Gran Pajonal ("Great Grassland") in the central Amazon (*selva* central) of Peru. Pajonal vegetation comprises tropical forests, scattered patches of savanna grassland, and agricultural systems based on extensive-style swiddening. Population of the Campa, who are the largest Amazonian indigenous group, was estimated at 30,000–45,000 in 2001 (Denevan 2001, 78), whereas the original 1971 publication surmised 24,000–26,000 persons (Denevan 1971, 498).[1] Denevan detailed how the characteristics of vegetation (mature forest) and soil (more fertility) are important siting factors in the vegetation and edaphic changes that occur with forest clearing for the purpose of swidden agriculture. He enumerated the diversity of Campa crop domesticates and semidomesticated plants as 48 species (1971, 505).[2] Still, it was the ample and irregular variation in agricultural vegetation and management, which Denevan synopsized as "unstable swiddens" (Denevan 2001, 78), that was considered most characteristic.

Conceptually this research employed three distinct applications of cultural plant geography. First was its emphasis on the variation of vegetation over time that is a distinguishing feature of swidden clearing, cropping cycles, and managed forest fallows. Second was the focus on adaptive strategies that enabled Denevan to refer to the food and cultural ecological functions of swidden by rooting this analysis in the distribution and occurrence of swidden plants (see also Denevan 1983 and section "Adaptation, Variation, and Cultural Geography" in Chap. 8).

[1] On the recent demographic growth of indigenous people in the tropical lowlands of Latin America, as well as the challenges of demographic estimates, see such works as McSweeney and Arps (2005).

[2] This richness of Campa crop diversity at the species level (a component of agrobiodiversity) was significant but overshadowed by the 101 cultivated plant species and other plants cared for that were documented several years later among the Karinya in the Venezuelan Llanos (Denevan and Schwerin 1978, 42–45).

Third was the role of human activities in relation to vegetation changes across space. Distinctive spatial variation became increasingly important in Denevan's descriptions, such as the Shipibo people's multiple food-producing biotopes consisting of floodplains, mudbars, and topographic positions on levees and backslopes. Each of the nine local biotopes was associated with distinct arrays of crop vegetation and cultivation techniques (Denevan 2001, 93–95). Similarly, Karinya cultivation in the Orinoco Llanos was found to correspond to nine biotopes, each distinct with regard to topography, vegetation, crop types, and field system (Denevan 2001, 98–100; see also Denevan and Schwerin 1978). The term "variable adaptation" aptly encapsulated this spectrum of diverse Karinya agricultural systems.

The "Fields" research and writing "falls within the conceptual discourse of cultural ecology, which is concerned with how people relate to, or interact with, their environment" (Denevan 2011, 10). This cultural ecology takes in geographical ecology, political ecology, ecological anthropology, and historical ecology. Notably omitted is the systems ecology perspective, perhaps for reason of its tendency to assume equilibrium-trending conditions (Zimmerer 1996), whereas the Campa findings had impressed on Denevan the variability and lack of systemic regularity that are characteristics of swidden agriculture in tropical lowlands (Balée and Erickson 2006).

Denevan's cultural plant geography in this reading must be seen as focused on the relation of human activities to vegetation distribution, in particular the temporal and spatial variation of vegetation in swidden agricultural systems. Denevan saw this variation as crucial to the realm of cultural adaptations to the environment that he positioned as the central topic of his research and scholarship (Denevan 1983). It also leveraged his capacity to comment briefly on implications regarding a then vociferous argument on protein deficit and the so-called Counterfeit Paradise of Amazonia that was being researched and debated by a host of leading environmental archaeologists and ecological anthropologists (Denevan 1971, 524).

The "Fields" reading also evidenced the influence of Denevan's faculty appointment. He drew extensively on the cadre of excellent graduate students investigating lowland tropical agriculture and resource systems at the University of Wisconsin, Madison, as well as elsewhere. "Fields" was also propelled through the inputs of collaborating faculty and research scientists, many themselves top scholars. Finally, financial support from the university and the Geography and Regional Science program of the National Science Foundation included grants for his field research projects in Peru and Venezuela in the 1970s and 1980s. These influences were parlayed into Denevan's growing interest in the "big questions" of the relations of people and land to the rise and fall of societies (Denevan 2001, 10) that complemented his earlier call for additional quantitative data collection (Denevan 1971, 528).

Discussion: Cultural Plant Geography in Context, Oeuvre, and Influences

The cultural plant geography illustrated in this pair of readings was crucial to the ensuring emphasis in Denevan's research on the mixed landscapes of Latin America that included, but were not limited, to the indigenous agriculture of native and pre-

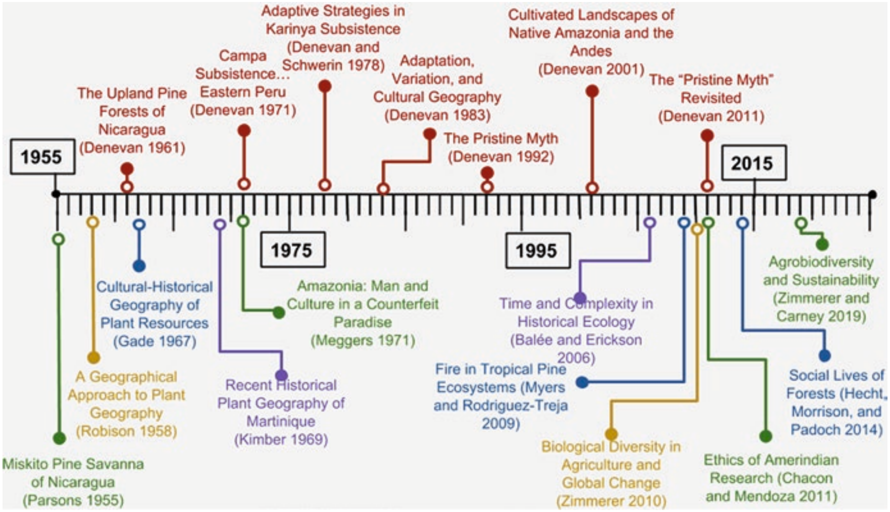

Fig. 3.1 Cultural plant geography in publications of William M. Denevan and related works

European peoples in South America. For instance, Denevan and Schwerin investigated the current indigenous management of vegetation change in contemporary Karinya agriculture in order to reflect on the extensive remains of raised-field complexes in Venezuela. Human burning related to vegetation change and patterns similarly was an enduring focus. Denevan integrated these insights to support his influential debunking of the so-called Pristine Myth of Nature in the Americas (Denevan 1992, 2011, 2016; Fig. 3.1). He drew heavily on the insights of cultural plant geography to argue against the claims of nominal or nonexistent levels of the demographic presence and environmental impact of indigenous people prior to Columbus' voyages and subsequent European colonialism.

Denevan's debunking of the Pristine Myth of Nature in the Americas bolstered new, enhanced awareness of the sophisticated indigenous agricultural systems of pre-European peoples as the basis of extensive areas of humanized landscapes in the Amazon and elsewhere (Denevan 2011). Denevan marshalled the concepts and tools of cultural plant geography to ground his growing engagement with the big questions of pre-European populations and environmental impacts in the Americas. While the Pristine Myth had been propelled by proponents as varied as the journalist Kirkpatrick Sale and literary and artistic figures of the nineteenth-century Romantic Movement, the new awareness triumphed by Denevan subsequently became propagated through influential, well-informed public figures such as the popular science author Charles Mann (Mann 2005).

Scholarly and scientific influence on the cultural plant geography of Denevan owed primacy of place to the work and guidance of his graduate thesis adviser and mentor, James Parsons (Denevan 1989), and Sauer's landscape approach (Denevan and Mathewson 2009). Parsons' field studies in spring 1953 had led to the publication of his article on the "The Miskito Pine Savanna of Nicaragua and Honduras" in the *Annals of the Association of American Geographers* (Parsons 1955). It argued elegantly for the causative role of human burning in the genesis of this pine savanna in the rainy Caribbean lowlands of Central America. Parsons highlighted the probable global scope of the influence of human burning on tropical pine forests (e.g., in Southeast Asia, Parsons 1955, 36). Later he extended his study of fire in arguing for its influence on the savanna grasslands of northern Colombia, the Colombian and Venezuelan Llanos, and the pastures of Central America.

The early cultural plant geography of Denevan, as well as some of Parsons' works in this domain, reflects the influence of Sauer's well-known 1925 treatise on *The Morphology of Landscape* (Sauer 1925; Leighly 1965). This influence is evident in the designs that Parsons and Denevan chose for their research on Central American pine forests, the organization of findings within their publications, and the contours of their reasoning and argumentation. Parsons and Denevan began their publications with information on the biogeography, taxonomy, and ecology of pines followed by accounts of regionally specific physical geography proceeding from topography and geologic parent material to climate and soils. Each then laid out the evidences for edaphic influences and, most importantly, the role of human fires and settlement in determining the region- and site-specific occurrence and distribution of pines in the tropics.

The Morphology of Landscape, it should be recalled, had propounded the case for studying and understanding the formation and functions of landscapes as the common ground of geography. This formulation of the landscape concept began with physical geographic factors and then overlaid the activities of cultural groups. Settlement counted as one of the principal factors of the cultural landscape. Fire too figured prominently, especially when it became etched in Sauer's contribution to the 1956 Wenner-Gren Conference that produced *Man's role in shaping the face of the earth* (Sauer 1956; Thomas 1956). In short, Denevan closely followed Parsons, and both were influenced to a significant degree by Sauer's concept (albeit not exclusively), in their applications of cultural plant geography to tropical landscapes.

Denevan's cultural plant geography benefitted from departmental strengths and campus-wide programs at the University of Wisconsin, Madison, in the fields of Latin American studies, biogeography, and historical approaches that were echoed in Gade's framings of "cultural-historical geography" and later "cultural biogeography" (Gade 1975) and Kimber's use of the term "historical plant geography" (Kimber 1969, 1988). Their works highlighted cultural and historical approaches combined with biogeographic and ecological concepts and methods. Other overlaps crucial to Denevan's own evolving approach to cultural plant geography were rooted in anthropology and archaeology.

The early phase of Denevan's cultural plant geography also reflected the widespread albeit mostly implicit influence of the tenets of cultural-historical ecology. The umbrella of cultural-historical ecology (Zimmerer 1996), which was associated with the works of James Parsons and others, had become a mainstay in human-environment geography of the mid-twentieth century and was distinguished by the characteristic use of ecological concepts integrated with biogeographic, cultural, and historical analysis. Subsequently the shift of Denevan's interests toward adaptive strategies became the basis of the research that was encapsulated in "Fields of the Mojo, Campa, Bora, Shipibo, and Karinya" that grew out of such individual case studies as those of the Campa (Denevan 1971), Karinya (Denevan and Schwerin 1978), and Bora (Denevan and Padoch 1988; Denevan et al. 1984). Denevan's vibrant circles of graduate students and colleagues, which extended to other departments and universities (Erickson 1988), helped propel this group's continuing interest in understanding adaptive strategies (Knapp 2017).

The evolution of Denevan's later cultural plant geography also contributed perspectives that subsequently expanded and gained momentum as distinct fields, in particular historical ecology, social forests, and agrobiodiversity (Fig. 3.1). In the case of historical ecology, for example, Denevan's contributions fueled the pioneering systematic investigations of anthropogenic and humanized landscapes across geographic regions, cultures, and time periods (Balée and Erickson 2006; Erickson 1988). Denevan's cultural plant geography also helped fuel research on the social dimensions of forests (Hecht et al. 2014) and the human-environment interactions of the biodiversity of food systems and agriculture that is referred to as agrobiodiversity (Zimmerer 2004; also termed "agrodiversity"; see Brookfield and Padoch 1994). Expanding attention is now also probing the regional and global geographic dimensions, cultural dynamics, and historical depth of agrobiodiversity (Coomes 2010; Zimmerer 2013; Zimmerer et al. 2018; Zimmerer and Carney 2019). Denevan and his collaborators continue to advance the understanding of historical ecology, social forests, and agrobiodiversity from a landscape perspective in the Amazon (Clement et al. 2015).

Conclusion: From Imprint and Adaptation to Historical Ecology, Social Forests, and Agrobiodiversity

Cultural plant geography has been integral to the career trajectory and contributions of William M. Denevan. The readings paired with this essay illuminate this central axis and how it has guided the growing spectrum of interest and activities devoted to human-environment interactions in general and, in particular, newer studies in historical ecology, social understandings of forests, and agrobiodiversity. In *The Upland Pine Forests of Nicaragua*, Denevan crafted a landmark study integrating the use of ecological concepts, observations of cultural practices, and historical analysis. It was rooted in the influential cultural-historical ecology of Parsons and others that traced to Sauer's framework for understanding the morphology of landscape.

Denevan subsequently broadened the scope of cultural plant geography to encompass the temporal and spatial variation of vegetation in the swidden, forest-fallow agriculture of the lowland tropics. This innovation became the foundation for his subsequent status as a leading scholar of the adaptive strategies of tropical swidden agriculture and the landscapes and earthworks of pre-European Amazonia.

Denevan's innovative turn in the use of cultural plant geography marked his transition from the ardent pupil in the field applying the lessons of Parsons and the Sauerian Berkeley School to his ascent and prominence as a leading scholar and scientist advancing new insights on indigenous agricultural adaptations, demography, landscapes, and environmentalist concerns. Denevan marshalled these insights in debunking the Pristine Myth of Nature in the Americas and supporting the alternative view of intensive agriculture amid humanized landscapes, dense human populations, and complex societies in the tropical lowlands. More recently, Denevan's cultural plant geography has inspired the initiation, growing interest, and expanding prospects of the interdisciplinary fields that focus on historical ecology, social forests, and agrobiodiversity.

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3.1 The Upland Pine Forests of Nicaragua

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Editor's Note: This is an excerpt, consisting of the original Preface, Chaps. 4, 5, 6 and 8, plus references and relevant figures and plates (herein relabeled as figures and incorporated into the text).

Abstract The genus *Pinus* in the Western Hemisphere extends from Canada to the Caribbean coast and interior mountains of Nicaragua. The highland vegetation is mainly mixed tropical broadleaf hardwoods, with sectors of *Pinus oocarpa*. The highland pines occur on poor acidic soils derived from granitic rock, whereas the hardwoods are on soils derived from both granitic and volcanic (basic) rocks. The question raised is why pines, usually a temperate climate tree, are found in the tropics, at their southern-most limit. Observation, historical information, and mapping indicate that the pines mostly occur (1) on acidic soils and (2) where there has been a long prehistory and history of human settlement involving forest clearing and frequent burning. The *oocarpa* pine is resistant to fire, whereas the hardwoods are not and thus are unable to compete with the pines on acidic soils. On the more fertile volcanic soils, however, the hardwoods dominate, even with burning. It is unlikely that extensive and pure stands of pines existed in Nicaragua before human arrival.

Keywords *Pinus* · Biogeography · Nicaragua · Forests

Preface

> There is a frequent correlation between actual vegetation and remote human occupations. The rate of succession towards the original forest community, the establishment and maintenance of certain plant communities and the dominance of certain species, can in many

> cases be attributed to past human interventions, some of them dating several centuries back. Budowski (1959a, 262)

This is a study in cultural plant geography,[3] a study concerned with the relation of human activities to the occurrence and distribution of the genus *Pinus* in Nicaragua – the area of the southern geographical terminus of the genus in the Western Hemisphere.

In the humid tropics, the climatic climax vegetation is a mixed forest containing a great variety of species; the nature of any other type of plant community is largely determined by the selective effects of nonclimatic conditions, especially edaphic factors but also human activities such as forest clearing, grazing, and burning. Students of both people and vegetation have been giving increasing attention to the correlation between the existence of many tropical savannas and grasslands and human burning. There has been much less concern, however, for the possible correlation between fire and tropical forest communities dominated by a single woody species; such a relation has been suggested, for example, for certain casuarina forests in the East Indies, eucalyptus forests in northeastern Australia, teak forests in Burma and Thailand, oak forests in Central America, and pine forests in Southeast Asia and Middle America.

Species of the genus *Pinus* extend well into tropical latitudes in the Western Hemisphere. On the Caribbean coast of Nicaragua near Bluefields, a *Pinus caribaea* – grassland association – extends to 12° 10′ N latitude (Fig. 3.2), and in the northwestern highland area known as the Segovias, discontinuous stands of pine, mainly *Pinus oocarpa*, extend south of Matagalpa to 12° 45′ N. Studies of the ecology of the lowland pine savannas of eastern Nicaragua have previously been made by Parsons (1955b), Taylor (1959a), and Radley (1960), but the upland pine forests (Fig. 3.3) have received little attention in the literature.[4]

Most pine species readily invade open sites and thus may be part of an early successional stage rather than a climax plant community. Pine seeds are known to germinate best in exposed mineral soil, and young seedlings of many species, including *P. oocarpa* and *P. caribaea* in Nicaragua, are intolerant of shade. How then can the Nicaraguan pines, all of which occur in the warm and humid climates of elevations below 5000 ft (Fig. 3.4), compete with much faster growing tropical plant species so successfully that they form large and pure stands?

My observations indicate that in highland Nicaragua, pines grow mainly on sites with thin soils and acidic parent materials, in an area having a long history of human settlement which involved forest destruction, periodic burning, and soil erosion; however, regardless of soil conditions, the upland pines seem incapable of competing successfully – except, possibly, in localized "natural habitats" – with broadleaf vegetation for a long period of time without the aid of at least occasional fire.

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[3] The term "cultural plant geography" has been proposed by Robison (1958b, 286) "…as a designation for the study of vegetation changes resulting from man's occupance of the earth…."

[4] For brief discussions of the highland pines, see Taylor (1959b, 207–209) and Food and Agricultural Organization (1950, 48–52).

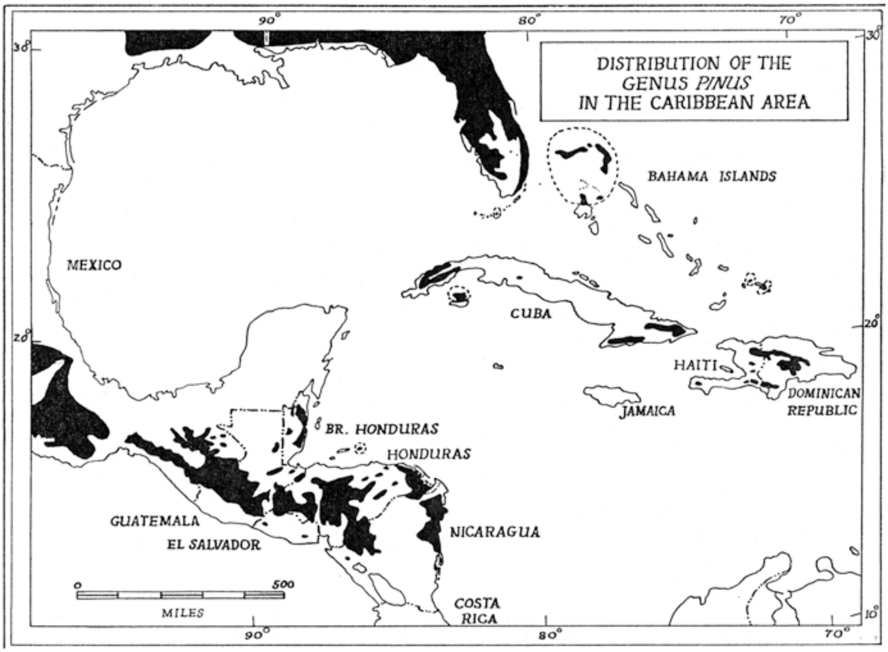

Fig. 3.2 The distribution of the genus *Pinus* in the Caribbean area

In this study climatic, edaphic, and biotic relationships as well as economic and historical human factors are examined to provide a basis for understanding the biogeography of the upland pine forests of Nicaragua. Special attention is given to the role of fire as an ecologic agent. Relief, parent rock materials, soils, climate, and vegetation are considered in some detail, primarily as they relate to the distribution of the pines, but also as they relate to settlement and land-use practices in the pine area.

It is important to point out that the physical and cultural geography of the interior of Nicaragua is very poorly known; consequently, this study was in many ways a reconnaissance. For most of Nicaragua, there is need for basic research in all fields of the physical and social sciences.

Fire and Pines

"These hills were covered with long-leaved pines, and the proportion they bear to the hard wood is said to have been increased by the Indian practice of burning the grass; the bark of the oak and other kinds of hard wood being more combustible, and more easily injured by fire, than that of the fir tribe." This little-known statement, made by Sir Charles Lyell in 1849 (Lyell, 69), concerned an area near Tuscaloosa, Georgia, but is equally applicable to many of the pine forests in the tropics.

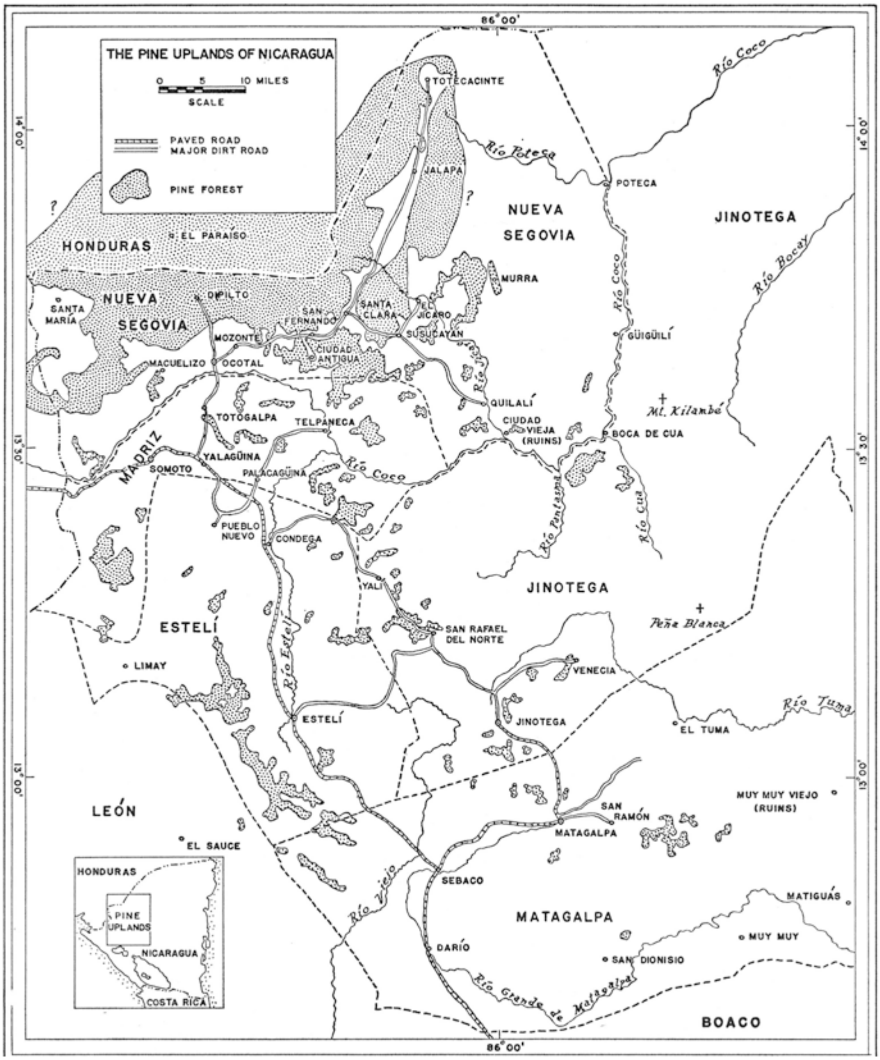

Fig. 3.3 The pine uplands of Nicaragua. (Sources for pine distribution: Aerial photographs 1956 and Taylor 1959b)

The Role of Fire in the Ecology of Tropical Pine Forests

O.F. Cook (1909) was probably the first to suggest that many of the Central American pine forests had succeeded mixed broadleaf forest on impoverished soils following shifting slash-and-burn agriculture. He argued that the pines were able to survive because of periodic, mainly human set fires, which kept out competing hardwoods. A number of reliable observers have since reached similar conclusions about various pine lands in tropical and subtropical regions of the Americas: for Central

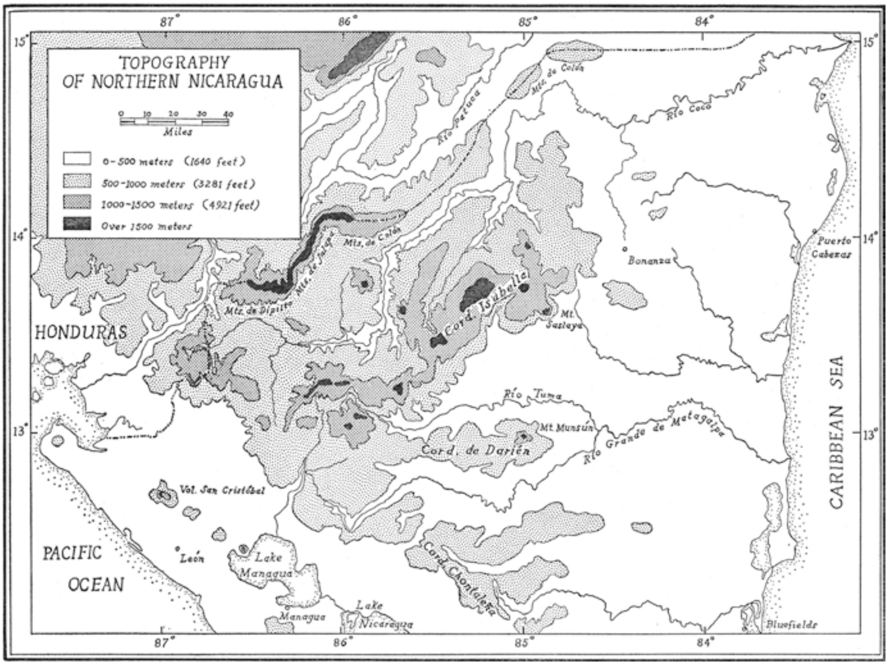

Fig. 3.4 Topography of northern Nicaragua. (Source: Tegucigalpa sheet. American Geographical Society, 1:1,000,000, 1942)

America, Allen (1955, 254), Budowski (1959b, 275–276), Johannessen (1959, 35–37), Parsons (1955b, 45–47), Taylor (1959a, 78–80; 1959b, 207–209), and Vogel (1952, 4–6); for the Caribbean islands, Beard (1953, 167), Ciferri (1936; see Bartlett 1957, 291–295), Durland (1922, 217), and Holdridge (1947, 64–68); and for the southeastern United States, Egler (1952, 232) and many others.[5]

Bartlett (1957, 284, 293), in reviewing and summarizing the studies of Ciferri (1936) and Chardón (1941)[6] on the pine forests of the Dominican Republic, commented:

[5] Comprehensive studies, including observations made over a period of years by Wahlenberg (1935, 1946) and others, indicate that the southern longleaf pine (*P. palustris*) is not only unusually fire tolerant, but is largely dependent on periodic fires. Chapman (1932, 330) expressed the opinion that lightning fires can occur frequently enough to account for longleaf pine forests. It has been suggested that pines elsewhere in the United States are dependent on periodic fires; see, for example, Weaver's article "Fire as an Ecologic Factor in the Southwestern Ponderosa Pine Forests" (1951).

[6] Chardón (1941) argued that the pines of the Dominican Republic were unrelated to human activities because they were geologically ancient and occupied high uninhibited mountains and because the abandoned *conuco* clearings he had observed had been invaded by *Cecropia* and other plants rather than pines. Bartlett (1957, 284) acknowledged the geologic relation, but added: "That lower-altitude *pinares* may not have been extended by human agency, just as prairies have, by clearing and fire, does not seem as yet to have been sufficiently investigated."

> It is hard to formulate an acceptable hypothesis for the persistence of pure pineland at low altitudes without involving fire as a factor. Fire, if it occurred frequently enough, would protect pine forests against replacement by deciduous [species] providing the climatic and edaphic conditions were such as to maintain the pine-forest floor in a seasonally combustible state … primitive man may well have greatly aided pine reproduction and extended pine by burning over land in hunting … [but] preparation of habitats for pine may conceivably result not only through the agency of man, but from natural causes such as wind-falls and fires caused by lightning.

The last qualification by Bartlett, the natural preparation of habitats, is frequently suggested, and although such preparation has been only rarely documented, natural phenomena, including landslides, blowdowns, floods, lightning fires, sterile soils, and rocky surfaces, have certainly provided favorable sites for the establishment of pines in tropical areas. It is my contention, however, that people's modifications of vegetation and soils by forest clearing and burning have made possible a considerable expansion of the tropical pine forests.

It is important to note that in Nicaragua *P. oocarpa* and *P. caribaea* are intolerant of shade: they are unable to regenerate beneath other trees, tall grass, or even in their own shade. The shade tolerance of the least common Nicaraguan pine, *P. pseudostrobus*, is unknown. During 6 months in the pine uplands, I did not once observe regeneration of any pine beneath heavy shade. This intolerance, substantiated by Taylor (1959b, 208) for *P. oocarpa* and (1959a, 79) for *P. caribaea*, is characteristic of many pine species. In the humid tropics, periodic fires are by far the most widespread means by which open stands of woody vegetation with little shade are maintained.

In the pine uplands of Nicaragua, light burning by the inhabitants takes place every year. In some areas it has probably been practiced since long before the Spanish Conquest. The importance of burning to the survival of pine forests in Nicaragua is partly shown by the existence of mixed hardwood stands, which do not burn, near pines and on comparable sites but with no young pines among them. Where mature pines do grow with a hardwood stand, the pines are apparently older; presumably they grew on an open site, and the hardwoods, no fires occurring on the site, came in later. This situation has been observed, for example, where intersecting trails block off fires.

The initial reaction to protection from fire in an open pine stand is a vigorous growth of young pine, but these shade out further pine regeneration. On some sites in the pine uplands which are protected from fire, there are very dense stands of pines, but with hardwoods exclusively, no pine seedlings, in the understory (Fig. 3.5). If protection from fire continues and the trees are not thinned, the hardwoods will probably take over such sites as the mature pines die. There have been several reports, from Nicaragua and elsewhere in Central America, of pine logs and buried pine roots amidst tall mixed broadleaf forest. Cook (1909, 20) noted that in Guatemala, in supposedly virgin forests east of Cobán in the bottom lands of the Polochic valley near Panzós and in the coffee district north of Senahu at 3000 ft elevation and above, dead pine roots were dug up by the Indians, who used them for torches. Cook was of the opinion that pines were once much more abundant when native populations were larger and there was more clearing of the forest. In Chiapas, Miranda (1953, 289–290)

Fig. 3.5 Dense stand of *Pinus oocarpa* east of Matagalpa which has been protected from fire for 2 or 3 years. There is no regeneration of pine in the dense understory of grasses, ferns, and leguminous weeds. If burning is not resumed, hardwood trees will grow up out of the moist shaded understory

reported buried pine logs south of Monte Libano in mature rain forest at an elevation of 900 m and at a distance of 15–20 km from the nearest pine ridges. He considered pines to be quite alien to the site and explained the logs as being the remains of either an extinct mesophytic pine species or an existing species which grew when the climate was drier than at present; neither suggestion seems tenable. Buried pine roots have also been observed in Honduras north of the junction of the Río Patuca and Río Guampu in a rain forest that contains tall cedar and mahogany, and buried pine stumps and logs occur in broadleaf forest in the pine uplands of Nicaragua just east of the Río Cua and also between Yalí and the Río Coco. It is surprising that fallen dead pines can resist decomposition under humid tropical conditions for an indefinite length of time. Where buried pine stumps occur north of Yalí, the present broadleaf forest is said to be at least 30 years old and possibly much older. The heavy bark or the resin content of pines may aid in their preservation.

Although burning can encourage pines at the expense of other plant groups, fire can also limit regeneration of pine if it is so frequent that pine seedlings do not have time to develop a fire-resistant bark and to grow high enough that their needles are above the flames of ground fires (Figs. 3.6, 3.7, and 3.8). (*P. oocarpa* can survive partial but not complete defoliation by fire.) Even if burnings are infrequent, a fire in accumulated debris and dead grass can be severe enough to destroy saplings and [even] older pines. In the pine uplands, a young pine requires from 3 to 7 years to become fire-resistant, depending of course on the severity of the fires. Early in the dry season, fires are less severe than they are at the end of the dry season when there

Fig. 3.6 Burned-over pine slope near Dipilto, Nueva Segovia. Although no pine seedlings have survived the fire on this site, the mature pines have been protected from serious damage by their thick layers of bark

Fig. 3.7 *Pinus oocarpa* seedling about 24 in. high near Matagalpa. If the surrounding grass were to be burned, this seedling would almost certainly be killed

Fig. 3.8 Stand of *Pinus oocarpa* on a steep slope near Dipilto, Nueva Segovia. Note the deep gully erosion on the left. All the young pines on the right were killed by fire a few weeks after this photo was taken

is more and drier fuel. If fires are very frequent, only grass survives, and if they are very infrequent, hardwoods begin to take over a pine stand. Thus, both the survival and the density of the pine forests are related to the frequency, severity, time, and extent of burning. Several Central American foresters have commented on the effects of different frequencies of burning in pine forests. Holdridge (1953, 43), writing of Middle America in general, noted:

> Pines also can be extended, as a result of burning, to occupy areas previously covered for the most part by broadleaf forest. With fires spaced at intervals of 5 to 20 years, the pines maintain themselves as dominants; with fires almost every year, the pines change in time to savannas; without fire, the larger part of the pine areas become covered with associations of broadleaf trees. [WMD translation from Spanish.]

After approximately 10 years without fire, however, not only do many deciduous species grow large enough to resist infrequent fires, but an evergreen hardwood formation can become so verdant that fire cannot penetrate it.

Vogel (1952, 4–6) stressed the harmful effects of too-frequently recurring fire on the pine forests of Honduras:

> During the half year from January to June, the pine forests in Honduras suffer annually from hot forest fires that rage unchecked over almost every square mile of the Central Region… Honduran pines seed well, and the climate is favorable to reproduction. The only factor which prevents an excellent stand of young pine for future generations is *frequently recurring fire*. We say "frequently recurring" because it is quite probable that pine would be succeeded on large areas by various other forest species in a century or two if the forests remained without any fire at all for that period. As a rule, pine does not reproduce well in a

> heavy ground cover of grass and brush. Only when the ground cover is opened by fire, water, or by mechanical means does the seed germinate and take hold.
>
> But, once germinated and rooted, the seedlings must be protected from fire for the next five to seven years, or they will be lost as surely as if they had never germinated. That is what has happened to pine seedlings everywhere that reproduction is absent today; it has started but has been killed by fire.

It is surprising, considering the amount of burning, that extensive pine forests still exist in Honduras and Nicaragua; apparently rough mountain relief breaks up fires sufficiently so that a few seedlings escape burning long enough to become fire-resistant and thus perpetuate an open pine stand. On the other hand, in the pine savannas on the gentle terrain of the Miskito Coast, though seeding is profuse, few seedlings survive the sweeping and unimpeded fires except where a close network of trails break the fires. Wind-blown upslope fires in the mountains are, of course, more severe than the slow-moving fires on the flats, but the former burn out rapidly and their coverage is spotty.

All these observations on the relations of fire to the establishment and survival of pine apply to *P. oocarpa* in the northern mountains of Nicaragua, where pines grow up to an elevation of about 5000 ft, but they do not necessarily apply to all the pines in Middle America. At high elevations, especially where frost occurs (above approximately 6000 ft), pines may maintain themselves without much aid from fire, although disturbances of sites may still be necessary for initial germination. Most of the Middle American pine forests actually do occur at fairly high elevations. As elevation increases, low temperature reduces the variety of plant species and rate of plant growth, i.e., the competition with pines which must contend. Yet except at very high elevations, there is much dense hardwood forest vegetation above the frost line in the humid tropics; consequently, generalizations about the relation of low temperature to occurrence of pine are not easy to make. Probably the combination of temperature and edaphic factors provides more natural habitats for pines at higher elevations than at lower elevations. But slash-and-burn agriculture in the high mountains would undoubtedly have increased the potential area there for the establishment of pine that was previously dependent upon natural disturbances and unusual localized conditions. Clearing and burning would also make it possible for pines to invade the warm lower mountains and coastal plains and survive. Conclusions similar to these have been reached by a number of observers, including Beard (1953, 167), Ciferri (1936, 259), Durland (1922, 217), and Holdridge (1947, 66), all with reference to Hispaniola, and Cook (1909, 19) for Guatemala. Holdridge, in his study of the pine forests of the Morne la Salle Mountains of southern Haiti (1947, 65–66), commented:

> Since a great number of tropical and subtropical tree species are not able to survive under the colder conditions at higher altitudes, the pine would not have been subjected to severe competition and would have been able to exist in pure stands or in mixture with some hardwood trees. Where soils are poor at high elevations, there is little reason to doubt that the pines occurred in pure stands in pre-Columbian days in a very similar state to that found at present.
>
> At lower altitudes below the frost line, the history of the pine distribution may have been quite different. By observations of the rapid invasion of hardwood species on richer soils where fires have been excluded for several years, one becomes conscious of the tremendous population pressure which a pine forest would have to exert to hold its own. Apparently, the pine stands below the frost line were less extensive in pre-Columbian time and occurred as

> patches or scattered trees mixed with hardwoods in the frost hollows, on areas of poor soil and along the crests of the ridges. As soon as man entered the area, occasional fires began the process of pushing back the hardwoods from sections which the pines were able to invade because local sources of seed were available and to hold because the pines are quite fire hardy except when young.

The Causes and Effects of Fires in the Segovias

The upland pines of Nicaragua are all found at relatively low elevations in a subtropical environment where their establishment and survival seem particularly favored by fire. The question remains whether natural fires occurred frequently enough before the coming of people to account for large and pure stands of pine.

There is very little documented evidence of lightning fires in Nicaragua or elsewhere in Central America (Budowski 1959b, 265). One lightning fire, which burned through 5 mi^2 of pine forest, was reported in British Honduras in 1954 (British Honduras, Forest Department 1955). In Nicaragua most electrical storms take place during the rainy season when the cover of vegetation is verdant and hardly combustible. A few storms do occur during the dry season, when fires could be ignited by lightning if it were not accompanied by heavy, steady rainfall. The frequent occurrence of lightning fires in the Florida Everglades, where the climate is comparable to the tropical *Aw* climate of Central America, has been documented by Robertson (1955). Lookouts observed 12 lightning fires in 1951 and 11 in the first half of 1952. These were grass fires, however, and it is doubtful that there was much grass in the Nicaraguan mountains before Indians first appeared and began clearing the forest and burning. Areas now being converted to grassland are first manually cleared of forest and undergrowth and then burned. Present savanna fires generally do not invade the forests of Nicaragua unless the forests are open and have a grassy ground cover. However, during an unusually dry season, the margins of a mature closed forest might be destroyed by fire, thereby extending savanna. Gallery forests in eastern Nicaragua were invaded by fire during the severe dry season of 1958 according to Taylor (personal communication 1961).

What is known about the causes, nature, and ecological effects of fire in the American tropics has been well summed up by Budowski (1959b, 270–272). He noted that crown fires are not known in primary tropical forests but may occur in very dry secondary forests and that recurring savanna fires may gradually penetrate the understory of a dry forest and encourage grasses and fire-resistant trees. The ecologist Dansereau (1957, 275) wrote about the burning of tropical vegetation: "Although it is too much to say that climax vegetation is immune to fire, … humid plant cover (from tropical rain forest to summer-green deciduous forest) hardly ever burns if it has not been previously disturbed, in such areas it is the jungle, the second growth forest, and the scrub or grassland that burn."

Thus, although both the Florida fires and the fire in British Honduras [today's Belize] show that lightning does start fires in the tropics, the frequency and long-term effects of such fires in tropical forests seem minor. However, secondary vegetation, usually a product of human activity, is often very susceptible to either natural or human fires. The dominant role of clearing and burning in extending the pine area in the Nicaraguan highlands is suggested by several additional circumstances: human activities have been the known cause of regular fires in the pine uplands since long before the germination of the oldest pine tree standing today, and existing pine forests are limited to parts of the highlands long settled and long burned-over. Possibly there have been pines in Nicaragua only within human times. A recent entry of pines into Nicaragua from northern Central America is certainly suggested by the presence in Nicaragua of only three pine species, none of which are endemic; by the small area of the country covered by pine in contrast to the large areas of pines in Honduras and Guatemala; and by the fact that the southern limit of the genus *Pinus* in the Western Hemisphere is in Nicaragua, even though there is no major climatic barrier to further advance.

The native people of tropical America, past and present, have always used fire to clear and prepare land for crops. The Indians of Nicaragua must have also set fires intentionally to drive game in hunting (a common practice all over the world), by accident, and for amusement. Where the same site was often fired, grass and fire-tolerant trees would be encouraged. Many grass fires undoubtedly burned over former *milpa* sites on the forest boundary, preventing regrowth of mixed forest and adding new clearings to the general area of regular burning.

The extent of slash-and-burn agriculture and the frequency of hunting fires would be expected to depend on the density of native populations, and because the upland pine forests in Nicaragua were in existence when the Spaniards arrived,[7] the size of the Indian population at that time should be meaningful. Within a few years after the entry of the Spaniards into Nicaragua in 1522, the expeditions they sent into the northern highlands in search of gold and to secure pine pitch for use in ship construction found an ample supply of settled Indians, probably mainly of the Matagalpa group, that could be put to work. The number of inhabitants in the pine uplands in the early sixteenth century is not known, but there is evidence[8] that the population of the entire country was at least half of the 1,300,000 estimated in 1956. Most of the present 37 towns and pueblos of the pine uplands were Indian villages at the time of the Spanish Conquest, and many other villages have since vanished. (Cuadra Cea 1957, identified at least 28 villages as existing in 1524.) That numerous settlements existed in the pine uplands long before the Conquest is indicated by the uncovering of artifacts, including, pottery, tools, and stone statues, that antedate the sixteenth-century cultures of Nicaragua. If the present 350,000 population of all the [five] Segovian departments (Nicaragua 1954, 22–26) is, like that of the country as a whole, slightly more than twice that at the time of Conquest, the population density at that time would have been about 20 per square mile.

[7] Pedrarias Dávila, first governor of Nicaragua, in a letter to the Emperor of Spain in 1525, mentioned pine forests north of León, where pitch was collected (Dávila 1954, 130). Oviedo, writing in 1547, mentioned pines in the "sierras" of Nicaragua (Oviedo y Valdes 1944, II:57, 270).

[8] Bartolomé de las Casas (1822, 68–69) wrote in 1542 that from 1523 to 1537, the Spaniards shipped over 500,000 Indian slaves from Nicaragua to Panama and Peru and killed another 500,000–600,000, leaving only 4000–5000 in the country. These figures are undoubtedly excessive but are indicative of a rapid demise of a large native population in Nicaragua. Lic. Diego de Herrera, in a letter to the Emperor in 1545, reported 600,000 Indians in Nicaragua at the time of the Conquest, of which, as a result of slave exports, disease, and killing, only 30,000 remained in 1545 (de Herrera 1875, 398–399).

There is reason to doubt, however, that even a fairly dense population is needed to bring about great modifications in vegetation through clearing and burning, especially in regions with a marked dry season, where grass fires, once started, could easily maintain themselves. For example, the Miskito pine savannas of eastern Nicaragua are currently almost completely burned over every year by a population having a density of between 1 and 2 per km^2, with most of the people concentrated in a few coastal towns. As far as is known, the main population centers in Nicaragua have always been on the rich volcanic soils of the Pacific coast, the population thinning out eastward through the mountains. Theoretically a small but fairly well-distributed population could have cut into the original broadleaf forest of the highlands, section by section, from the west. Each abandoned plot behind the agricultural frontier might subsequently have been burned over every year or every few years, thus favoring such pyrophytic plant associations as grasslands, scrub savanna, and pine or oak forests. In contrast to tropical forest destruction from shifting agriculture along an expanding frontier is the situation in many of the tropical forests of the world, where either land pressure is so great that the native people [disperse] their shifting farms throughout their territory as part of a planned rotation or forest-fallow system or slash-and-burn farms are dispersed simply because the population is small and very dispersed as is true of the present-day Sumo Indians in the rain forests of eastern Nicaragua.

Where a population is expanding from a nucleus into an area of unlimited new land, little attention need be given to the land abandoned behind the frontier, although it may be burned over freely in hunting or to improve pasture for livestock. Such abandoned land would burn much more readily than the forest ahead of it. Grasslands and savannas have probably been produced in various parts of the tropics as often by this means as from the extensive cultivation by a population too dense to allow abandoned plots to return to forest fallow.

In 1874, Thomas Belt (1928) reported section-by-section cutting into the eastern forest in the southern highlands of Nicaragua in the Department of Chontales. Belt showed an early awareness of how the actions of people determined the boundary between the eastern rain forest and the grassy upland savannas. He observed a sharp break between the two without a significant corresponding change in soil, bedrock, or climate. He attributed this break to the practices of the Indians of cutting and burning the forest for planting maize and beans. These farm plots were then abandoned, he wrote, not because the soil was worn out, but because cutting a new clearing was easier than weeding out the invading grasses and shrubs:

> Should the brushwood ultimately prevail and cover the ground, the Indian or Mestizo comes again after a few years, cuts it down, and replants it with maize. But as most of his old clearings get covered with grass, he is continually encroaching on the edge of the forest, beating it back gradually, but surely, towards the north-east. As the process has probably been going on for many thousands of years, I believe that the edge of the forest is several mi nearer the Atlantic than it was originally (Belt 1928, 187).

The process of cutting back the forest from the west has been extensive in the eastern parts of Nueva Segovia, Jinotega, and Matagalpa, where pine forest, savannas, and pasture lands end abruptly before a wall of broadleaf forest, which forms the boundary line of regular burning. Aerial photographs reveal that beyond this boundary there is a checkerboard pattern of clearings and forest, the clearings becoming fewer and fewer eastward (Fig. 3.9).

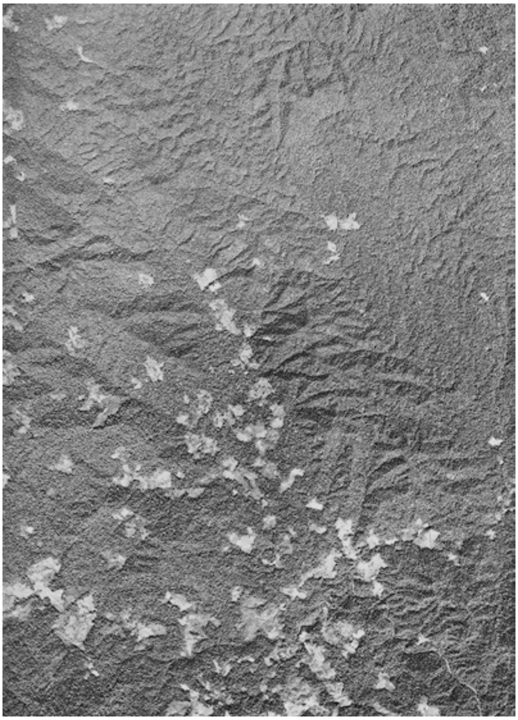

Fig. 3.9 Aerial photograph (1956) of a mountainous area about 20 mi east of San Rafael del Norte and near the Río Tuma. The settlement frontier and area of regular burning lie further west; here there are only scattered *milpa* clearings, which thin out to the east. Annual rainfall is about 80 in., and the vegetation is seasonal evergreen rain forest. Scale: 1:61,000. Photo courtesy of the Inter-American Geodetic Survey

Indian fires on any given site would probably have the irregularity that does not completely destroy pine regeneration. Furthermore, many of the Indian fires must have been light fires occurring at the beginning of the dry season when grasses can be burned but are not so tall, dry, and combustible as at the end of the dry season, when hot fires would be most destructive of pine seedlings.[9] Since the establishment of a large number of cattle herds in Nicaragua,[10] the people have burned their lands every year to encourage and improve annual growth of pasture and to destroy ticks and other harmful insects. Almost all this burning is done in the last few weeks of the dry season just before the first rains bring up new grasses. Jaragua (*Hyparrhenia rufa*), which often grows 6 ft high, is the main pasture grass in the pine uplands. By the end of the rainy season, it is usually too coarse to be palatable for cattle, and within a few more weeks, it is completely dried out and without food value. Consequently, the pasture grasses are not grazed low, even with overstocking, and hot ground fires that are very

[9] Egler (1952, 225–228) discusses the time of occurrence and the effects of Indian fires in comparison with subsequent types of burning in the pine areas of southern Florida.

[10] The size of the cattle herds of colonial Nicaragua is unknown, but Sofonias Salvatierra (1939, II, 209–210) commented, without documentation, that during the seventeenth and eighteenth centuries, Nicaragua was the leading cattle producer of Central America and regularly provided beef and hides for the other provinces. He wrote that at the start of the eighteenth century, 52,000 head of Nicaraguan cattle were sent each year to the fair at Chalchuapa (El Salvador). Lévy (1873, 477) reported that there were 1,200,010 cattle in Nicaragua in 1872. In 1952, a total of 1,182,000 head of cattle were reported by the Ministerio de Economía (Nicaragua 1956, 35).

Fig. 3.10 *P. oocarpa*. One of the southernmost outliers of upland pines, located southeast of Matagalpa overlooking the valley of the Río Grande de Matagalpa. Burning is regular here, and there is no pine regeneration. The mountains of Chontales are in the background

destructive to pine seedlings and young pines up to 6 or 7 years old are possible. The native grasses, on the other hand, are almost all short and burn less vigorously, even when allowed to accumulate for several years. In either short or tall grass, the fires in the pine uplands are relatively slow-moving ground fires, which seldom race through the tree tops or damage property. Most observers agree, however, that burning practices effectively limit the regeneration of pine in the pine uplands. Still, rugged relief in many sections tends to break up fires, and enough seedlings escape fire long enough to become fairly fire-resistant and so maintain an open stand of pines. In addition, a single logging operation may leave behind a system of fire-breaking trails that helps protect new pine regeneration. Pines are disappearing completely only where regular burning is accompanied by persistent logging (Figs. 3.10 and 3.15).

Human Settlement and the Distribution of Pines in the Segovias: The Eastern Limit of Upland Pines and the Settlement Frontier

The Eastern limit of the upland pine forest in Nicaragua lies near the eastern boundary of permanent settlement. This boundary has not changed significantly since pre-Conquest times (Fig. 3.11). From Totecacinte in Nueva Segovia to San Carlos at the southeastern corner of Lake Nicaragua, a frontier line can be traced beyond which there are no settlements, other than a few scattered river villages, in a vast expanse of tropical rain forest that stretches over 100 mi to the savannas of the Caribbean low-

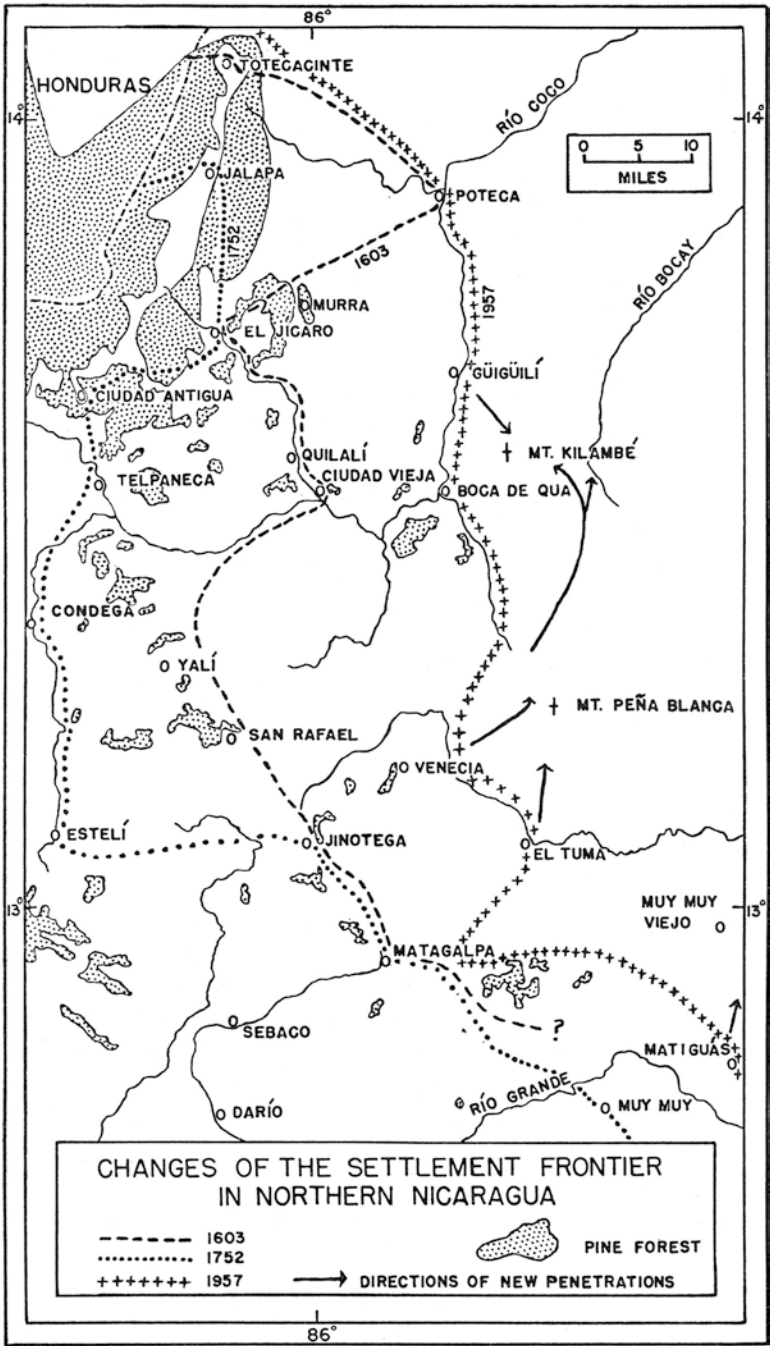

Fig. 3.11 Changes of the settlement frontier in northern Nicaragua

land. The upland pine forests are all west of this line, which marks no sudden change in the physical environment, but does roughly mark the eastern limit of regular burning. There is no sharp transition in parent materials or climate, and lateritic soils commence at variable distances east of the pines. The granitic, schistose, and acidic volcanic rocks on which most of the pine stands are found all extend east of the upland pine area (Fig. 3.12). It is true that annual rainfall is high east of the pine zone,

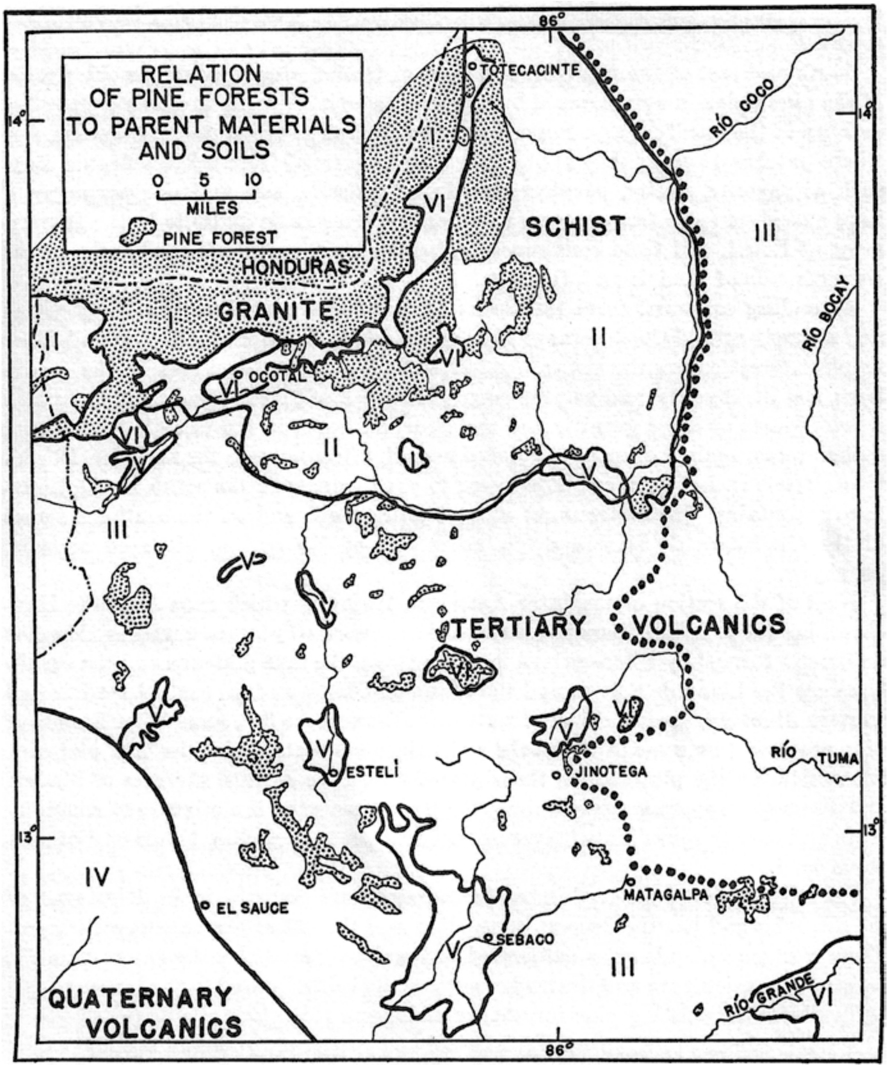

Fig. 3.12 Relation of pine forests to parent materials and soils. I, granite; II, metamorphics (mainly schist); III, Tertiary volcanics; IV, Quaternary volcanics (mainly ash); V, recent alluvium (mainly black clay); VI, Tertiary sediments. The dotted line indicates the approximate boundary between shallow upland soils (west) and deep tropical brown and reddish-brown latosols (east). East of the line, rainfall is over 70 in. annually and the vegetation is rain forest; to the west vegetation is mainly secondary deciduous forest, scrub savanna, and pine forest. (Main source: Taylor 1959b)

usually exceeding the 80 in. that is about the maximum known for *P. oocarpa*; nevertheless, *P. caribaea* is adapted to the rainy lower eastern mountains of Nicaragua and *P. pseudostrobus* to the cool and humid high eastern mountains of Isabella and Darién.

Soils change from tropical brown soils to reddish-brown latosols as rainfall increases east of the pine uplands, but this change in itself does not seem to prevent growth of pine. The pines grow on soils that are thin with little organic topsoil remaining, while mature broadleaf forest grows on a fairly fertile topsoil, although one rapidly leached of nutrients upon exposure to heavy rains. Today the thin, eroded soils on pine-covered slopes are unsuited for crops, but the same slopes may once have been covered with heavy broadleaf forest on more fertile soils that would have made possible the shifting slash-and-burn agriculture that theoretically prepared the way for colonization by pines. That *milpa* farming was possible is evidenced by the fact that the poor soils derived from granite and schist in Nueva Segovia – soils that are very infertile under pines – are deep and rich enough where broadleaf forest does exist to support some coffee and food crops.

The pine uplands are an area of thin soil and regular burning. Both of these are conducive to establishment and survival of pine, and neither are characteristic to the east of the settlement frontier. The fact, then, that fires, soil degradation, and extensive replacement of broadleaf forest by secondary and deflected climaxes, including pine forest, are all limited primarily to the area of long permanent settlement suggests that human activities have been a major reason for the present distribution of upland pines in Nicaragua.

No corresponding frontier exists in adjacent Honduras except south of the Río Patuca. High mountains bordering the Atlantic coast have produced local rain shadows in central and eastern Honduras, and relatively low rainfall, along with fertile valleys, have made much of interior Honduras more suitable for permanent settlement than are the dense and humid rain forests of central Nicaragua. As a result, clusters of settlement are dispersed throughout Honduras. Extensive pine forests are also found throughout the country (Fig. 3.2), generally in areas of thin, stony soils, acidic parent materials (schist, granite, sandstone, andesite), and regular burning. Somewhat analogous associations exist in Guatemala and Mexico; there are few areas of pine anywhere in the tropics or subtropics that are not subject to periodic burning.

The easternmost pine stands in highland Nicaragua are usually found with other deflected or secondary plant associations, but often there is a sharp transition from pine to tall evergreen broadleaf forest. I have seen areas where the tension zone between pine and broadleaf forest shows no relation to climate, topography, or parent materials, although the contrasting plant communities suggest two completely different environments. On the 4500 ft range east of Murra in Nueva Segovia, for example, *P. oocarpa* and *P. pseudostrobus* cover the western slope and the uppermost eastern slope, while all visible vegetation eastward is submontane rain forest. At another site on the Río Tapalchi, a small tributary of the Río Poteca in eastern Nueva Segovia, an open forest of *P. caribaea* ends abruptly at the bottom of a small valley. Here, in May 1957, I observed the burning of dry grasses beneath the pines (Fig. 3.13), but the adjacent broadleaf forest undergrowth was too verdant to ignite (Fig. 3.14). The local inhabitants claimed, however, that if new patches were cut out of the margin of the *montaña* and abandoned to grass and brush, then the edge of the fire line would tend to advance. A number of settlers had huts among the pines, but in order to clear land

Figs. 3.13 and 3.14 *Top*: Open stand of *P. caribaea*, "inland form," with the understory being burned, located near the Río Tapalchi, a tributary of the Río Poteca in eastern Nueva Segovia. Annual precipitation here is over 70 in. The view is toward the west. *Bottom*: Edge of mixed hardwood forest less than 100 ft from the pine stand shown in Fig. 3.13. A single pine appears at the left. The view is toward the east

for *milpas*, all went into the broadleaf forest where there was a dark organic loam topsoil instead of the reddish subsoil exposed by erosion beneath the pines. The parent material throughout the region is schist containing numerous quartz veins.

In other sites farther south, such as the regions around Ciudad Vieja (Nueva Segovia), northeast of Yalí (Jinotega), and near the Río Cua (Jinotega), patches of pine are interspersed with pasture and tall secondary semi-evergreen forest. Some of these areas, all in the frontier zone, were completely abandoned by both native

Fig. 3.15 Slope near Santa Clara, Nueva Segovia; originally pine covered, but now used for pasture. A single pine stump is in the foreground, while pines line the ridge in the background

and Spanish inhabitants during the colonial period because of attacking Indians and English pirates from the east. During the past hundred plus years, revolutions and bandit uprisings have led to further abandonment. East of the Río Cua and between Yalí and the Río Coco, buried pine stumps and logs are found in the midst of tall secondary broadleaf forest. These seem to be explained only by the fact that burning ceased when settlers were gone. The extent of such replacement cannot even be guessed at. Replacement of pine is also indicated by occasional individual mature pines unaccompanied by seedlings in mixed broadleaf forests on Finca La Trampa east of Venecia in Jinotega and in the mountains south of the town of Matagalpa. In both instances the pines are several mi from the nearest pure stand of pines.

A review of the settlement history of the Segovias shows that the frontier line has not been stable, but until recently has failed to advance significantly without subsequent retreat. The eastern limit of upland pine forest may likewise have fluctuated, but pines have failed to maintain themselves where people have not maintained strong pressure on the broadleaf vegetation by clearing and burning.

The History of Settlement

The present settlement frontier in northern Nicaragua, as represented by the easternmost highland towns, does not differ greatly from that established by Spanish gold seekers in the sixteenth century (Fig. 3.11), which, with the exception of the town of Nueva Segovia,[11] was based on already well-established Indian villages. These

[11] The original site of the town of Nueva Segovia, which is now the ruins of Ciudad Vieja, was the first permanent Spanish settlement in the Nicaraguan highlands. It is believed to have been founded in 1536 by Rodrigo de Contreras, the third governor of Nicaragua (Guillén de Herrera 1945,

villages include the original sites of Totecacinte, Poteca, Jalapa, El Jícaro, Telpaneca, Jinotega, and Matagalpa (Cuadra Cea 1957). The early Spanish accounts mention no large permanent Indian villages east of these, all of which are located near the present eastern margin of the pine forests. There were, however, numerous roving river and forest tribes (Sumo and Miskito) farther east.

Very little is known about the nature and background of the Indians who occupied the pine uplands at the time of the Spanish Conquest. The Matagalpas were the main tribe; however, they had been overrun by one of the several waves of Nahuatl peoples from Mexico who swept into western Nicaragua between the twelfth and sixteenth centuries, introducing their language but otherwise adopting much of the existing culture. Many of the place names in the pine uplands, including all those on the frontier listed above, are of Nahuatl origin, while most of the others are Matagalpan (e.g., Estelí, Güigüilí, Dipilto, and Yalagüina).

At the time of the Conquest, the Matagalpas were a sedentary people with a subsistence economy based on maize farming, as were most of the tribes of western Nicaragua. The Matagalpas lived in large villages in the river valleys or on river terraces where they apparently cultivated alluvial soils but also relied strongly on slash-and-burn *milpa* farms on the surrounding mountain slopes. The same pattern is still followed by the modern Lenca Indians of Honduras, the Lencas having originally occupied much of the pine lands of central Honduras. Doris Stone (1948, 205), in describing the Lencas, wrote: "The male members of a family generally spend five to six days a week in a straw hut built near the field. They return bringing food to the village at the end of a week." Such a system made permanent settlement possible, but the surrounding forests, once cleared, were given little opportunity to reestablish themselves because of burning and frequent reclearing.

The Spaniards apparently experienced little difficulty in establishing control over the area occupied by the Matagalpa Indians. The hostility later encountered came from the eastern forest tribes, which are of the Sumo-Miskito language stock. Almost all of the place names east of the Spanish frontier are Sumo-Miskito.[12] These people were migratory hunters, gatherers, and fishermen. Although they did grow such crops as manioc and plantains, cultivation was (and still is) a less important part of their subsistence economy than it was among the tribes of western Nicaragua. The Indians of eastern Nicaragua seem to have always confined their activities, including farming, to the low valleys and consequently must have had little effect on the vegetation of the high eastern cordilleras. Archaeological investigations, of course, may someday reveal a pre-European people who inhabited the mountains of Isabella and Darién.

36–38). As the major non-Indian Spanish settlement in the Segovias, the town of Nueva Segovia remained the center of Spanish gold-mining activities throughout the colonial period and was long the third city of Nicaragua after León and Granada. Lévy (1873, 164) wrote: "La Segovia fué, durante mucho tiempo, la parte más rica, populosa y lujosa del país."

[12] The numerous Sumo-Miskito place names that are found near the margins of the original Spanish frontier include Bocay, Matiguás, Pantasma, and Murra. East of the Spanish frontier line, there are only a few Matagalpan names, including Munsún and Güina (a tributary of the Río Bocay). See Alfonso Valle (1944) for translations and origins of the Indian place names of Nicaragua.

Thus, the Spaniards occupied that part of the Nicaraguan highlands controlled by permanently settled farming Indians. This was the general pattern of the Spanish Conquest throughout Latin America; rain forest areas with wandering tribes received little lasting attention. The Spaniards made almost no concentrated effort to penetrate farther into the interior of Nicaragua, partly because no gold was known east of the pine uplands.[13] They were also discouraged by the lack of rich soils such as are found on the Pacific coast of Nicaragua and in the highlands of Costa Rica; by the denseness of the tropical rain forest, which makes movement much harder than in the pine forests; and by the extreme hostility of the independent eastern Indian tribes.

Soon after occupying the Segovias, the Spaniards found native opposition so intense that several times the frontier settlers and their conquered Indian slaves were forced to flee. In some instances the entire villages were abandoned or transferred westward to more secure sites. The main early encounters seem to have been with Honduran tribes, the Lenca, Jicaque, and Paya, who frequently attacked the Spanish outposts in Poteca, Totecacinte, Jalapa, and the large town of Nueva Segovia. In 1611 Nueva Segovia, the regional capital city, had to be moved from its original site at the junction of the Río Jícaro and Río Coco (Ciudad Vieja) to what is now Ciudad Antigua, and in 1617 Poteca was abandoned when its inhabitants fled to the Llanos de Totecacinte (Guillén de Herrera 1945, 113–115).

Possibly even more feared than the Indians were the Dutch, French, and English pirates who frequently raided the cities and fleets of Spanish Middle America during the seventeenth and eighteenth centuries. Hearing of the wealth of Nueva Segovia, buccaneers sought out the town from both the Atlantic and Pacific coasts. Nueva Segovia and Matagalpa were both sacked in 1654, and in 1688 Nueva Segovia was completely destroyed (Guillén de Herrera 1945, 170–174). In the eighteenth century, the raids on the Segovias took on a new character as the British government sought to undermine Spanish control of Nicaragua. Miskito Indians and Zambos (mixed Miskito and Black), allied with the British and often led by British officers, repeatedly moved up the Río Coco and Río Grande de Matagalpa to harass the highland Spanish settlements. The towns of Nueva Segovia, Telpaneca, Matagalpa, Jinotega, Sebaco, and Muy Muy were attacked many times between 1704 and 1781. The gold camp of Muy Muy (the present site of Muy Muy Viejo) east of Matagalpa was forced to retreat to its modern site in the valley of the Río Grande following a Miskito attack in 1749. In 1789 the town of Nueva Segovia was again moved, this time from what is now the site of Ciudad Antigua to the present site of Ocotal (Guillén de Herrera 1945, 175–183). Miskito raids ceased in the nineteenth century, but then the Matagalpa Indians turned against their masters. There were major outbreaks in Matagalpa and Jinotega in 1824, 1827, 1844, and 1881 (Gutierrez Castro 1954, 10).

[13] The very productive Bonanza and La Luz gold-mining districts of eastern Nicaragua, discovered by rubber gatherers in the 1880s, were apparently not known by either the Indians or the Spaniards (Parsons 1955a, 51). Spanish gold mining in Nicaragua was largely confined to river placers in Nueva Segovia, and it was mainly after independence (1821) that a large number of hard-rock mines were opened up in the Segovias and in Chontales.

The colonial period, then, was one in which the settlement frontier did not advance, but retreated, as is best evidenced by the two westward transfers of the city of Nueva Segovia. Bishop Morel de Santa Cruz, who visited and described the Segovias in 1752, found that Totecacinte had also been abandoned by that time, leaving Jalapa, El Jícaro, Nueva Segovia (then at Ciudad Antigua), Telpaneca, Yalagüina, Palacagüina, Condega, Estelí, Jinotega, Matagalpa, San Ramón, and Muy Muy as the outposts of Spanish settlement. He mentioned that despite armed garrisons in most of these towns, the people lived in constant fear of the frequently attacking Miskito Indians.[14]

The approximate retreat of the Spanish frontier in the Segovias from 1603 to 1752 is shown in Fig. 3.11. It can be assumed that most of the Christianized Indians retreated with the Spaniards; moreover, it is certain that all of the native population of the Segovias was greatly diminished under Spanish rule, as it was elsewhere in Nicaragua. The effects that this retreat of settlement and native depopulation had on vegetation can only be surmised. Much of the originally well-populated land east of Jalapa and El Jícaro, some of which is now in pine, could well have returned to tall broadleaf forest. Behind the frontier, slash-and-burn agriculture undoubtedly decreased appreciably, but vegetation continued to be under attack because of the establishment of large herds of livestock. The Nicaraguan historian Salvatierra (1939, II:209) wrote that Nicaragua was the leading cattle-raising country of Central America during the seventeenth and eighteenth centuries, thanks to suitable "condiciones naturales" including "grandes pampas en Chontales y Segovia." The grasslands necessary for stock raising must have been in existence when the Spanish arrived, but they could well have been created by the slash-and-burn agriculture of pre-Conquest native people. Nevertheless, the Spanish ranchers maintained and improved pasture by intentional burning, much as the country people do today. With large herds of cattle, it is possible that burning became more regular than it had been among the Indians, even though the human population had greatly declined. The pine uplands having become range land subject to burning, there is no reason to believe that pines would have been replaced by broadleaf forest during the colonial period within the area of Spanish settlement. Burning by the Spaniards may either have promoted the extension of the upland pines or have seriously retarded the reproduction of pine, as regular burning often does today. Only speculation is possible, because almost no descriptions of the Segovias under Spanish rule are available.

Since independence was gained from Spain in 1821, general national disorganization and an almost continuous series of revolutions have hindered new settlement in the interior of Nicaragua. The eastern tribes remained troublesome, and the Nicaraguan armies were too occupied elsewhere to attempt to pacify them. However, the discovery and exploitation of gold and silver veins in the Segovias, mainly by North Americans, led to the founding or reestablishment of several towns, including

[14] According to Morel de Santa Cruz, as summarized by Ayon (1956, II, 389–398), the other important settlements in the Segovias in 1752 were Sebaco, Somoto, Totogalpa, and Mozonte. Morel found only a few settlements in the southern highlands of Nicaragua. He noted that at least six former towns in Chontales had been abandoned by the time of his visit.

Macuelizo (1801), Dipilto (1840), Santa Maria (1849), Quilalí (1880), and Murra (1900), all in the Department of Nueva Segovia. Then, toward the end of the nineteenth century, political and economic events sent thousands of Nicaraguans into the central highlands and eastern rain forests. The first economic incentive was the demand for rubber, and the *Castilla elastica* tree of eastern Nicaragua soon became the leading source of rubber north of the Amazon Basin.

More recently, coffee has been the main cause of the expansion of frontier settlement in the Segovian highlands. In the 1890s North American, German, and English colonists planted millions of coffee trees in the mountains just east of Matagalpa and Jinotega. Penetration any farther into the interior from these towns was long hindered by the almost complete lack of transport facilities and roads, but motivated by high coffee prices and the successes of the European- and American-owned fincas, hundreds of small farmers pushed eastward from the long-established frontier settlements. This pioneer thrust, the first of significance since the Spanish Conquest, was mainly confined to the period of peaceful and progressive rule by the dictator José Santos Zelaya between 1893 and 1911. Several new towns were founded, including Güigüilí, Yalí, San Fernando, and Matiguás, while Telpaneca, Muy Muy, and San Ramón were revived by the coffee boom. After Zelaya was ousted, however, Nicaragua found itself in a revolutionary turmoil that lasted until 1934 and at times involved the United States Marines. Most of the peasants in the country were conscripted into the armies, with the result that small farms were abandoned and the coffee crops of the large *fincas* went unpicked. The Segovias suffered especially from its own infamous rebel leader, Sandino, who turned against all Segovians who did not come to his aid. He killed hundreds of people and destroyed dozens of farms and small villages. The frontier coffee lands were almost totally evacuated as the settlers fled to Ocotal, Jinotega, Matagalpa, and even Managua. In a few years' time, thousands of coffee trees and extensive pasture lands were swallowed up by tropical forest.

Once stability had been returned to Nicaragua under the regime of Anastasio Somoza (1933–1956), people began filtering back to the frontier area. The lack of a program of road construction, together with World War II, hampered new settlement, however, and only in the late 1940s did a major modern pioneer push get under way. The stimulus again was rising coffee prices, but drought and shortage of land in the heavily populated valleys of Estelí and Sebaco also helped encourage thousands of new settlers to move into the Cordillera de Darién east of Matiguás, the Cordillera Isabella northeast of Jinotega, and the Mt. Kilambé area (Figs. 3.4 and 3.11). New settlements are as yet only beginning to form, but previous outposts such as Quilalí, Güigüilí, Yalí, and Matiguás (Fig. 3.11) are now boom towns where, during the harvest seasons, long mule trains loaded with sacks of coffee meet convoys of supply trucks. Since about 1950 the settlement frontier has been pushed eastward more persistently than at any other time during the past 400 years.

The eastern limits of the permanently settled part of northwestern Nicaragua, then, have changed little since the Spanish Conquest. Between 1603 and 1752, the frontier actually retreated, and only in the last 70 years, and particularly in the last 10, has it advanced beyond that initially established by the Spaniards and by the Matagalpa Indians before them. The eastern limit of pines corresponds fairly closely with the eastern limit of relatively dense settlement up to the present century. Pine forest is found today only where human activities have brought about a fairly continuous disturbance of the vegetation. It is possible that the eastern limits of upland pines have fluctuated with the frontier. The pine trunks, stumps, and roots in the tall tropical forest of the Río Cua and Yalí areas prove that former pine lands have been invaded and the pines replaced by broadleaf species on at least a few sites. Such areas may have been abandoned by settlers and occupied by tropical forest during the recent revolutionary period or possibly earlier.

The Southern Limit of Upland Pines

The failure of the genus *Pinus* to extend its natural range south of Nicaragua has generally been attributed to the marine breaks between Panama and Nicaragua and in southern Nicaragua (the San Juan Depression); the former apparently existed until the Late Cretaceous and the latter from the late Eocene to the late Miocene, both acting as barriers to the spread of South American plants northward and North American plants southward. Both marine breaks, however, were bridged by many plants, largely by means of temporary land connections and by permanent connection since the early Pliocene (Schuchert 1935).

The barrier to the further southward spread of the southernmost North American conifers seems to be largely climatic, based on the absence of high mountains with low temperatures. Between central Honduras and northern Costa Rica, there is a distance of approximately 300 mi with no elevations above the 6560 ft Mt. Saslaya in the Cordillera Isabella in Nicaragua. The frost line in Central America being between 6000 and 7000 ft, a large area for the most part below the frost line could well retard further migration of many northern cold-climate species,[15] including most but not all pines. Several North American conifers have their southern limit in the high mountains (up to 9300 ft elevation) around Lake Yojoa in west-central Honduras; this is apparently the limit of *Abies guatemalensis*, *Cupressus lindleyi*, *Taxus globosa*, *Pinus ayacahuite*, and *Pinus montezumae* (Allen 1955). Certain pines have been able to migrate farther south than other conifers partly because of their adaptation to the high temperatures of low elevations.

If edaphic conditions and natural fires alone were sufficient to open the way for the migration of pines into tropical and subtropical habitats of Central America, then there seems to have been enough time since the last sea barrier was closed during the Pliocene for pines to spread into southern Nicaragua, Costa Rica, and even farther south. On the other hand, if clearing of broadleaf forest and human fires are responsible for the extensive spread of pines into Nicaragua from the high mountains of northern Central America, then the period that people have been on the

[15] The absence of high mountains in Nicaragua and southern Honduras also seems to have been a barrier to the northward spread of tropical American mountain plants, many of which have their northern limit in the Costa Rican highlands (Lauer 1954, 344).

scene, possibly 30,000 or 40,000 years, might be short enough to explain at least partly why pines migrated no farther south than they have.

The actual southern termination of upland pines in central Nicaragua can be attributed to a number of factors, none of which, however, seem adequate to form a permanent barrier to expansion. Parent materials and soils are very important. The parent materials in the southern mountains of Nicaragua are mainly basalts, with a minimum of the acidic rocks that form the soils occupied by most of the Nicaraguan pines.[16] The larger areas of acidic parent materials in the southern highlands, which would be most receptive to invasion by pine and could thereafter serve as centers for further dispersal, as do the granitic rocks of Segovia, seem to be mainly at elevations lower than the observed range of *P. oocarpa*.

Climate is a factor. The valley of the Río Grande de Matagalpa probably forms an altitudinal or temperature obstacle to *P. oocarpa* (Fig. 3.4). South of the pine uplands, this valley is 10–15 mi wide, with an elevation of 1000–1700 ft; temperatures are probably too high for *P. oocarpa* and *P. pseudostrobus*, while the tropical *P. caribaea* is not found anywhere in the southern region of the upland pines. A leap over the valley to the mountains of Chontales by *P. oocarpa*, whose seeds can be carried by the wind, might be possible, however, if there were suitable soils or the other side.

New invasions by pine, even when competing species are suppressed and climate and soils are suitable, have been further prevented in recent times, or at least hindered, by excessive burning by cattlemen, as well as by heavy grazing and the wide distribution of tall introduced grasses. These are all hazards to the survival of young pine seedlings.

Climate, elevation, and parent materials do not establish a permanent southern limit for pine in Central America, but together they may have been able to at least temporarily stop the southward march of the upland pines. This barrier is strengthened by present human activities, which make it very difficult for pines to advance farther south, even on a small scale, by natural seeding. It is interesting to note, however, that pines have been planted successfully on the volcanic plateau of Masaya in southern Nicaragua, in Costa Rica, and in various parts of South America.

The southernmost stands of pines in the upland pine area of Nicaragua are widely scattered but form two southward-pointed prongs separated by the low plains of Sebaco (elevation 1700 ft); one ends west of Sebaco and the other southeast of Matagalpa. Figure 3.10 shows two solitary pines overlooking the valley of the Río Grande de Matagalpa. These trees are surrounded by grasslands on which there are no young pine trees or seedlings, apparently because of the severity of recurrent fires. I saw no young pine trees anywhere along the margins of the southern stands, and the local people say that these stands have existed with little areal change for as long as they can remember. The pine forests east and southeast of Matagalpa descend to about 2500 ft elevation on moderate slopes with thin soils derived mainly from andesitic parent materials. On Cerro Padre, a steep pinnacle rock south of

[16] In Mexico and northern Central America, pines generally occur on parent materials (granite, schist, and rhyolite) similar to those in the pine uplands of Nicaragua. Pines also grow on sandstone, on serpentine, and possibly on basalt in the Sierra Occidental of Mexico. *P. caribaea* occurs on limestone in some areas, especially in the Caribbean islands.

Matagalpa and a few mi northeast of the village of San Dionisio, there is a patch of mature pines that constitutes the southernmost stand of pines known in the highland area of Nicaragua (12° 45′ N.).

The southernmost stands of *P. oocarpa* do not occur in the pine uplands, however, but slightly farther south, some 30 mi west of Cerro Padre, on the upper slopes of the adjacent volcanoes San Cristóbal (or El Viejo) (elevation 5545 ft) and Casita (elevation 5085 ft) (Fig. 3.4); Casita is the farther south (12° 44′ N, 86° 59′ W). These pines were observed by Taylor (personal communication 1958), who commented:

> I have climbed Volcán Casita which is immediately south of San Cristóbal to see the pines. These stands are very small but are somewhat bigger than those on San Cristóbal. They are formed on the typical soils of the volcano, i.e., shallow but fertile silty loam. I suspect that they entered since the last eruption and that the successions were never permitted to mature but were burnt regularly for grazing thus permitting the pines to persist… The trees concerned are young, mostly less than 60 ft [in height] and 10 in. in diameter, and the stands only cover a few ha each; elevation is from 2,000 to 4,000 ft but could be higher on San Cristóbal.

Pines do not grow on any of the other high volcanoes of western Nicaragua, although they do grow on volcanoes in Guatemala (e.g., Volcán Fuego). On San Cristóbal and Casita, the pines may have been planted; and if not, then they indicate how pine seeds can be carried long distances by the wind or by biotic carriers to seed new areas where conditions are suitable for pines. The prevailing winds are from the northeast and therefore from the pine uplands. In general, however, wind direction probably has had little bearing on the distribution of pines in the Nicaraguan highlands.

From time to time, there have been rumors that there are pines in the Departments of Boaco and Chontales in southern Nicaragua, but such rumors have never been verified. I searched without success for pines in the mountains of Boaco and Chontales, and Taylor reports (personal communication 1958) that he could find none during several weeks of plant collecting in the same departments. A plant called *pino* (unidentified) is common in the hills on the southeast side of Lake Nicaragua, and "pino" means pine in Spanish, which may explain the rumors of pines in southern Nicaragua. The Nicaraguans commonly use the Nahuatl Indian term "ocote" for the true pines of the Segovias.

The southernmost pines in the Western Hemisphere, which occur not in the Nicaraguan highlands but on lowland savannas in eastern Nicaragua, where stands of *P. caribaea* extend to 12° 10′ N near Bluefields, have a distribution and southern termination closely related to the presence of quartz gravel sediments in eastern Nicaragua; these sediments would probably support a low hardwood forest, however, if it were not for annual burning (Taylor 1959a, 80).

Conclusions

The thesis presented here is that the upland pine forests of Nicaragua are a deflected climax, a formation resulting from human clearing of broadleaf forest and repeated burning, and it is unlikely that extensive and pure stands of pines existed before the appearance of Indians. The evidence contained in this paper, which is supported by the literature on many of the pine forests elsewhere in the tropics, suggests that, in general, the degree of disturbance of site and frequency of fire necessary to establish and sustain a tropical or subtropical stand of shade-intolerant pine is greatest in areas with rich and deep soils, basic parent materials, and high average temperatures and high precipitation and is less in areas with poor soils, acidic parent materials, low rainfall, and especially increasingly lower temperatures. Because people are the main disturbing element in the environment, the presence of pines on a given site can in part be related to the extent and nature of their activities on the site.

There is little doubt that the present upland pines of Nicaragua germinated and matured while being subjected to periodic fires. The question remains whether or not similar pine forests could have existed before the coming of humans. Restrictive edaphic conditions may well have originally provided habitats for pines which served as centers of dispersal to receptive sites provided by such natural events as blowdowns, landslides, lightning fires, and volcanic eruptions. Natural habitats were probably only local, however, and natural disturbances do not seem to occur frequently enough on any given site in highland Nicaragua to suppress mixed broadleaf forest continuously.

Of significance is the occurrence of the upland pines only in areas of long-continued, permanent settlement. There are no pines in the central mountains of Nicaragua east of the settlement frontier, although parent materials and climate often appear to be suitable. On the other hand, neither are there pines in the settled part of the southern uplands of Nicaragua, where the history of clearing and burning is similar to that of the pine uplands, but where parent materials generally are better suited to the growth of broadleaf forest than pine.

The conclusions for the upland pine forests of Nicaragua seem to be relevant to the problem of the occurrence and distribution of pines elsewhere in the tropics and subtropics. Many, if not most, of the pine forests of Middle America do occur on acidic parent materials and thin impoverished soils and are subjected to at least occasional fires. There is a danger, however, in attempting to apply ecological interpretations in one region to others, especially with reference to pines. Not only may climatic, edaphic, biotic, and human factors differ in other areas, but pine species differ widely in their requirements and tolerances. Individual studies of the various tropical pine species in different environments are needed in order to understand more fully the distribution of the genus *Pinus* in the tropical world and people's relation to that distribution.

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3.2 Fields of the Mojo, Campa, Shipibo, and Karinya

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Abstract Presented here are four case studies of indigenous cultivation in Greater Amazonia based on Denevan's own field work, plus information from others, and the use of historical material. They provide examples of different types of agricultural systems: relatively intensive swidden or shifting cultivation (colonial Mojos); extensive swidden (Campa); floodplain cultivation (Shipibo); and multiple biome use (Karinya). A fifth type, managed fallow (Bora), included in the original but removed here to avoid duplication, is examined in Chapter 6.2.

Keywords Campa · Floodplain cultivation · Indigenous cultivation · Karinya · Mojo · Shifting cultivation · Shipibo · Swidden

The Mojo: A Colonial Reconstruction

For the colonial period, seldom is there enough information available to reconstruct agriculture for a specific tribe or region. Following are some early descriptions of forest cultivation in the Jesuit Province of Mojos in northern Bolivia (Fig. 3.16) (Denevan 1996), a region better known for pre-European drained, raised fields in seasonally flooded savanna. Shifting cultivation was and continues to be practiced in gallery forest and in forest islands within savanna, both habitats tending to have semi-deciduous forest relatively easily cleared with stone axes. The main Indians involved were the Mojo and the (related) Baure chiefdoms.

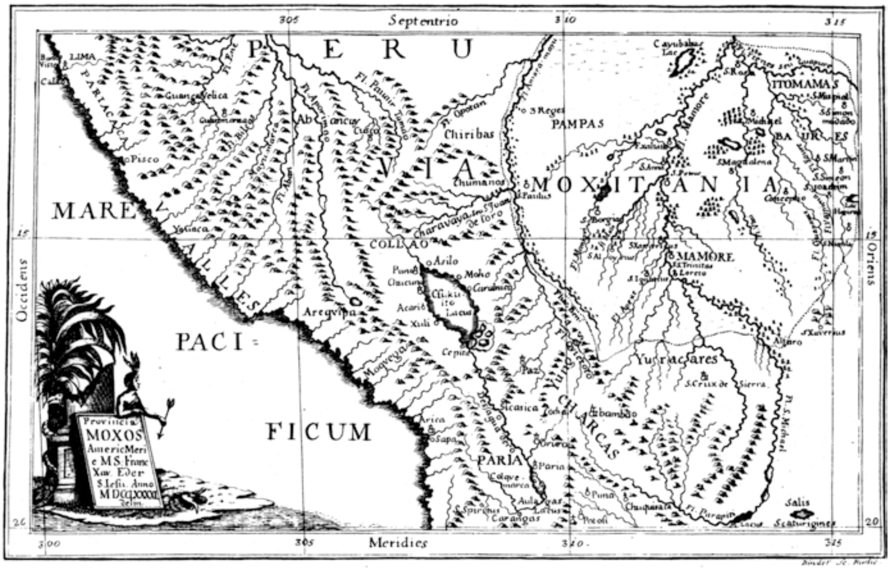

Fig. 3.16 Map of colonial Peru c. 1767 showing Mojos (Moxitania). From Eder (1985, 428)

Swidden (shifting cultivation) fields were called *chacras* (or *chácaras*) during the colonial period and are now referred to as *chacos*. There are many early references to forest cultivation but few details. Several of the descriptions of Mojos by members of the Solís Holguín expedition in 1617 mention fields: "*chácaras* in carefully cleared *montaña*" and "great *chácaras* of maize and other vegetables" (de Lizarazu 1906, 149, 195). The Jesuit Diego Altamirano (1891, 30) wrote in 1710 that the Mojo first felled the trees and rooted out the useless weeds and grasses. Coronel Aymerich, Governor of Mojos from 1768 to 1772, wrote that because of flooding, crops were grown in the forests on *alturas* (high ground) next to the rivers (gallery forests on natural levees), where transport was easy to villages that were sometimes 2 or 3 days away (René-Moreno 1888, 68). Padre Francisco Eder (1985, 75), in 1791, said that cultivation of the *campos* (grasslands) was impeded by flooding but that they were not inferior to the forests because the ashes of burned grasses provided good fertility.

The process of clearing forests for fields in Jesuit Mojos has been described by Métraux (1942, 59, based on Eder 1985, 73–74):

> The Mojo and Baure cleared fields in the forests, which were not flooded during the rainy season. At the end of August they first destroyed the underbrush, then cut the base of large trees by alternately charring and hammering the wood with stone axes. They waited until a strong wind blew down the undermined trees, or else felled selected trees, which knocked down all the others. The dry trunks were burned and their charred remains left on the field to protect young maize stalks. The Spaniards who penetrated the country with Solís Holguín were amazed at the size of the Mojo fields, which were crossed by wide roads.

The Mojo and Baure used digging sticks for planting, and presumably so did the other tribes in Mojos. Stone axes were used by the Mojo to clear forests. Alonzo Soleto Pernia, a member of the Solís Holguín expedition, said that "we found trees cut, as if by stone axes; they have mines where they obtain stone for axes for cutting trees, and their edges are like iron" (de Lizarazu 1906, 211). Rock outcrops may not have been far from the area visited by the expedition; however, in the central savannas, most stone tools were obtained in distant trade and were a valuable commodity. Possibly in much of Mojos, there were not enough axes to clear sufficient forest to support large numbers of people. The Mojo had cutting and sawing tools made from bone, teeth, and chonta palm wood, but these would not have been very effective for clearing mature forest. The change to metal tools undoubtedly had revolutionary effects for shifting cultivation. By 1676, and probably much earlier, Mojo Indians were traveling south to Santa Cruz to trade cotton goods for "machetes to cut and clear their *chacras* [fields]" (Marbán 1898, 148). The Jesuits used axes and machetes as major gift items in gaining the friendship of the native people.

In the early seventeenth century, the Indians of southeastern Mojos had large farms producing great quantities of food. These must have been forest fields, assuming that most raised fields in the savannas had been abandoned by that time. This is indicated by the reports of the members of the Solís Holguín expedition. The relation of Juan de Limpias (de Lizarazu 1906, 170) states that a Captain Diego Hernández Vexarano [Verarano] saw a large number of *percheles* of maize and other legumes and told Juan and another soldier to count them. Juan de Limpias counted over 700 *percheles* of maize in 1 group which formed one of the granaries (de Lizarazu 1906, 158).

Métraux (1942, 59) translated *percheles* from these accounts as "probably the forked sticks used to support maize." This usage is apparently based on one of the meanings of *percha* as perch or pole and *perchonar* meaning to leave shoots on a vine stock. However, it would be impossible for a single "forked stick" to support a harvest of 30–45 bushels of maize. A unit of land is a possibility, but most likely *perchel* refers to a maize crib on pilings for protection against flooding and animals (the term has been so used in Portugal). Such cribs were still being built by the Chácobo in Mojos when visited by Nordenskiöld (1920, 3) in the early twentieth century. Seven hundred *percheles* each holding 30–45 bushels of corn would total 21,000–31,500 bushels – a sizable amount for what was presumably 1 village.

Padre Joseph Castillo (1906, 309–310), in 1671, listed the following Indian crops: manioc, maize, beans, squash, sweet potato, peanuts, papaya, chili pepper, cotton, arracacha, tobacco, and plantain. Most of these were also listed in the reports of the earlier Solis Holguín expedition in 1617. The Old World plantain was apparently pre-Jesuit, being cultivated in 1677 according to Castillo. The staple seems to have been manioc. Padre Pedro Marbán (1898, 139) wrote that "yuca [sweet manioc] is the common bread of the land," and Padre Antonio de Orellana (1906, 13) in 1687 said that "yuca is their principal food." On the other hand, the numerous maize *percheles* suggest that maize was at least locally important. In the reports of the Holguín expedition, maize is mentioned ten times and manioc only once. But Marbán (1898, 138) later said that "there is not much maize because these Indians do not use it for *chicha* [maize beer], except once in a while."

The Jesuits introduced rice, and they said that rice produced as many as five crops a year and that harvesting was done in canoes (Eder 1985, 75–76). This indicates that the Jesuits were growing wet rice on the savannas; however, the Indians may also have been harvesting a wild rice.

The colonial fields contained both indigenous and Jesuit techniques and crops. Raised fields in the wet savannas were largely abandoned. Land use today is quite different, with subsistence fields being smaller. Steel axes and machetes are now used for clearing and weeding. *Percheles* no longer exist. Manioc is the dominant crop, and maize and rice are rare. The savannas are used for livestock. Food is imported.

Thus, it has been possible to extract considerable information on Mojo forest agriculture from sixteenth- and seventeenth-century exploration and missionary accounts. However, our information on the Mojo is from different places and times and may pertain in part to tribes other than the Mojo. And we are told little or nothing about field types, cropping/fallowing patterns, and agroecological techniques. For most other Indian groups in Amazonia, even less early information is available, and we have to rely on twentieth-century reports long after initial contact, or on what can be learned from archaeology.

The Campa

Unstable Swiddens

> I wouldn't want to live in a world without lions. These people [Campa] are like lions. (Herzog 1982)

The Campa (Asháninka) live in the eastern foothills of the central Andres of Peru. They number at least 30,000 and possibly 45,000, making them the largest indigenous group today in Amazonia (Hvalkof 1989, 128).[17] In the 1960s I made a field study of Campa agriculture in the Gran Pajonal, a dissected plateau with scattered patches of savanna (Fig. 3.17) (Denevan 1971).[18] These Campa are best described as extensive swidden farmers with a strong emphasis on hunting and minimal gathering and fishing. While males spend most of their working time hunting, most household food by weight and calories comes from cultivated plants. Manioc is the staple, but each field is initially planted in intermixed manioc and maize (Fig. 3.18).[19]

Fields are usually cropped for only 2 years, with a fallow of 10 years or more. In a typical year, a new field is cleared and planted, the crop in the previous year's

[17] It has been incorrectly claimed that the Yanomami, with about 20,000 people (Chagnon 1992, 1), is the largest Indian group today in Amazonia.

[18] Studies also have been made of the agriculture of the nearby and linguistically related Machiguenga (Johnson 1983) and Amuesha (Salick 1989; Salick and Lundberg 1990).

[19] A minor crop of interest is the Amazonian potato, *Solanum hygrothermicum*, which I encountered in a few Campa villages at elevations of around 1200 m (Ochoa 1984).

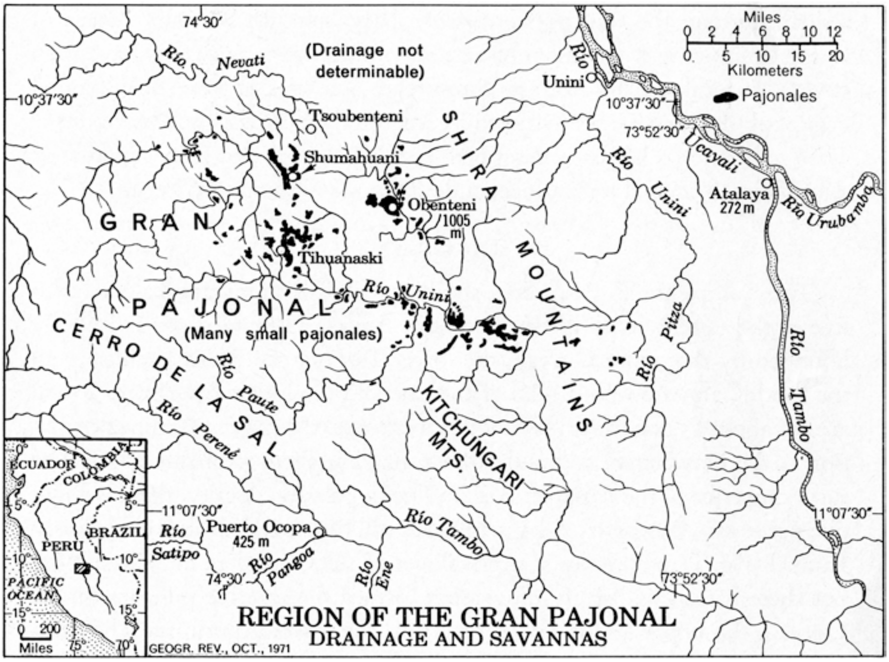

Fig. 3.17 Map of Gran Pajonal, Peruvian Amazonia. (From Denevan 1971, 497)

Fig. 3.18 Campa boy planting maize with a digging stick on a recently burned swidden, Peruvian Amazonia. (From Denevan 1971, 506)

clearing is harvested, and residual crops in a 2-year-old field are also harvested. There is relatively little management and use of either swidden-fallow fruit trees or house gardens, given frequent movement. This contrasts with the Río Pachitea Campa to the north, who have longer cropping and shorter fallows (Allen and de Tizón 1973, 143), and the Bora, who have managed fallows (see section "Indigenous Agroforestry in the Peruvian Amazon: Bora Indian Management of Swidden Fallows" in Chap. 6).

I was impressed that many Campa are not systematic land-use planners. Clearing and burning can take place well into the wet season, with a poor burn resulting, leaving little fertilizing ash and much debris. Planting is done immediately after burning, regardless of the season, even weeks before the rainy season begins. Resulting yields, therefore, may be poor for most crops, although manioc does fairly well. The Campa are certainly aware of the ideal timing of clearing, burning, and harvesting, but other factors intervene.

A field that is still producing may be abandoned prematurely because of a house shift so that a family is located too far away to be able to utilize an old field. Relatives may move in and help to deplete a field. Because of bad weather, an extended trading or fishing trip, or sickness or an injury, a farmer may not clear a field every year. As a result, some families have plenty of food and their future needs are assured, whereas others are caught short with a field depleted before another comes into production. Then they either move in with relatives or live off the land, hunting and gathering, until the new field is producing. Such instability of production seems to be common in the Gran Pajonal and helps explain why the Campa frequently clear, burn, and plant out of season. They fully realize that they will not get a good crop, but a poor crop planted in the wrong season is better than no crop at all. Such seasonal and managerial irregularity in swidden systems may be more widespread than we realize (Brookfield 1968, 421; Salick and Lundberg 1990).

A new field may be adjacent to a current one or as much as tens of kilometers away. Given plentiful land, the reason for distant moves of houses and fields can possibly be explained (not always) by game depletion rather than by soil depletion, pest invasion, or social factors, since game is the primary source of protein. Game is rapidly hunted out or scared away around a settlement, hence the frequent moving to new locations. This so-called protein thesis of Amazonian settlement is discussed below.

Seminomadic tribes with a strong emphasis on hunting, such as the Campa, are often thought of as being incipient or primitive agriculturalists. However, the large number of crops cultivated[20] and the many varieties of each, plus the utilization of a wide range of microecological conditions, suggest considerable agricultural sophistication, more so than that of the average nonindigenous colonist in tropical Peru. The strong emphasis on manioc cultivation is misleading. It is a labor-saving way to provide calories, while the Campas' greater physical efforts are directed toward hunting for the more basic food element, protein. Although a labor/time study was

[20] The Gran Pajonal Campa cultivate at least 49 crops; however, fields are dominated by manioc.

not made, agricultural productivity seems to be a high in terms of time expended, whereas hunting productivity is low for time expended.

The Protein Thesis

It has been postulated that the greater population densities and more developed cultures have been located along the large Amazonian rivers, in contrast with sparsely populated interfluves, because of the availability of protein-rich aquatic resources which supplement the protein-poor root crops that dominate the diet of Amazonian people (Lathrap 1962, 547–549; 1968; Carneiro 1970; Denevan 1966; Gross 1975). Away from the rivers, game is the main source of protein, but it does not seem to exist in quantities large enough to support large social units, nor is it permanent enough to support long-enduring settlements. Hence, the aboriginal pattern in the upland forests is usually one of small seminomadic social groups with a limited material culture.

One of my purposes in studying the Gran Pajonal Campa was to test the above argument with a brief dietary study (Denevan 1971). These Campa clearly fit the non-riverine model. Their total protein intake is low (less than 50 g most days), and they seem to go to great efforts in hunting, with small returns, to stay above the minimum. The result is settlement instability. The Gran Pajonal Campa move about once every 2 years, to average distances of about 8 km.[21] This is not to say that other factors besides game depletion are not important, and a careful sociological study is needed to define these factors, their causes, and their relative significance compared to the dietary argument. In contrast with the Gran Pajonal Campa, the riverine Campa are much less nomadic.

Certainly diets can change, and a greater use of protein-rich maize and beans would reduce the need for animal protein.[22] The emphasis on protein-poor root crops in Amazonia is rational given their great productivity and ease of ground storage, so long as protein-rich fish and game are available. It is interesting to note that the missionaries have been able to establish much larger and more permanent Campa villages along the lowland rivers. On the other hand, the Seventh Day Adventists prohibit meat eating, or at least restrict the varieties of game and fish that the Campa in their missions can eat. As a result, severe nutritional problems arose in the past at some missions, as on the Perené (Paz Soldán and Kuczynski-Godard 1939); elsewhere, the Campa have often ignored the restrictions. The Adventists have made major efforts to shift the Campa diet from traditional manioc toward maize, beans, peanuts, and other crops with a relatively high protein content.

[21] Bodley (1970, 36) documented four long-distance shifts of houses of from 20 to 80 km; in each case the reason given for moving was depleted game or fish resources.

[22] However, the Amahuaca of eastern Peru, one of the few Indian groups in the Amazon Basin for whom maize is the staple rather than root crops, are still seminomadic despite the apparently relatively high protein content of their vegetable diet (Carneiro 1964).

Robert Carneiro (1960) and others have shown that quite substantial settlements and population densities can be supported by indigenous shifting cultivation in Amazonia. On the other hand, if shifting cultivation does not supply sufficient protein, the availability of unevenly distributed animal protein becomes a limiting factor. Such a limitation, apparently applicable to the Campa, must be viewed as culturally determined in so far as the dietary pattern responsible for it is culturally determined.

The Campa obtain at least 90% of their food, by weight eaten, from agriculture and at most 6% from hunting, 3% from gathering, and 1% from fishing. The evidence for the Campa, though not precise, indicates that a group consistently thought of as being hunting-oriented actually may obtain no more than 5–10% of its total food (by weight consumed) from hunting.

The argument that the availability of protein from game in Amazonia not only influenced shifting cultivation but determined low population density, small and unstable settlement, and cultural development became a major debate in cultural anthropology in the 1970s well after my Campa research and Carneiro's 1970 paper, and it has continued (Denevan 1984a; Hames 1989). The catalyst was an essay on "Protein Capture" in the *American Anthropologist* in 1975 by Daniel Gross. Numerous field studies followed which attempted to support or disprove the thesis, one direct result being the stimulation of research on Amazonian cultural ecology.

Following Gross, the topic was picked up by Marvin Harris (Harris and Ross 1987) and the cultural materialists as a prime example of how human behavior can be explained as invariably functional in some way in terms of survival, in contrast to the structuralists who argue that much behavior can be explained in other ways or is inexplicable. The materialists further claim that limited game availability can also explain other aspects of behavior in Amazonia, such as warfare (competition for game territory), food taboos (restrictions on large game animals), and sex (greater availability for successful hunters).

Many of the leading Amazonian scholars became involved in the debate. Opponents of the thesis include Beckerman (1979); Chagnon and Hames (1980); and Diener et al. (1980). Beckerman and Diener argue that there is little evidence of protein scarcity. Brokers include Johnson (1982) and Sponsel (1983). Renewed support has come from Baksh (1985), Good (1987), and Frank (1987), even though Chagnon (1992, 96) maintains that "the protein debate has now pretty much been laid to rest." Johnson emphasizes perceived versus actual protein scarcity. Good emphasizes greater labor inputs to procure adequate protein from progressively smaller game as population size grows, rather than absolute scarcity.

Thus, we have a situation today in the Amazonian interfluves where Indian settlements, almost without exception, are small and moved often, with low population densities (mostly 1.0/km^2 or less; Beckerman 1987, 86). Why? Limited game seems to be more critical than poor soils. Despite evidence that game is more plentiful than previously thought, there is some threshold where it will not be adequate, possible at 2 persons/km^2 or even 20, but certainly before 200. However, this is not a direct environmental limitation. It is the result of a diet dominated by manioc with most protein coming from animal sources, and this particular diet is a cultural choice given options available, pressures present, and history. A diet based on maize and legumes, as in tropical Mesoamerica, is nutritionally well balanced and not dependent on protein from fish and game. The Amazonian Indian diet works because population densities are low and because labor inputs are low. A denser population could be supported without game if the diet were changed to emphasize seed crops and legumes, but the labor inputs would be high; there are numerous examples in Asia and Africa.

In my opinion, protein scarcity is one but not the only explanation for the consistently extremely low densities of historical *terra firme* Indian populations (Denevan 1984b). The argument is less valid, however, for prehistoric times when shifting cultivation was limited by stone axes and cultivation and settlement were probably more permanent.

The Shipibo: Multiple Biotope Use

The Indians of the major floodplains of the Amazon, such as the Tapajó and Omagua, were rapidly destroyed by European contact, and few survive today. One exception is the Shipibo along the central Río Ucayali in Peru; they number over 15,000 and have much of their culture still intact. The economy of the village of Panaillo provides some idea of aboriginal floodplain subsistence, since the sustaining area lies entirely within the floodplain of the Ucayali. The cultural ecology of the village was studied in 1971–1972 by a research team led by my student, Roland Bergman, and I spent a brief period with them in July 1971. The information here is drawn mainly from Bergman (1980; also see Myers 1990, 25–36).

Panaillo in 1971 was a small village located near the juncture of the Río Panaillo and the Río Ucayali, one of the major tributaries of the western Amazon in Peru (Fig. 3.19). The Shipibo there had regular contact with the river port city of Pucallpa, spoke Spanish, and had a resident Peruvian schoolteacher. Their subsistence system remains largely traditional, being based on plantain cultivation and fishing.

Typical of Amazonian meander-type rivers, the central Ucayali forms a floodplain that is some 30 km wide, an unstable biotope (microhabitat) network of natural levees, side channels, backswamps, sandbars and mudbars (*barriales*), islands, and lakes (Lathrap 1968). During low water, extensive *playas*, which may be wider than the river itself, are exposed. Tributary streams, such as the Panaillo and Aguaytia, add their own levees and backswamps to the complex floodplain landscape. The village is situated along the top of the levee (*restinga*) of the Río Panaillo a few hundred meters from the Ucayali. Facing the river (foreslope), the levee breaks sharply down to the water. On the other side (backslope), the levee grades down more gently into a large backswamp (*tehuampa*), which is bounded by a former levee of the Río Aguaytia, and behind that there is a permanent lake (*cocha)*. Continuing westward, the area to the Río Aguaytia consists of lakes, backswamps, levee remnants, and *playas*. To the north lie the large *playas* and levees of the Ucayali (Fig. 3.19).

The Shipibo farmer is thus faced with a varied environment but with repetitive sequences of biotopes and an annual sequence of rise and fall of water level. This

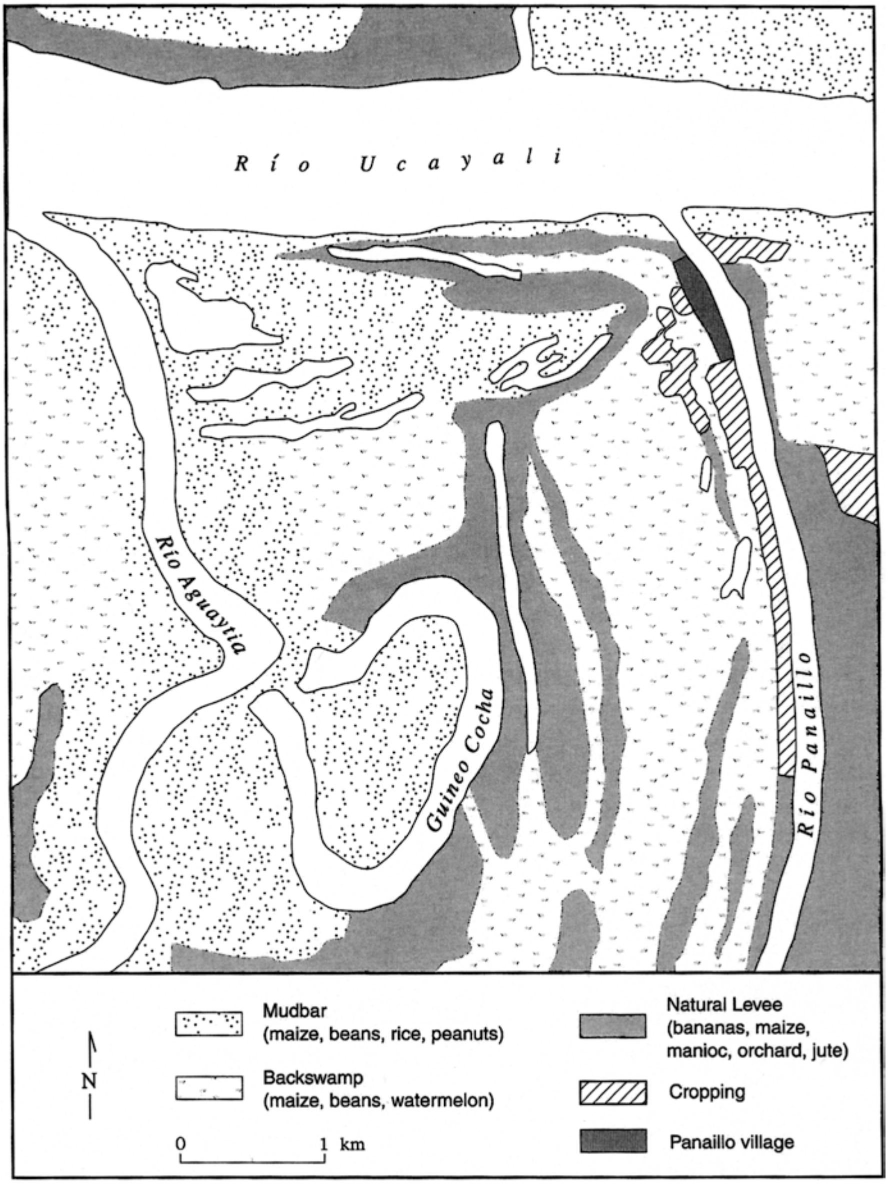

Fig. 3.19 Map of land types and major crops at Panaillo (Shipibo) on the Río Ucayali, Peruvian Amazonia. Most of the area shown is also used for hunting and fishing. (Adapted from Bergman 1980, 90)

zonation is matched by a horizontal zonation of crops. However, the size of individual biotopes and distances between biotopes vary considerably. Major advantages are diversity and good soil. The major disadvantages are periodic early or unusually high floods. Success in subsistence is dependent on knowledge of changing river levels and the related availability of biotopes for different lengths of time and hence for different specific crops.

Bergman (1980, 60, 90, 93) mapped and diagramed the land use of Panaillo, recording houses, individual fields, and crops (Fig. 3.20). The crops associated with the principal biotopes there are as follows:

Mudbar In the Río Panaillo; flooded annually, silt loam soil; short growing season crops, including maize, beans, rice, peanuts, sweet potato, watermelon; potentially farmed every year, but only small portions are above water long enough to be cropped

Levee Foreslope Silt loam soil; sugarcane

Levee Top, Riverside Sandy soil; orchard and garden crops, including star apple, guava, cotton, shapaja, mammee, soursop, hog plum, and the Old World crops mango, lemon, grapefruit, sugarcane, and tangerine

Levee Top, Center Houses, dooryard plants, similar to the riverside biotope above, but only a few scattered crops

Levee Top, Backswamp Side Dominated by permanent bananas; a few short-fallow swiddens with maize and manioc; scattered guava, sapote, star apple, genipa, cacao, pejibaye, breadfruit, shapaja palm, tangerine; some commercial jute

Levee Backslope Silt loam soil; sugarcane

Higher Backswamp, Lower Levee Silt loam soils; swamp forest, cecropia, wild cane; maize, beans, watermelon, manioc, rice; potentially farmed every year

Lower Backswamp Swamp forest, no cropping

Playas of the Río Ucayali Enormous sand- and mudbars; exposed as long as 6 months; flooded annually; beans, maize, rice, and peanuts (Fig. 3.21)

Thus, the Panaillo Shipibo make use of nine biotopes for several distinctive forms of agriculture – permanent, annual, and short fallow – each with a different group of crops.

Plantains (including bananas) were the principal crop, with manioc, maize, beans, and rice all secondary. These were supplemented by a variety of orchard and garden crops. Fish was the main source of protein except during the highest water (February–March), when fishing was poor. At that time, game, which tends to be trapped and concentrated on the levees, is important. Of the food crops, there were 10.75 ha of bananas, all on the levee. There were only 0.031 ha of manioc and 1.17 ha of maize on the levee, but 7.29 ha of jute for market. The low-water *playa* and backswamp crops of maize (4.15 ha), watermelon (1.87 ha), beans (1.28 ha), and peanuts (0.10 ha) totaled only 7.40 ha, even though there was considerable unused backswamp land

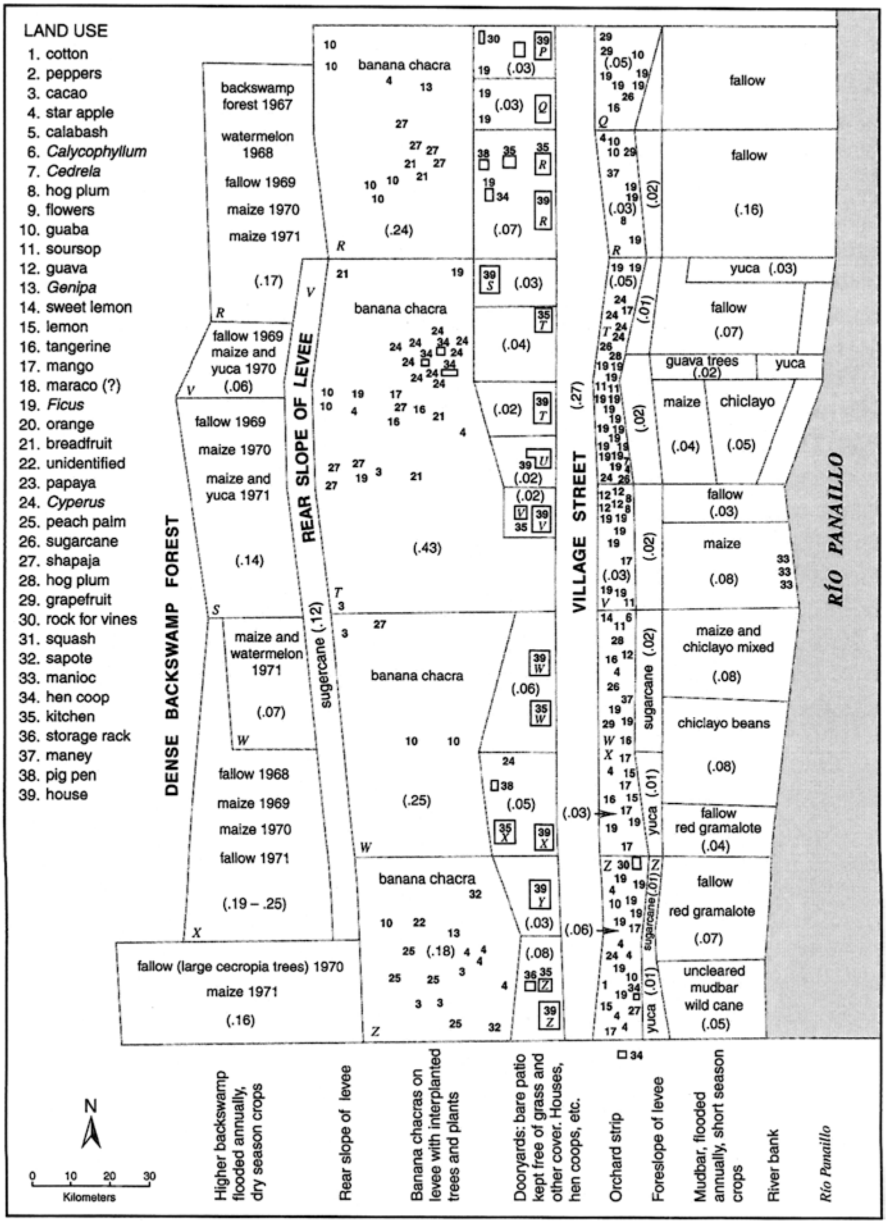

Fig. 3.20 Map of fields and crops at Panaillo, Río Ucayali, Peruvian Amazonia. According to Bergman, "The trees and plants shown are economic, whether deliberately planted, as most are, spontaneously seeded, or wild but cared for. In the banana *chacras* [fields] useful species grow surrounded by dense stands of bananas. An orchard strip runs the length of the village between the street and the front edge of the levee. Only a few scattered banana plants are grown here amidst the fruit trees. In the orchard strip of [household] X manioc grows on the steep foreslope of the levee. On the rear slope of the levee [household] V grows sugarcane in a long narrow strip that is too low for reliable banana growing. Numbers in parentheses indicate areas in ha. Capital letters indicate households. Crops are for 1971 unless otherwise indicated." (Adapted from Bergman 1980, 93)

Fig. 3.21 Shipibo woman planting maize and rice on *playa* of the Río Ucayali at Panaillo, Peruvian Amazon. (Photograph by Roland Bergman, 1971)

available. The low-water crops, however, cannot provide year-round food, as can levee crops, hence the traditional underutilization of the low-water biotopes despite their potential for high levels of annual production. The Panaillo Shipibo do not have much mudbar land on the *playas* of the Río Panaillo that are exposed long enough to plant rice for commercial production. Most of the large nearby *playas* of the Ucayali, where there is good rice land, were controlled by non-Indians.

There is also an ecological zonation of fish and game resources, based on types of water body, vegetation, and seasonality. The patterns of actual catches reflect the ecological zonation in combination with distance from the village. These patterns are mapped and described by Bergman (1980, 135–66).

Biotope agricultural patterning at Panaillo is representative of the kind of zonation that occurs throughout the floodplains of the Amazon Basin. However, it is not necessarily typical, given the wide variation in the environmental factors discussed earlier, in crop orientation, in accessibility to land or in land ownership, in population pressure, and in availability of commercial outlets. Variation from region to region is considerable, but there tends to be local consistency in agricultural zonation, as we see at Panaillo.

Most years the levees stand above flood levels. The highest local levees flood about every 10 years, but the slightly lower Panaillo levee floods every 5–7 years

(Bergman 1980, 53–60). Houses are on raised platforms and people move about in canoes, but crops are vulnerable. In the 1971 flood, the river rose 9 m above the dry season low-water level, although this was only a meter or so above normal floods. Staple crops, especially plantains, were mostly destroyed. Where the water covering the plants exceeded 60 cm for over 30 days, the crop loss was total. At lower durations more plantains recovered. Prehistoric crops of maize or manioc on the levees would have been more vulnerable than the post-conquest plantain. *Playas* are exposed for up to 6 months; however, unusually high-water levels during the dry season can result in destruction of *playa* and also backswamp crops (maize, beans, watermelon, peanuts, and rice today). When crop loss is severe, the Shipibo travel to distant swiddens located on high levees and in upland forest to harvest plantains and manioc.

Plantains, the staple, are a European introduction that replaced manioc on the better drained soils. Fish is the main source of protein except during brief high water when maize and game are more important (Blank 1981). This system of permanent (levee top plantains), short-fallow (levee top manioc), and seasonal (*playa* and backswamp maize, beans, etc.) cropping supported a population of 107 people in a permanent village (over 25 years old in 1971); the resource area exploited had a population density of about 4 per km^2 (Bergman 1980, 203).

The present Shipibo village of Panaillo is similar to other Shipibo villages in utilizing multiple microhabitats for cultivation. However, many Shipibo villages, both past and present, were located on bluff tops, in contrast to Panaillo, and thus also had direct access to the high-forest habitat where the poor weathered oxisols of the *terra firme* could be used for long-fallow shifting cultivation emphasizing manioc. This is true of the present Shipibo village of San Francisco de Yarinacocha (see Fig. 8.4), as well as prehistoric occupations on the same site (Lathrap 1968, 74).

The Karinya: Multiple Biome Use

Indian farmers commonly utilize multiple microhabitats (biotopes), as we have seen with the Shipibo. Most, however, are still thought of as specialized to a particular macrohabitat (biome), such as rain forest, savanna, or floodplain, but some cultivate in more than one biome. In Chapter 8.3 "A Bluff Model of Riverine Settlement in Prehistoric Amazonia", I argue that prehistoric riverine people farmed both the floodplains and the adjacent bluff forests. For both multiple biome and multiple biotope exploitations, the objectives are to maximize and diversify production and to minimize the risk faced if only one habitat is utilized, at the cost of increased travel time.

The Karinya of the Orinoco Llanos are a particularly good example of a society with multiple resource strategies. Farmers in the same community farm four biomes – the Orinoco floodplain, forest (*monte*), savanna, and palm swamp (*morichal*), comprising at least nine different biotopes.

The Karinya were studied by anthropologist Karl Schwerin (1966) in the early 1960s. When I was examining pre-European raised fields in the Venezuelan Llanos at Caño Ventosidad in 1972 (Zucchi and Denevan 1979), I took the opportunity to also observe the Karinya ditched fields, assisted by Roland Bergman (Denevan and Bergman 1975). Schwerin and I later collaborated on a broader treatment of Karinya adaptive strategies (Denevan and Schwerin 1978).

The Karinya are a Carib-speaking group widely dispersed throughout the eastern Llanos west of the Orinoco delta in some 30 communities, including a few villages south of the Orinoco (Fig. 3.22). The total population in 1962 was 3828, most Karinya having regular contact with regional gas and oil industries and with urban centers. Our study focused on the communities of Cachama and Mamo.

The Orinoco Llanos, which I consider part of Greater Amazonia, cover a vast area north of the Orinoco in Venezuela and Colombia. Much of this plain is low lying and poorly drained; however, there are extensive tablelands of Tertiary age north of the river forming what are often called the Llanos Altos.

Despite a long dry season, the streams of the eastern Llanos flow year-round, dissecting the terrain into large *mesas*. The *mesas* are covered by savanna – open grassland with a few trees, with very infertile, sandy soils. The stream channels, however, are lined with *moriche* palm (*Mauritia flexuosa)* gallery forests, and swamps (*morichales*), with fertile alluvial soils. The intervening region between

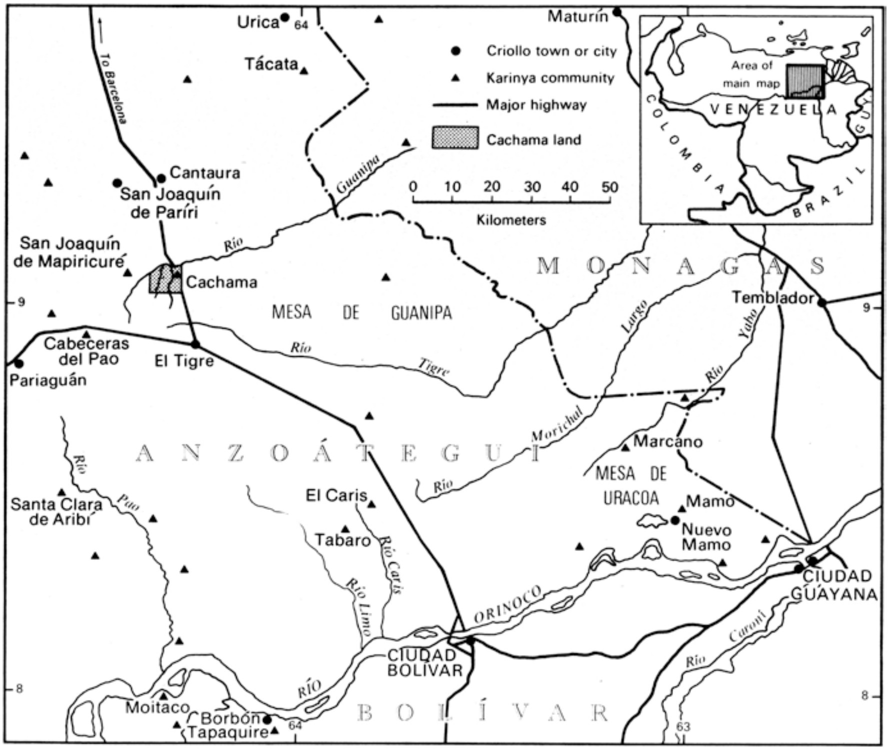

Fig. 3.22 Map of the Karinya region, Orinoco Llanos, Venezuela. (From Denevan and Schwerin 1978, 6)

the *mesas* and the Orinoco is a low-lying floodplain. During the rainy season, the great river overflows its banks, flooding much of this area and replenishing the many lakes, lagoons, and backwaters which are found there, often at considerable distance from the main stream. At the same time, there are high places in the floodplain which are rarely or never flooded, including natural levees, river terraces, and islands within the Orinoco channel. This region of sharply contrasting savanna, *morichales*, and floodplain comprises the Karinya territory (Fig. 3.22).

The Karinya have adapted their agricultural techniques to the exploitation of a range of macro- and microenvironments. Seven types of cultivation are practiced, some occurring in several different habitats, while some habitats are utilized for several different types of cultivation. The forms of agriculture are as follows: swidden mixed cropping, *playa* mixed cropping, river-bottom drained fields, floodplain drained fields, house gardens, *playa* monoculture, and savanna monoculture. The locations of these systems are indicated in the profile shown in Fig. 3.23, and each is briefly described in Table 3.1; for more detail see Denevan and Schwerin (1978). Drainage of the palm swamp (*morichal*) fields was undertaken by means of a network of ditches.

The Karinya not only exploit a range of ecological situations for cultivation, but raise domesticated animals (chickens, pigs, cattle, goats, burros), and engage in fishing in small streams (Cachama) and in the Orinoco (Mamo), as well as some hunting (rabbits, iguana, deer, birds, capybara). Most men also participate to some degree in wage labor in the petroleum industry, ranching as field hands, or as workers in the nearby cities.

The Karinya have adapted not only to a varied physical environment but also to a changing socioeconomic milieu (Denevan and Schwerin 1978, 59–66). The result is a flexible and opportunistic economic system, one that is now being recognized as common for rural Indians and peasants in the Andes, Amazonia, and elsewhere.

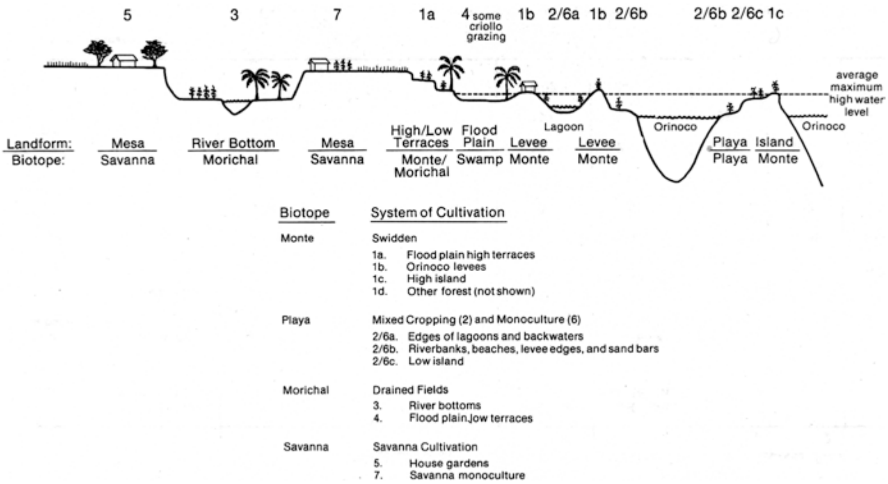

Fig. 3.23 Biotopes and Karinya cultivation, Orinoco Llanos, Venezuela. (Adapted from Denevan and Schwerin (1978, 14; See Table 3.1)

Table 3.1 Systems of Karinya cultivation

System[a]	Biotope	Types of crops	Tools used	Technological improvements	Communities
1. Swidden mixed cropping (short to long fallow)	Primary and secondary forests of river levees, high terraces, and islands	Subsistence; esp. tubers	Axe, machete, *garabato* (wood hook)	Minimal	Mamo, others
2. Playa mixed cropping (annual)	Levees, beaches, lake margins, islands	Subsistence; esp. grains, legumes	Axe, machete, *garabato*, *chícora* (digging stick), shovel	Minimal	Mamo, Tapaquire, others
3. River-bottom swamp (*morichal*) drainage (continuous or short fallow)	Gallery swamps along rivers draining the *mesas*	Subsistence; esp. tubers, bananas	Axe, machete, *garabato*, *chícora*, shovel	Swamp drainage, some irrigation	Cabeceras del Pao, Tabaro, Cachama, Tácata, S. Joaquín, Santa Clara, Morichal Largo, Marcano, others
4. Floodplain swamp (*morichal*) drainage (continuous or short fallow)	Low terraces of the Orinoco floodplain	Subsistence; esp. tubers, bananas	Axe, machete, *garabato*, *chícora*, shovel	Very long drainage channels, efficient drainage, local crop specialization	Mamo, others
5. House gardens (continuous)	Savanna and elsewhere next to houses	Supplementary crops; fruit, herbs, medicinals, vegetables	Machete, *garabato*, *chícora*	Individualized care	All
6. Playa monoculture (annual)	Levees, beaches, lake margins, islands	Cash crops; esp. grains, fibers, legumes	Axe, machete, hoe, *chícora*	Minimal, but with crop specialization, large fields	Mamo, others
7. Savanna monoculture (annual)	Savanna	Cash crops, esp. grains, fibers, legumes	Tractor-drawn machinery	Mechanization, fertilizer, large fields, crop specialization	Cachama

[a]Numbered cultivation systems are keyed to Fig. 3.23. Crops are listed in Denevan and Schwerin (1978, 42–5)

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